POTENTIAL OF THE IMPLEMENTATION OF DEMAND-SIDE MANAGEMENT AT THE THEUNISSEN-BRANDFORT PUMPS FEEDER

by

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DECLARATION OF INDEPENDENT WORK

I, KHOTSOFALO CLEMENT MOTLOHI, hereby declare that this research project submitted for the degree MAGISTER TECHNOLOGIAE: ENGINEERING: ELECTRICAL, is my own independent work that has not been submitted before to any institution by me or anyone else as part of any qualification. Only the measured results were physically performed by TSI, under my supervision (refer to Appendix I).

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SIGNATURE OF STUDENT **DATE**

Acknowledgement

My interest in the energy management study concept actually started while reading Eskom's journals and technical bulletins about efficient-energy utilisation and its importance. First of all I would like to thank ***ALMIGHTY GOD*** for making me believe in ***MYSELF*** and giving me courage throughout this study.

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Summary

Demand-side management (DSM) is one of the integrated energy planning concepts that has only recently been introduced in South Africa. This concept needs to be fully developed in order to suit current industrial development situations. South Africa's coal and water reserves will not last forever because of the growing population and the accompanying demands on our energy resources {[5] of Chapter 1]}. Therefore the demand-side interventions are considered on an effective means of overcoming these problems. The traditional approach of electrical energy utilisation by Eskom and its customers has to be reviewed. Socio-economic and environmental development benefits must also be reviewed. Advanced research on demand-side management has benefited the international world tremendously and this kind of research should also be done in South Africa.

The research project for this study as described from chapter 1- 8 was undertaken to show the potential implementation of demand-side management and its interventions (DSM programme) on the Theunissen-Brandfort Pumps 11kV feeder (TBP). This would result in the generating of potential energy and cost-savings that would flow from the feasible DSM programme. This would be measured and verified by billing the actual saved energy at the TBP electrical system for the future. Every potentially saved-energy means one less potential reduction in emission.

The case studies were conducted on Eskom's entire TBP network and on four large power users which were identified and which provided the relevant potential results. Methodological design protocol processes for best-practice pollution prevention and the efficiency-energy (EE) audit protocol model, with its accompanying goal and objectives were used. The project concentrated on EE and time-of-use (TOU) factors related to the selected customers and the TBP as a whole, thus: potential ***Replacement*** and ***Rewinding*** of low efficiency with higher efficiency motors and the TBP feeder potential ***Load-Shifting***. The stages within the EE, LS and DSM project process which were used for potential implementation are the following: project identification, energy audits and assumptions and recommendations for implementation. The M&V interaction with DSM, EE or LS project processes (methodology) for future implementation purposes (actual retrofitting) is also shown. The TBP feeder collective baseline (Figure 6.2) was quantified by trapezium rule.

The feasible EE and LS programmes opportunities analysis on motors and the entire TBP were performed by inference and stipulation techniques and the potential energy reduction effects using a simulation programme called International Motor Selection and Savings Analysis (IMSSA). The potential LS programme was also performed based on the Eskom's miniflex tariff defined time of use.

TBP plant-wide EE and LS assessments conducted with the methodology mentioned, identified and quantified a total of two EE savings opportunities and were divided into four categories: those for short-term, long-term, none and best solution potential implementations (Table 7.9).

As far as indirect results are concerned, DSM is a very new concept in South Africa and is consequently not well known. The study was based on simplicity in order to make the DSM subject very simple and easily accessible to future research. By using a simple and user-friendly IMSSA software programme, quick, relevant results were obtained. The study played an important role in influencing and educating interested parties about the importance of potential demand-side management concepts and objectives. The study compiled valuable information on EE, DSM (LS) and M&V that was previously unknown and, which will make future research much more accessible and manageable.

It is recommended that all the motors identified as inefficient be rewound and replaced by new and efficient ones in the future. It is also very important that the potential LS programme be implemented only after these potential EE opportunities are implemented so that there will be sustainability and the DSM objectives may be achieved (Table 7.10).

The project led to better grasp of electric energy consumption by the customers. From a socio-economic perspective, Eskom can distribute the surplus potentially saved energy of capacity at the TBP to other communities, which would also create employment if a new network could be built. Allocation of potentially saved energy to other population groups or customers of low-income groups in the Theunissen area would mean a significant lifestyle change. With regard to environmental benefits, previous research has proven that for every kWh of electricity saved, fewer emissions (e.g. $C0_2$) would be generated at the power station. The study addressed TBP-wide power use, focusing primarily on the demand-side interventions, but implications for improvements in the supply-side emission reductions were also considered.

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Key Words:	**Descriptions:**
Baseline:	Pre-DSM Programme Implementation
Billing:	Verification of Saved Energy Measured in kWh
DSM Programme:	Demand-Side Management Activities (EE &LS)
E.E (Energy-Efficiency):	Efficient-Energy Conservation Measure/Interventions
EE Opportunity Programme:	Motors Rewinding & Replacement Opportunities (Projects)

Energy-Intensity: Energy Use Per Unit of Output or Activity

Energy-Savings**:** Measured in kWh/yr & R/kWh/yr

Greenhouse Gas Emissions: Atmospheric Gases Contributing to the Greenhouse Effect

IMSSA: International Motor Selection and Savings Analysis.

LS Opportunity Programme: TBP Feeder's Plant Wide Energy Use from Peak to Standard Peak

LS (Load-Shifting): Efficient Load-Shifting Conservation Measure/Interventions

Metering: An activity by indicating, recording or regulating an amount or volume e.g. an electrical current, time, speed etc.

M&V Programme: Measurement and Verification Activities

Opportunities: Potential Projects (Activities) for Implementation

Profiling: Graphical Presentation of Plant's Energy Consumption over Specific Period

Tariff: Utility Structured Rates

LS (Load-Shifting): Efficient Load-Shifting Conservation Measure/Interventions

<u>Description of Other Words:</u>

(Active) Energy Charge: A Fixed or Time and/or Seasonally Differentiated Charge linked to each kWh or unit of Energy Consumed.

Adjustment**::** Effects of Feasible Intervention (activities).

Consumption**:** The Energy Used by a Customer During a Specific Period, Measured in kWh.

DSM Programme: All Applicable DSM Activities to the Project (Energy-Efficiency, Load-Shifting Activity Projects)

Measures/Options/Intervention: Activities to meet DSM objectives.

Machine**:** Electrical System (Motor and Pump Coupled).

Potential Savings: Measured in kWh/yr & R/kWh/yr.

Reticulation: The reticulation network performs the function of transporting and despatching power from the distribution network to the point on the network where the service connection is made. This is usually done at voltages of 22kV or lower (TBP reticulation network feeder).

Tariff: A tariff is a combination of charging parameters applied to recover measured quantities such as consumption, capacity costs and unmeasured quantities such as service costs.

Variables: Factors influencing the level of energy (electricity) consumption.

Verification: Performed by billing saved energy.

List of Acronyms

A: Ampere

CDM: Clean Development Mechanism

$C0_2$: Carbon dioxide

ºC: degrees Celsius.

DSM: Demand Side Management

EES: Energy-Efficiency Services (TSI).

ESCO: Energy Services Company.

EF: Emission Factor.

GHG: Green House Gas

h: hour

H_2O: Water

IEP: Integrated Energy (Electricity) Planning.

IPMVP: International Performance Measurement and Verification Protocol.

kg: kilograms

***km*:** kilo meter.

***kWh*:** kilowatt-hour

kW: kilowatt

***kVA*:** kilovolt-ampere

***kV*:** kilovolt

mm/s: millimeter per second.

***MW*:** Mega-Watt

rms: root mean square

rpm: revolutions per minute

***SABS*:** South African Bureau of Standards.

sec: seconds

***TBP*:** Theunissen-Brandfort Pumps.

***TRF*:** Transformer.

TOU: Time of Use.

V*:* volt

%: Percent

CHAPTER 1: INTRODUCTION

This Chapter states the background of Eskom's adoption of integrated energy planning (IEP) regarding the need to manage its generation capacity, and also gives the overview of South Africa's position with regard to energy resources, consumption and the green house gas (GHG) emissions.

1.1 Background

Eskom adapted an integrated electricity (energy) plan (IEP) in 1997. The plan sets out an optional combination of various supply-and demand-side interventions to increase the value of electricity to customers and to highlight the need for management of Eskom's generation capacity. The plan also sets out specifications on the supply-side that are being actively pursued [1]. Electricity supply and demand-side management (DSM) techniques are being actively sought to enable electricity to be provided and to be used more judiciously and efficiently. This benefits the utility (Eskom) because its infrastructure is being optimised, i.e. these techniques will boost energy sales without incurring more capital investments. From the supply point of view, generators use sophisticated techniques to save on costs and probability methods to predict system loading so that they can cut the extent of their standby capacity to a minimum. From the demand-side point of view, Eskom is providing incentives to the whole spectrum of customers, i.e. use of electricity out of peak hours and efficient equipment to self-correct their poor power-factor loads.

Eskom, with its steady growth in terms of electricity demand and consumption has, however, necessitated a greater need for action and the awareness in the energy sector for both the supplier and the end-users. Eskom's sectoral energy consuming programmes have a target of 5 million additional connections by the year 2007, based mainly on the residential electrification programme with an annual growth of 15%, and also an expected annual growth in other different sectors [2]. To make the situation even worse, projections have estimated that Eskom will have run out of excess capacity by the year 2007. This can be seen in Figure 1.1, where the maximum demand forecast is shown against the available capacity. The decision to build new capacity should have already been made. DSM becomes an extremely attractive alternative when considering the cost implications of new generation capacity provision, which allows the utilities and end-users to "buy time" whilst new generation capacity is being developed. Eskom generates approximately 95,7% of South Africa's electricity and this constitutes a generating capacity of 36,500MW, which is primarily coal-fired, but also includes one nuclear power station (1,930MW), two gas turbine facilities, two conventional hydro-electric plants and two hydro-electric pumped-storage stations. In 1998 the nuclear power station at Koeberg generated 13,6billion kilowatt-hour (bkWh) of electricity, accounting for 7, 1% of the country's electricity generation [2].

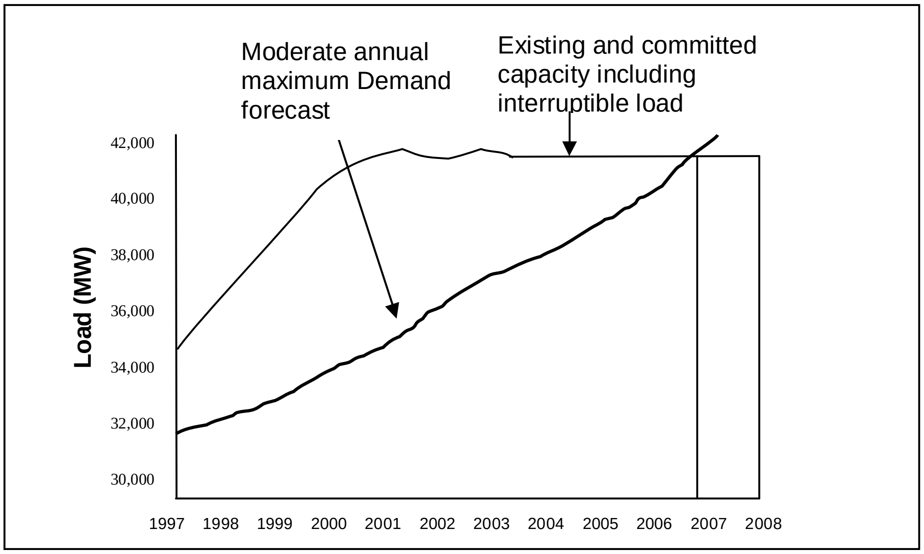

Figure 1.1: Eskom's generation capacity and long-term maximum demand forecast.

1.2 Overview of South Africa's Position.

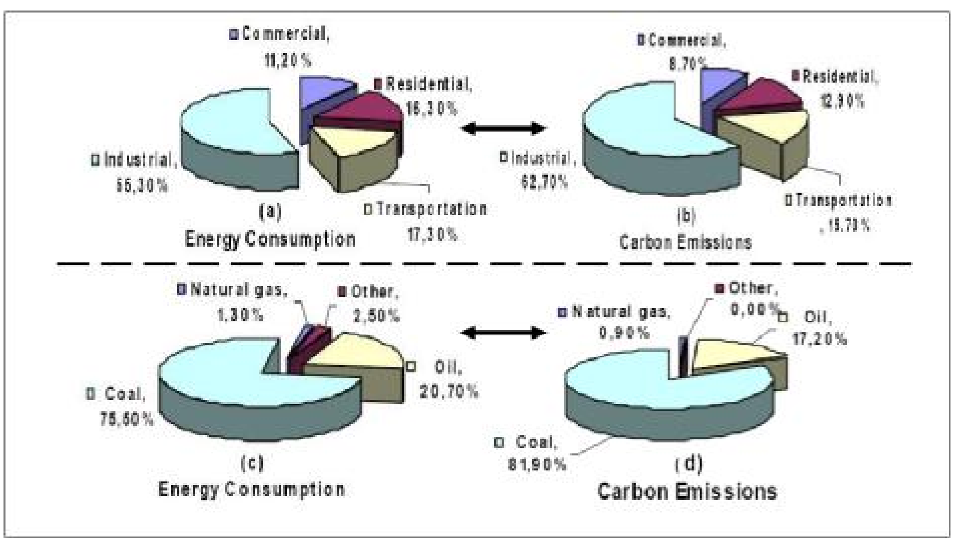

Figure 1.2: Sectoral and fuel share of annual electricity (energy) consumption and carbon emissions in South Africa.

Note: Figures 1.2(a) and 1.2(b) relate and both represent energy consumptions due to different South African sectors and their contributions towards Carbon gas emissions. Figures 1.2(c) and 1.2(d) relate and both represent energy consumptions due to different energy sources and their contributions towards Carbon gas emissions.

Figure 1.2 provides a more detailed breakdown of South Africa's energy balances in terms of energy use for 1997. From the data in Figure 1.2 of the sectoral share, it can be seen that the South African industrial sector poses the largest potential for electricity consumption reduction, which would result in the largest emission reduction due to decreased electricity requirements. These emission reductions do not include the reduction decreases due to process changes in the industry itself. The industrial sector has the largest consumers e.g. mining, and quarrying, and these are followed by iron and steel industry. The residential sector is the largest single consumer of energy generated by utilities; it comprises a large number of small users [2].

Approximately 75, 5% of South Africa's primary energy comes from indigenous coal. Another 20, 7% comes from imported crude oil. Coal is the primary fuel produced and consumed in this country. South Africa is responsible for more than 90% of all burnt coal in Africa. The country is the third leading coal exporter in the world and coal is its second largest foreign exchange earner after gold. The estimated domestic consumption of coal was 177, 1 million metric short tons (mmst) in 1998. The majority of domestic consumption comprises coal used to produce steam for electricity generation. Other major coal-consuming sectors include mining, the cement industry as well as the brick and tile industry.

South Africa is by comparison an energy and carbon-intensive country compared with other African countries as well as many other developed countries. The per capita energy consumption and carbon emissions, on the other hand, are high in comparison with the rest of Africa, but relatively low when compared to many developed nations. In 1998 South Africa's per capita energy consumption was 29,426kWh, while per capita energy-related carbon emissions registered 2, 3 million metric tons of carbon. From Figure 1.2 it can be seen that the South African industrial sector was responsible for 55,3% of the national annual energy consumption, while transportation used 17,3% , the residential sector consumed 16,3% and the commercial sector used 11,2% [Figure 1.2(a)].

The largest sector share of carbon emission also came from the industrial sector, which was responsible for 62,7% of the annual carbon emission in South Africa, followed by transportation at 15,7% [Figure 1.2(b)]. Figure 1.2 also shows that coal is used to generate 75, 5% of all electricity consumed in South Africa. A percentage of 20, 7% is generated through oil and 1, 3% is generated from natural gas [Figure 1.2(c)]. The fuel share of carbon emission is 81, 9% for coal, 17, 2% for oil and 0, 9% for natural gas [Figure 1.2(d)]. During 1998 South Africa was responsible for 102 million tons of carbon emissions per year, which resulted from the burning of fossil fuels. This is equivalent to 42% of Africa's carbon emissions per year and equivalent to about 7% of the U.S.A.'s emissions per year. South Africa emits 869, 9 tons of carbon emissions per million US$ GDP per year.

1.3 Objectives of the Integrated Energy Planning (IEP).

The objectives are to:

- Actively promote time of use tariff and maximisation of demand shifting by customers.
- Involve major municipalities with their own generation capacity.
- Identify potential customers for co-generated electricity available within regions.
- Formulate and implement load-management strategies.
- Reposition sales programmes, taking into account the changing generation capacity.

1.4 Background of Supply-Side and Demand-Side Options

While electricity demand and consumption have been notoriously difficult to forecast over the past 15-20 years, it is now recognized that uncertainty in forecasting must be accepted. This uncertainty arises for the following reasons:

- The price of fuel fluctuates on the worldwide market almost daily.
- Cost of construction varies due to property and land-price variations.
- Environmental constraints are forever changing, dependent upon pressure groups and green policies.

- Uses of electricity for comfort and convenience can change with local climatic conditions.

- The effects of economic and political changes are increasingly difficult to estimate.

1.5 Supply-Side Options

The most important option to the supplier is that of price. By setting prices, a number of varying objectives can be achieved, viz:

- Economic efficiency

- Government policies e.g. subsidies to rural areas, target rates of return, environmental policies etc.

- Revenues to cover costs of investment, operations and maintenance etc

1.6 Demand-Side Options

On the demand-side or consumer side, the options available should endeavour to contribute to economic efficiency as a whole. Proper choices for the demand-side management programme will contribute towards the utility and the customers achieving cheaper operating costs and exercising their available options or opportunities to maximise the benefits of DSM.

1.7 Opportunities to Exploit Demand-Side Options:

Measures include the use of alternative fuels to achieve DSM objectives, e.g. minimum annual costs, private contract purchase of electricity, improvement in end-use efficiency, lifestyle change and end-use storage. With the proper choices of options, the user can achieve cheaper operating costs because of the shorter lead times, compared with increasing generator capacity. The user can end up with less risk-taking on capital investment than on the supply-side. This could provide an answer to coping with uncertainty and to encourage consumers to exercise their available option to maximise both supply and demand-side benefits.

1.8 Demand-Side Management and cost-effective planning

Demand-side management is the process of influencing customers' demands throughout a 24-hour period by encouraging the use of electrical energy when tariffs are favourable or by assisting them to employ conservation measures in such a way that their overall energy bills are acceptably low [1]

1.9 Benefits of DSM:

- Reduction of peak demands.
- Improved load factor.
- Better load forecasting.
- Lower supply costs to customers.
- Improved cash flow with improved billing for customers.
- Metering facilities.
- Emission reduction.

1.10 The Key Factors in Evaluating DSM Measures (Options)

- Load profile and coincidence of peaks need to differentiate between groups and classes of customer type (e.g. commercial, domestic and industrial).
- Measures required maintaining customer participation.
- Strategies required to assist customers to change habits of energy use.
- To become really effective, DSM requires good and continuous contact between suppliers, utility companies and customers.

1.11 Why must Emissions be Reduced ?

The increasing greenhouse effect results in global warming, which in turn affects climate and weather conditions. In the long term the earth must shed energy into space at the same rate that it absorbs energy from the sun. Solar energy in the form of short-wave radiation heats the earth's surface. The earth sheds this energy, which is then absorbed into the atmosphere by water vapour, CO_2 and other gases. These gases prevent energy from passing directly from the surface into space above, but instead they transport it higher into the atmosphere from where it radiates into space.

This slower, more indirect process serves to create a blanket around the earth. Without it, the earth's surface would be some 30ºC colder than it is today. The greenhouse gas emissions are disturbing the climatic mode of maintaining the balance between incoming and outgoing energy. The most direct result is likely to be global warming of 1, 5º C to 4, 5º C over the next century [2]

1.12 Macro-economic Hierarchy

This hierarchy consists of various levels, viz : at macro level it is energy, at an intermediate level it is an energy sector (source)-electricity, at sub-sector level is Demand-Side, and the DSM outputs are: *Profiling, Marketing, Metering and Billing* (Figure 1.3).

It is important that the customer understands the basic concept of the economic and management context of the supply and demand of electrical energy. The customer is of paramount importance and the pricing policies, supply and demand options or programmes are directed towards producing maximum benefits in consuming electrical energy in efficient and effective ways for the benefit of both the customer and the utility. Effective energy usage should not benefit consumers and the utility only, but also signal the re-allocation of resources in society and be of benefit to the environment. Since electricity is generally not stored, its production (generation) and use (distribution) are simultaneous, e.g. on supply-sides there are methods of generation (thermal, coal, oil, gas, nuclear, hydro) and these eventually become exhausted. On the demand side there are consumers with a large variety of end-use equipment, hence the existence of consumers depends crucially on stable networks and economic prices for the energy consumed [1].

The focus of this research project is on the demand-side. The demand-side management (DSM) intervention outputs are ways or methods in which energy in the form of electricity can be managed so that it may be used in the most effective way, with the purpose of reducing electricity costs to end users e.g. farmers and municipalities. An understanding by the end users of the proper energy usage could lead to a significant improvement in their quality of life. This in turn could lead to social upliftment of the Theunissen rural and local communities and South Africa as a whole.

In this research project an investigation of the implementation of the DSM interventions' (measures) potential on the Theunissen-Brandfort Pumps (TBP) feeder is undertaken.

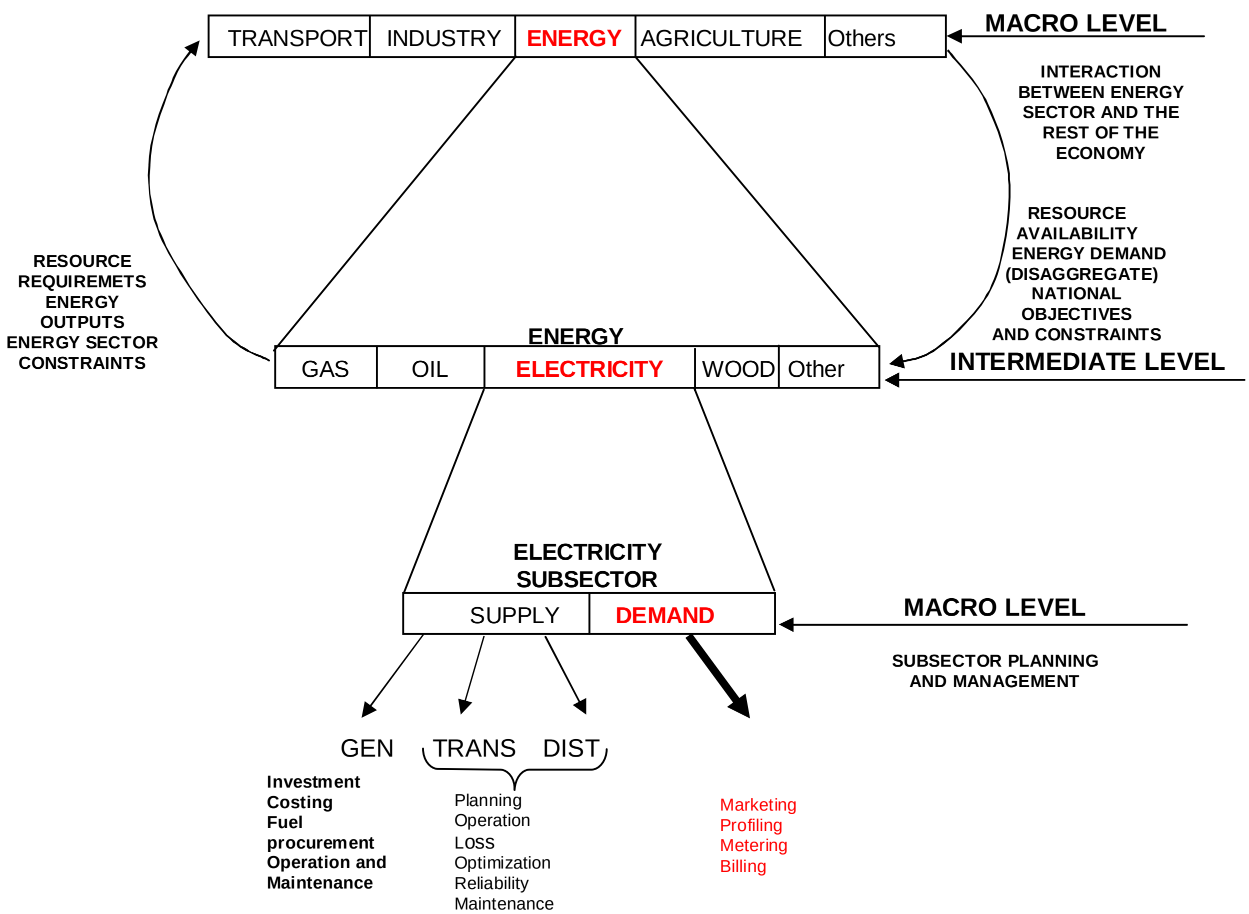

Figure 1.3: Macro-economic hierarchy of energy within the national economy showing electricity sub sector.

1.13 Problem Statement

Since the acceptance of South Africa back into the international community, major macro-economic developments have occurred. All the macro-economic sectors such as transport, industry, agriculture and others require more energy to be sustained. The same situation applies to Eskom, where statistics show that there has been a major demand for electricity from Eskom since 1994. One of Eskom's high-demand electricity distributing areas is the Theunissen area. The Theunissen-Brandfort Pumps (TBP) feeder was identified among others, as one of the installation which would soon be running out of spare capacity due to numerous additional customer applications.

Many customer applications were rejected on this feeder due to growing uncertainty about sufficient spare capacity, consequently, the question arose as to whether that was what caused the unavailability of electrical spare capacity, or the erroneous feeder's data. In order to rectify this situation, Eskom would have to build more spare capacity and in turn, the customers would also have to bear the costs incurred. Alternatively, demand-side management (DSM) could be applied to the TBP feeder. This involves the process of influencing customer demand throughout 24 hours by encouraging their use of electrical energy when tariffs are favourably low or by assisting them in the employment of conservation measures (interventions) in such a way that their overall energy bills are acceptably low. In addition, DSM could assist in the prevision of the potential energy savings effects that these activities would employ. The DSM interventions comprise energy-efficiency, load-shifting and strategic-growth. Each intervention, however, has to be feasible for the TBP electrical system in order for it to be implemented. The feasibility of each intervention is also determined by the complexity of the project. Interventions must be measured and verified (M&V programme) by recording the energy-savings that would have resulted from their implementation.

1.14 The Objective of this Study

This project considers ways of potentially implementing demand-side management interventions and measuring the output for the Theunissen-Brandfort Pumps feeder. The potential energy-savings that these interventions would employ, will be measured and verified. The (M&V) programme will be implemented in the future by billing the TBP's potential saved-energy. The aim is to determine the potential savings on the Theunissen-Brandfort

Pumps feeder for the benefit of DSM. The following methodological processes will be observed to address this problem.

1.15 Delimitation of Project

Research projects have been undertaken for Eskom and abroad, on the principles of DSM and its interventions in the commercial, residential and industrial sectors; however, this research specifically deals with the implementation of DSM measures' potential on Eskom's electrical rural network. This project is unique in the sense that the Theunissen-Brandfort Pumps are a combination of commercial, residential, but mostly industrial segments or classes. Difficulties encountered in other research projects are not the same as those encountered in this research, due to different environmental aspects and the uniqueness of this project. It is difficult to show the best potential DSM and M&V programmes for the TBP electrical system because it involves different types of customers.

The long term goals of any DSM project are often hampered by the inability of project partners / stakeholders to agree on the quantity of savings that could have been achieved. It is therefore very important to ensure that a positive customer attitude is aimed at, since it will also contribute towards the success of this project.

Eskom data management is in the process of rectifying and making field data more reliable, since it in a way contributed negatively to this research project. During the execution of this project, customers have had to agree to apply the principles of DSM mechanisms, while they are in operation. Large customers' transformer sizes were not identified as anticipated, due to changes in the daily upgrading and downgrading of existing customers' transformers on the TBP feeder.

1.16 Hypothesis

The Theunissen-Brandfort Pumps feeder load can be optimally managed technically, financially, environmentally and socially with the potential implementation of DSM activities. They can be measured and verified (M&V programme) in the future, by realising these potential energy-savings to ensure sustainability of resources and reduction of GHG mitigations.

1.17 Scope of Work

The scope of this study is to ensure that the Theunissen-Brandfort Pumps feeder‘s energy is utilised optimally. The main scope objective of this study is to identify the best-practice of preventing pollution and to maintain an efficient-energy audit protocol, as well as to determine how, potentially it will influence the magnitudes and patterns of energy consumption at user levels and the whole feeder itself. This is achieved through identified and quantified DSM opportunities. The potential DSM and M&V applications can be implemented and the energy and cost savings resulting from the above can be determined. To determine the scope of work, a data collection plan and specific methods were formulated in order to address and quantify this issue.

1.18 Profile of the Study: This research project comprises of 8 Chapters:-

Chapter 1: Provides the introduction of Eskom’s adoption of integrated energy planning (IEP) regarding the need to manage its generation. It also gives an overview of South Africa’s position regarding energy resources, consumption and the GHG emissions.

Chapter 2: Provides a literature survey of energy-efficiency (EE), DSM and M&V investigations and their interactive processes.

Chapter 3: Describes the pollution prevention and resource efficiency-energy audit protocol used in this project. It also describes methods and stages within the energy-efficiency and DSM project processes that are used for potential implementation on the worksite. The stages include: project identification, energy audits, assumptions and recommendations for implementation. Its primary goal is to demonstrate the stages, achievements relating to potential pollution prevention, and resource efficiency at the worksite. The Chapter also describes the interaction between M&V and DSM or energy-efficiency project processes (methodology) for future implementation purposes (retrofitting).

Chapter 4: This Chapter provides the background to the physical and practical approach on site per selected customer, the TBP feeder and the Theunissen area as a whole. The scope is wide, practical and clear in order to provide the reader with the essential technical and economic details and the intended objectives of the protocol. Theory and literature applicable to the case studies in Chapter 5, are tabled according to the best-practice pollution-prevention and efficiency-energy audit protocol goal, and objectives achieved at the (TBP feeder) worksites.

Chapter 5: Describes the TBP feeder's best optimal practice of pollution-prevention and energy-efficiency (EE) audit protocol goal and objectives achieved per selected (TBP feeder) worksites. The following aspects are considered: measuring of energy consumption, efficiency monitoring, and evaluating energy savings technology, and energy-savings opportunities. All these are achieved by undertaking relevant detailed worksite case studies.

Chapter 6: This describes the whole plant-wide (TBP feeder's) best-practice pollution-prevention and energy-efficiency (EE) audit assessment achieved. The following aspects were considered: trapezium rule application for collective average baseline determination, pollution prevention and EE audit model. The identification and quantification of potential energy-saving opportunities. The demonstration of how to achieve and implement feasible TBP potential DSM programme, and the determination of its potential impacts for future implementation. A discussion on how the tariff structure is achieved, and finally an investigation of how to determine the potential savings of energy-efficiency and Load-shifting opportunities. All these are achieved by considering the whole TBP plant-wide best-practice assessment.

Chapter 7: Provides the potential energy and cost savings resulting from the identified opportunities (projects) on the selected customers' case studies and the TBP feeder as a whole. These opportunities would also assist South Africa with potential (greenhouse gas) GHG mitigations.

Chapter 8: Concludes with the potential energy and cost savings findings, resulting from the identified opportunities (projects) on the selected customers and the TBP feeder as a whole. Recommendations are also made on the basis of evaluated potential EE and DSM opportunities that show the greatest potential, based on their individual and combined feasibility, for the purpose of future implementation.

1.19 Summary

South Africa has a large industrial sector compared to the whole of Africa, which is responsible for the largest part of 62, 7% of national GHG emissions. Moreover, it competes with the world's largest industrialised countries like the U.S.A, Canada, Germany, U.K and others in this regard. The focus must be directed to the industrial sector for the initiation of DSM and CDM projects. For example, one of South Africa's largest consumers of coal is Iscor's steel-producing industries. Sasol is another large consumer of coal, while other industries comprise mines and the quarrying industry. These facilities consume nearly 40 mmst of coal. This high consumption of coal contributes to GHG emissions. It is, however, clear that the industrial sector in general shows a significant potential for emission reduction if the DSM projects are initiated as soon as possible [2].

Emphasis must be placed on Eskom's electricity generation. Achievement of demand for energy consumption would mean additional savings. Additional benefits would involve improved environmental policies, pollution and the development of infrastructure to support new technology and renewable sources. The integrated approach would play a major role in the development of expertise, training of staff, the implementation and sustainability of GHG mitigation projects, and the sustainability of DSM measures and would also create a market for innovative ways to reduce emissions.

1.20 References

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CHAPTER 2: LITERATURE SURVEY

This chapter provides a literature survey of how to conduct energy-efficiency, DSM (LS) and M&V investigations and their interactive processes. The potential implementation mechanisms of energy-efficiency (EE), DSM interventions and the M&V process stages are discussed. What is Energy-Efficiency? What is load-management? Determination of the impact of DSM interventions, thus the interaction between the DSM mechanisms, the M&V process and the tariff structure/s applicable which will be discussed further in Chapters 6.

2.1 Introduction to the Literature Review

A literature review was conducted, and formed the first stage of research for this dissertation. The review consisted of the detailed investigation and scans of relevant literature and was conducted from similar research projects which deal with the EE, DSM and M&V process and programmes and their benefits. It was conducted over a period of one year. The literature used for this dissertation is unique, applicable and it was also adapted to suit the objectives of this particular research project. Experts on the topic of DSM, a statistician, mentors as well as relevant sources were regularly consulted.

Many similar research projects have been conducted locally and internationally and they mostly fall under different classes, which are mainly residential and commercial. The research approaches are not the same as those employed in this project, which has mostly an industrial character because of the customer's pumps and motors (electrical systems) on the TBP feeder. Electricity is a very useful and valuable source of energy, therefore, we need to manage and use it optimally for the following reasons:

◙ The more energy we use, the more energy needs to be generated e.g. more power stations need to be built, which results in customers having to bear the costs [4].

◙ South Africa's coal reserves will not last forever because of the growing population and accompanying demands on our energy resources [4].

◙ The environment will benefit from efficient use of energy e.g. every kilowatt hour (kWh) of electricity saved, means less carbon dioxide (emissions) generated by power stations and released into the atmosphere [4].

The implementation mechanisms, which would address the following questions: how potentially the interventions would provide the building of new generation capacity by potentially reducing the loads at the TBP's customers' level, which would in turn also assist the end-users in reducing the ever increasing costs of electricity, and would assist South Africa with GHG emissions reductions.

The emphasis is placed on the stages of the potential project activity cycle, thus the identification, energy audits and recommendations for implementation are displayed [Figure 3.1].

2.2 The Potential Benefits of DSM Programme

These include:

- The reduced demands during peak time, would delay the supply infrastructure capital investment.

- The improved value of electricity services to customers by reducing energy costs e.g. customers can choose from the range of energy-efficiency options and benefit financially.

- The efficient conservation of energy would provide environmental benefits due to the reduction of emissions and water consumption at the power stations.

- Supporting of macro-economic development of the economy, through job creation and improved productivity.

2.3 Energy or Load-Demand Management

It is the utility's (Eskom's) desire to reduce the load peak demands for future capacity additions and also to reduce the high energy costs of serving these peak demands. It also desires to increase off-peak hour load demands to improve the utilization of its facilities and those of the customer. Load-demand management is segmented into two approaches (DSM programmes):

2.3.1 Direct-Load Management

This is achieved by directly disconnecting, reconnecting or modifying the operation of the end-use electric devices. Examples are load-shifting and energy-efficiency.

2.3.2 Indirect-Load Management

This is achieved via an electric rate structure to encourage the desired load change. Examples thus achieved include strategic growth and load-shifting.

2.4 Energy-Efficiency

"Energy-efficiency'' is often described as the volume of energy consumed per unit of production. A facility can improve its energy-efficiency (EE) in one or two ways: By making capital investment in new, more efficient equipment or through better monitoring, maintenance and verification of energy flows in existing equipment. The capital improvement approach implies that a piece of machinery will improve efficiency [15].

2.5 Implementation of interventions

The options explained are based on the holistic DSM aims and objectives. Figures 2.1, 2.2 and 2.3, show potential DSM interventions that could serve as implementation mechanisms on the Theunissen-Brandfort Pumps Feeder. DSM interventions include:

2.5.1 Energy-Efficiency: The usage of more efficient appliances of energy-saving devices.

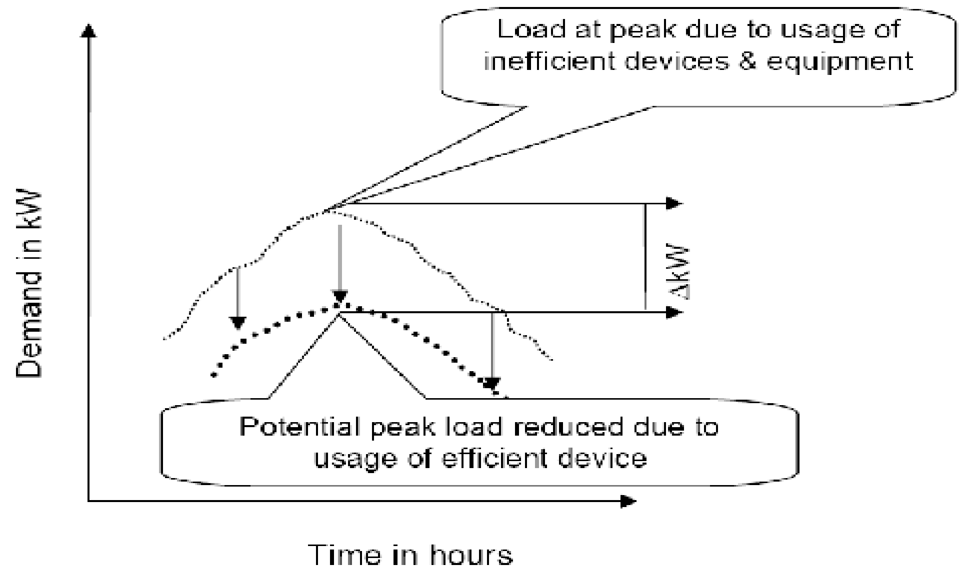

Figure 2.1: The savings effect of energy-efficiency activity.

2.5.2 Load-Shifting: Shifting of electricity from peak to standard and off-peaks.

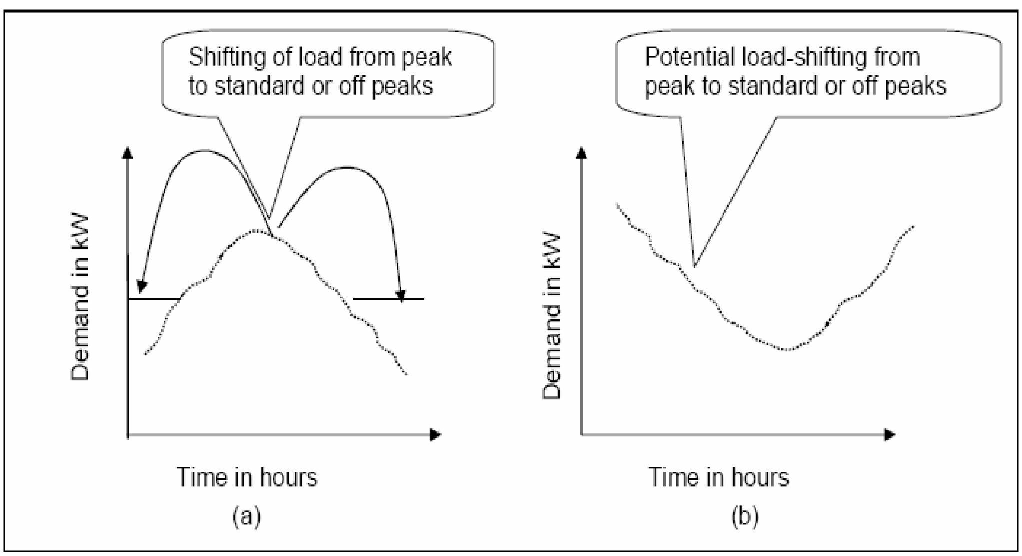

Figure 2.2: The savings effect of load-shifting activity

2.5.3 Strategic Growth: Motivating customers to use more/less electricity with real benefit when there is surplus/lack of capacity.

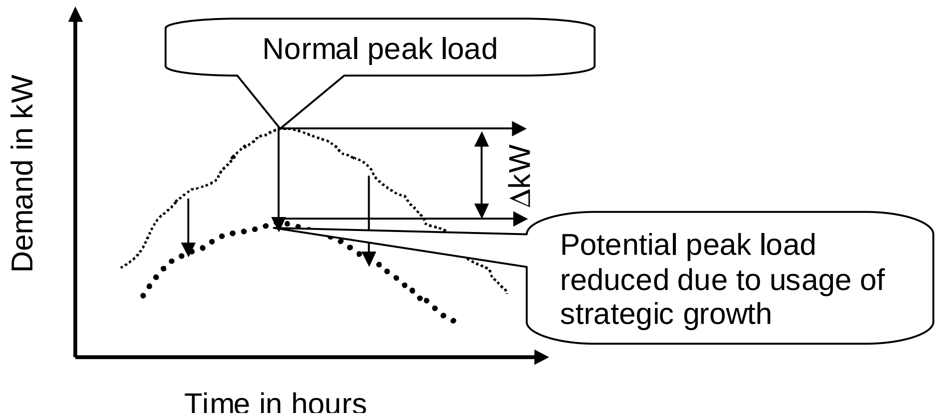

Figure 2.3: Strategic reduction effect of load-shifting activity

An example of strategic growth is peak clipping which involves the reduction of load during peak periods by agreeing with the customers to control their appliances.

2.6 The Importance of Measurement and Verification (M&V).

M&V is the quantification and assessment of the savings that result from the energy-efficiency and DSM projects which are measured in an impartial manner. This process includes the stakeholders (M&V team) such as the utility (Eskom), the client, the energy service company (ESCO) or energy-efficiency service (EES) and the financial institution (Eskom Bank) [2].

The Client - Wants to reduce his monthly energy costs when he reduces his peak demand or energy consumption.

The Financial Institute (Eskom Bank) - Wants to protect its investment in the project.

The ESCO - Is the Electricity Services Company that wants to share in the energy cost savings.

2.7 M&V Process and the DSM Programme Abroad and in South Africa and the Development of the Measurements and Verification (M&V) Stage.

The measurements and verification (M&V) process involves the activities and procedures that will be followed to measure and verify the DSM activity outputs. The M&V should include a description of the project TBP feeder or customer and state the assumptions and variables that influence the saving potential of the DSM activities.

The applicable M&V process (plan) is discussed in Chapter 7, section 7.2 to 7.4, after the analysis of potential results, for the purpose of determining the feasibility of these results. The environmental and social-economic benefits of using EE, LS and M&V will also be discussed.

2.8 Why is Measurement and Verification Carried out?

Eskom has commenced with the implementation of national energy-efficiency (EE) and load-shifting (LS) DSM measures and initiatives in the industrial, commercial and the residential sectors. Its long-term strategy is to reduce South Africa's electricity demand during peak periods. Large financial investments are being made and the increasing number of clients are realising the need for energy-efficiency and the sustainability of load-shifting projects. If the project impacts are known, focus areas as well as potential problems for EE and LS (DSM projects) can be identified. It encourages investment in the EE and the LS (DSM projects) and also reduces risks for financial investors, mainly ESKOM. The realised or potential energy-savings, will result in be reduction on emissions and water usage [2].

2.9 How does One Measure and Verify?

The basic principle of M&V is to compare the measured energy consumption with the demand after implementation. This is demonstrated in equation 2.1.

Energy Savings= ***[(Base year energy use)–(Post-retrofit energy use)] ±Adjustments*** ***Eq 2.1:***

2.10 Basic Approach for Potential DSM Impact determination:

Step 1: Select the appropriate IPMVP option by stipulating and inference.

Step 2: Gather relevant energy and operating data from the base year and process it for future use.

Step 3*:* Design the energy saving programme. It includes documentation of design intention and methods to be used for demonstrating achievements.
This is usually done by the ESCO, EES or the client.

2.11 The Baseline

The baseline (Figure 2.4) is the prediction of what the energy-savings would have been if nothing had been altered on the TBP feeder. Savings result from subtracting the actual energy consumption (baseline) from energy consumption predicted by using the DSM programme. The TBP feeder has a specific energy-demand before EE and LS interventions (DSM programme) are be implemented. There is potential for reducing this energy demand by a certain amount after the implementation of the DSM programme. Adjustments to the baseline will only be made when any of the EE and LS (DSM programmes) become feasible and when there are certain factors affecting the process; e.g. variables etc.

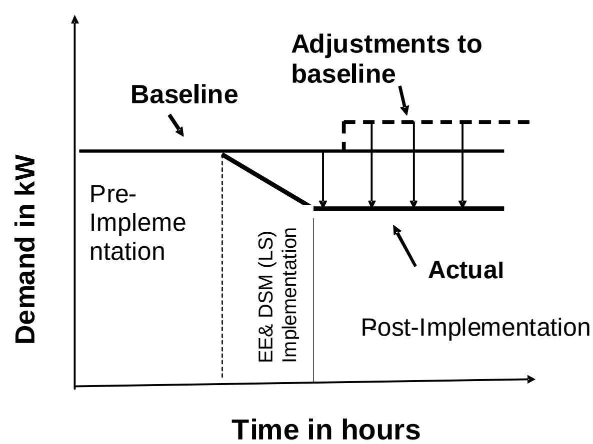

Figure 2.4: Rationale DSM Project process

2.12 The Rationale Energy Savings Determination:

With reference to the International Performance Measurement and Verification Protocol (IPMVP), options interacting with the DSM interventions and the M&V plan, the energy - savings can be determined using the three basic stages, viz: the pre-implementation, implementation and the post-implementation stages. These stages can be seen in Figure 2.4. The system has a certain amount of energy-usage before implementation and after the implementation and the energy usage is reduced by a certain amount.

In order to determine what the savings are, one needs to determine what the energy savings would have been had the energy-efficiency and the DSM interventions not taken place. This is achieved through the use of the baseline, based on certain known measurable input variable or patterns. Adjustments are made to the baseline when any of these assumptions become invalid or when they are no longer satisfied by the baseline [2].

2.13 Formulae to Measure and Verify the Potential of EE and DSM Options Effects

These are shown in Figures 2.5, 2.6 and 2.7***.***

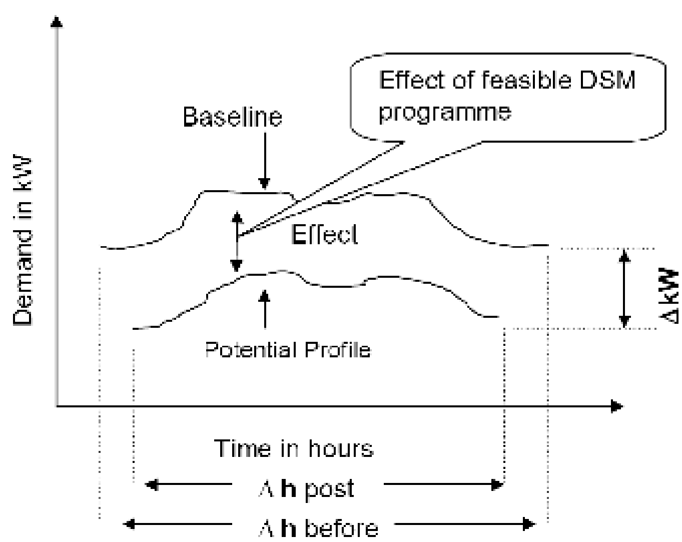

Figure 2.5: The savings effect on both kW and time

Where**:** **kWh (saved)** = (kW before x Δh before) **–** (kW post x Δh post)

Δh = h before **–** h post

ΔkWh = kWh before **–** kWh post

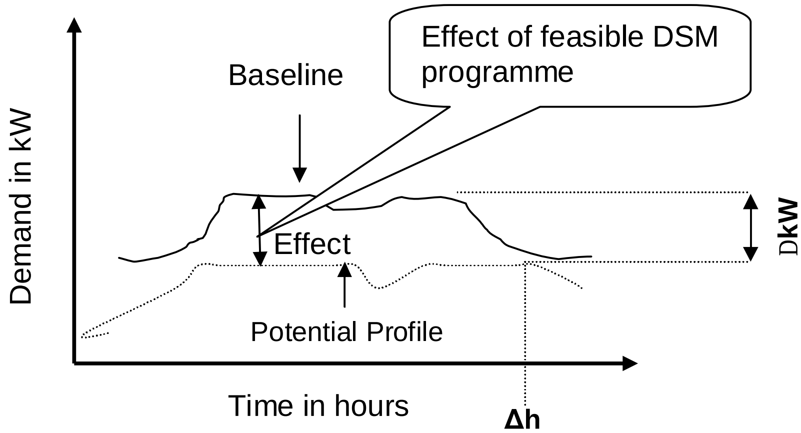

Figure 2.6: The savings effect for kW with minimal Δh

Where: **Δh** ≈ minimal hours ≈ 1unity

kW ≈ post actual

kWh (saved) = (kW before x kW post) x (Δh hours)

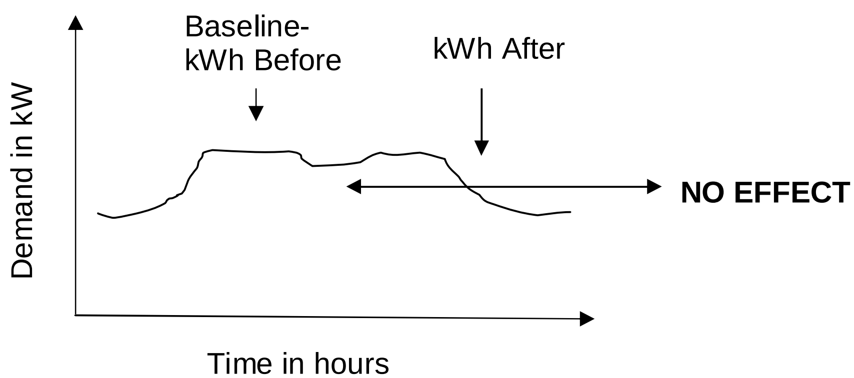

Figure 2.7: Invisible or minimised impact and only time is visible

Δ kWh ≈ 0

Where: **.˙. Δh** ≈ h before **–** h after ≈ 0

.˙. kWh saved ≈ kW installed x Δh

.˙. kWh (saved) ≈ kW installed x (Δh before **–** Δh post)

.˙. Δ kWh ≈ 0

2.14 The M&V Report

This report contains all the relevant information and findings of a DSM project illustrated in Figure 3.1.

2.15 Summary of Chapter 2

Chapter 2 outlines the process overview which in turn highlights the practical application of the literature survey and theoretical methodology of DSM. The assessment approaches which are based on protocol and theory, as well as the emphasis on the future implementation of the methodology will be discussed in Chapter 3.

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CHAPTER 3: METHODOLOGY

This Chapter describes the pollution-prevention and resource efficiency-energy audit protocol used. It describes the method and the stages within the energy-efficiency and DSM project process, which must be used for potential implementation on the TBP's feeder worksite. The stages are: Project identification; Energy audits and assumptions; and recommendations for implementation. The primary goal of this chapter is to demonstrate these stages and the achievements which contribute towards potential pollution-prevention and resource efficiency at the worksite. The Chapter also describes the M&V and interaction between M&V and DSM or energy-efficiency project processes (methodology) for the purpose of future implementation (actual retrofitting). The M&V aim is to show how to determine the impact of DSM interventions, which involve the M&V process and the applicable tariff structure/s applicable, that will be discussed in Chapter 6.

3.1 Methods

The energy-audits protocol describes the method utilised to establish current and historical energy consumption by the TBP feeder, based on specific DSM interventions being undertaken, and the cost of this energy. Using the baseline information collected, the TBP electrical system's potential energy-efficiency and load-shifting opportunities are quantified and identified in Chapters 5 and 6 and analysed in Chapter 7. Further appropriate potential energy-savings opportunities are also identified and quantified were potential savings and emission reductions are also considered.

The TBP's energy demand, consumption and pattern trends are benchmarked against a typical industrial averaged pattern of similar operations to identify potential areas as well as potential mechanisms for realising the potential savings (refer to Figures 4.1, 4.2 and 4.3). By reviewing the TBP feeder's energy consumption on an ongoing basis, unexpected increases or decreases in demand or consumption are highlighted and addressed.

The following methodology was followed to audit the TBP electrical system facilities' efficiency and conservation of energy use. Thus the site and source energy, and these describe the facility's energy consumption [1]. Site energy includes only the energy consumed at the facility. Source energy includes the site energy plus the energy used to produce the site energy, including the energy required to generate, transmit and distribute the site energy to the facility. Because source energy embodies the generation, transmission, and distribution impacts associated with various fuels used at the site, it is a more accurate indicator of energy, economic, and environmental performance (Figure1.3). The distinction between site and source energy is important when describing the environmental and economic impacts associated with the building of energy performance. Site energy is a familiar and common convention used for discussing facility energy consumption when multiple fuels are used in a facility (e.g. electricity and natural gas).

The overall purpose of this energy audit protocol is to provide a uniform approach for estimating energy consumption and for identifying opportunities for more efficient use of energy. Table 3.1 shows pollution-prevention and resource efficiency-energy audit protocol methodology.

Table 3.1: Pollution Prevention and Resource Efficiency Energy Audit Protocol Methodology

AIM	DESCRIPTION	METHODS
3.1.1 **Identify Energy Sources and Costs**	The identification of energy source and costs establishes a baseline for the energy structure at the TBP facilities, which in turn allow determination of the marginal cost of energy and show the potential cost impact of energy reduction.	◙ Identify and list all energy sources used by the facility including: electricity, gas coal, petroleum fuels and biomass. ◙ Compile a process-flow diagram indicating all energy input points ◙ Review the costs for each energy source for the last 12 months to establish the pricing structure in Rands per unit of energy, i.e. from accounts for energy purchases.
3.1.2 **Establish Profile of Energy Consumption and Energy Intensity**	Establishing the facility's (TBP) energy consumption profile will quantify energy consumption over the daily, weekly and monthly production cycle, as well as identifying and quantifying the facility's production and the specific energy consumption patterns for different time scales.	◙ Establish the profile of the energy consumption for each energy source (electrical system) over: a typical 24-hour period, one production week and one month period. ◙ Obtain production records for the corresponding periods. ◙ Calculate the baseline energy consumption per unit of production, i.e. energy intensity prior to introduction of conservation measures (DSM interventions).
3.1.3 **Energy-Usage Inventory**	This section aims at identifying major energy use units / activities by establishing an energy-use inventory	◙ Identify all major energy users within the facility, including: steam and hot water production, ***water pumping***, gas or oil burners, electrical appliances and lighting. ◙ The term "major" includes any facility or equipment using over 100GJ/year. ◙ A detailed list of energy use information is compiled by collecting the following data on ***Motors:*** - Motors greater than 3,5kW, and providing functionality for each. - Standard or high efficient motors are selected for opportunity analysis. - The current power drawn at maximum operating conditions (kW) from each listed/selected motor. - For single or fixed speed motors list number of hours per year motor operates at full load, thus ¾ loads, <½ load and idle.
3.1.4 **Energy-Usage Patterns**	This section aims to quantify energy usage for each unit/activity/user over different time frames, thus daily, weekly and monthly cycles, thereby giving an indication of the key factors affecting the units/activity/user energy-use patterns	◙ Measure or estimate the electrical energy consumption over 24 hours, one week and one month for each unit / activity / user (major user identified previously). ◙ For each electrical unit/ activity/user, calculate the percent utilisation factor as follows: ***% Utilisation*** = Daily / Weekly / Monthly /Yearly Consumption (kWh) / Peak demand (kW) x Number of hours in day / week / month / Yearly ***Note:*** *continues to next page*

Note: Table continues to the next page

		▪ Compile a graph of energy consumption for each major energy user against the following production periods, thus 24 hour, one week and one month. ▪ Include the periods of electricity peak demand on the graph, as well as the volume of production over relevant production periods.
3.1.5 **Determine the following from the graph**	Non / low-production periods, production effects, equipment start-up and shut-down and impact on demand, impact of weather conditions, cyclic loads.	▪ Interaction between systems, effects of occupancy loads on demand, problem areas and potential for peak load reduction.
3.1.5.1 **Peak-Load Reduction.**	Identify essential electrical loads or such loads that can be shed for short periods during peak loads	▪ Determine what is the potential is for installation of load management control system? ▪ Determine electrical utilisation or load factor. ▪ Investigate means of increasing the load factor.
3.1.6 **Comparative Analysis**	This section aims at identifying high energy consumption activities as means of prioritising areas for more detailed investigation for the energy saving measures.	▪ Establish industry average energy consumption figures for different activities and compare to calculated energy consumption per unit of production for company/facility under consideration.
3.1.7 **Identify Energy Saving Opportunities**	Identify potential energy savings opportunities by undertaking a review of alternative energy technologies appropriate to the company/facility, thus identify energy reduction, and establish an order of magnitude cost estimate for each identified opportunity.	▪ Establish potential energy cost savings based on the structure for the various forms of energy, as well as optimising the energy demand patterns. ▪ The opportunities for energy savings are analysed and prioritised.

3.2 Integrated Stages of EE, DSM and GHG Mitigations in the Project Environment

The different stages associated with the potential implementation mechanisms are as stipulated and inferred. These stages are the same for both energy-efficiency and DSM projects. DSM projects must be supported by energy-efficiency projects, because without an energy-efficiency component, there will not be any load-demand and GHG emissions reductions. The CDM process for GHG mitigations is not discussed. Previous studies have shown that the GHG emissions have only been realised when the energy savings were also realised. This study's aim is to show the potential regarding the implementation of the DSM measures [2].

3.3 DSM Interventions Project Stages

Identification of potential DSM interventions on the feeder depends on the project complexity of energy audits and assumptions**:**

- Identification of needs

- Energy audits are conducted on the Theunissen-Brandfort Pumps feeder and per customer by determining the type, quantity and rating of all energy-using systems.

- Recommendations for implementation**:**

a) Better estimate of the potential savings is calculated once the TBP feeder and systems information has been gathered.

b) DSM interventions (opportunities) that show the greatest potential are recommended.

c) Whenever the activities or opportunities will be hindered by customer disagreements and other factors, they are inferred and stipulated based on their strongest feasibility, which would be the introduction of the M&V programme (Chapters 5 and 6).

3.4 Project Stages for TBP Potential DSM Implementation Study are as Follows:

3.4.1 Project Identification

The need, potential or opportunity for DSM and energy-efficiency are identified by the client or ESCO. An ESCO would mostly be contracted to determine the potential impact and savings that could be achieved (Figure 3.1).

3.4.2 Energy-Audits/Assumptions

An energy-audit is conducted to determine the type, quantity and rating of all relevant energy-using systems. This information is used to determine the potential savings that could be achieved by energy-efficiency activities. It consists of a walk-through audit followed by a detailed audit. Assumptions are also stated regarding system information that is not available. Factors that could influence the potential to generate savings through energy-efficiency are identified (Figure 3.1).

3.4.3 Recommendations for Implementation

A better estimate of potential savings can be calculated once the system information has been gathered. Upon evaluation of the various potential energy-efficiency and load-shifting (DSM Programme) together with their feasibility study, the EE and LS activities that show the greatest potential are selected, based on their individual and combined feasibility (Figure 3.1). The M&V activities and stages are explained in sections 7.2-7.4 of Chapter 7.

3.5 Procedures and Activity Stages Relating to the Determination of the DSM Measures Impact

3.5.1 The M&V Delivery Stages (Process):

- ***Scoping Report Stage:*** This stage enables the M&V team to gather all relevant and available data regarding the energy-efficiency and the DSM projects, viz : project information, project objectives, site description, tariff structure, audit of system, proposed activities, expected results**,** conclusions and comments. The scoping study is an important document for the utility as the financing party of the project. It provides the expected impacts of the project [3].

- ***The M&V Plan Stage:*** This stage outlines the complete process that is expected for the project. It sets buy-in before the M&V activities may proceed. The plan is updated with the negotiated recommendations of the stakeholders if the buy-in is not obtained [3].

The first part of the M&V plan repeats the first few sections of the scoping stage; this is only to ensure that the M&V plan forms an independent part that provides a complete overview of the project. The plan includes the following sections:

Project information, project objectives, site description, tariff structure, audit of system, proposed activities, expected results**,** evaluation and the M&V option selection. The M&V option selection is part of the M&V plan where the selected options will be utilised to determine the project baseline and ultimately the project savings. There are four basic options for the M&V designed from the International Performance Measurement and Verification Protocol (IPMVP), namely: (viz)

The IPMVP Process:

The applicable potential EE & LS programmes are investigated based on feasible interventions. Potential opportunities per selected customers and TBP feeder for determining the baselines reductions and the potential energy savings will be tabled in Chapter 7.

- **Stipulating:** stating clearly and firmly all the electrical equipment rated consumptions on the name plates.
- **Inference**: reasoning, logical thinking and the drawing of conclusions relating to the findings.
- **Measurements**: measured load data results using calibrated meters.

The discussion of these preferred options will be explained and analysed in Chapters 5 and 6. All these options are based on the holistic DSM interventions of energy-efficiency, load-shifting and strategic-growth:

- ***OPTION A – Partially Measured Retrofit Isolation:***

This involves isolation of the energy use of the equipment, affected by a project from the energy-use of the entire facility. All relevant energy-use equipment is isolated during pre-implementation and post-implementation stages. Partial measurements are used with some parameter(s) being stipulated rather than measured.

- ***OPTION B – Retrofit Isolation:***

The savings determination is the same as that of option A, except that no stipulation is allowed, full measurements are required. Short-term or continuous metering is used.

- ***OPTION C – Whole System or Whole-Facility Plant:***

Utility meters or the whole-facility plant sub meters are used to assess the energy performance of the total facility. This option assesses the impact of any type of project. This option determines the collective savings of energy-efficiency and Load-shifting projects.

◙ ***OPTION D – Calibrated Simulations:***

The option uses advanced computer simulation software to predict facility energy use.

3.6 Potential-Implementation Stages

Potential-implementation stages are required to determine the baseline against which the new energy performance and the implementation can be compared in order to calculate the savings. Post-implementation audits, post-implementation measures, calculation of savings (DSM impact) and adjusting the baseline are stages to be implemented in the future [2].

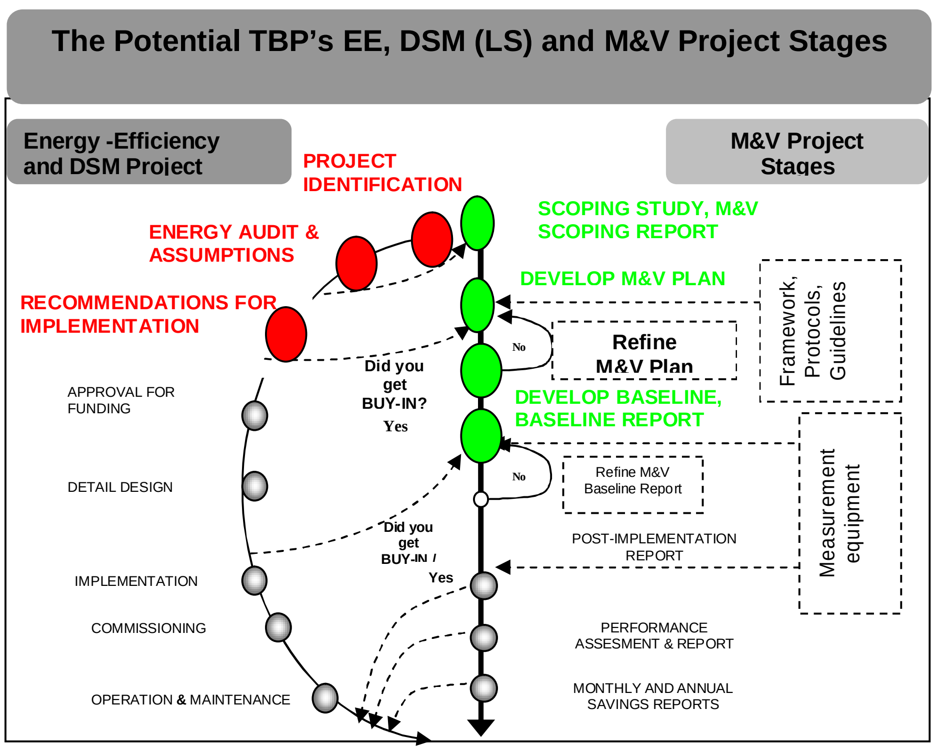

Figure 3.1: The integrated approach interaction between EE or DSM and M&V

Figure 3.1 demonstrates the potential processes for energy-efficiency, DSM and M&V project stages in short, and is fully explained from section 3.1 – 3.6 of this Chapter.

3.7 Conclusion

The methodology stages involved in the description of the facilities' potential energy consumption are the following: project identification energy audits, and assumptions. The recommendations for implementation and M&V interaction stages comprise a scoping study, the development of the M&V plan, and the M&V baseline report [Figure 3.1].

Source energy is used to produce the site energy, such as the energy required to generate, transmit and distribute the site energy to the facility. Because source energy embodies the generation, transmission, and distribution impacts associated with various fuels used at the site, it is therefore the most important and accurate indicator of energy, economic, and environmental performance for the best-practice pollution-prevention and energy-efficiency on the worksites.

The distinction between site and source energy is important in describing the environmental and economic impacts associated with the facility energy performance. Site energy is a familiar and common convention used for discussing facility energy consumption, especially when multiple fuels are used in a facility (e.g. electricity and natural gas).

3.8 References

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CHAPTER 4: WHOLE WORKSITE STUDY

This Chapter provides the background to the physical and practical approach on site per selected customer, the TBP feeder and the Theunissen area as a whole. The scope is wide, practical and clear in order to provide the reader with the essential technical, economic, environmental and area details and the intended objectives of the protocol. Theory and literature applicable to the case studies in Chapter 5, is tabled according to the best-practice pollution prevention and efficiency-energy audit protocol goal and objectives achieved per TBP feeder worksite.

4.1 Introduction

The study involves the potential of implementing the demand-side management interventions on the Eskom's Theunissen-Brandfort Pumps feeder in order to foresee the potential savings. The most effective use of electricity as a source of energy on this feeder, electricity cost reduction, an understanding of proper energy management by end-users, particularly farmers, municipalities and the Free State province and South Africa as a whole, are also the focal points of the project.

A change in the patterns of energy use of this feeder must be considered to ensure sustainable energy resources which must be measured and verified in the future. Electricity has made daily life easier when compared to the old methods of energy consumption (e.g. wood, dung etc), but it is also very important to manage it optimally. To achieve these objectives, DSM Interventions must be feasible.

The in-depth investigations were firstly conducted on sufficient and relevant data collected per selected customer, the Theunissen feeder and the Theunissen area using the research parameters. The types of customers selected were those who were mostly using motors for water pumping, irrigation, processing, and manufacturing. All the selected customers are classified as industrial. Most of the farmers (customers), the Theunissen-Masilo communities and surrounding rural area utilise water from the Erfenis Dam, which is situated on the South Eastern side of the Theunissen-Masilo Town. The selected customers' businesses are as follows:

◙ **Brandfort-Municipality:** water pumping for Brandfort-Majwemasweu.

- **Theunissen-Municipality (Purification):** water pumping for Theunissen-Masilo and surrounding areas.

- **Koppiesfontein:** District (farmer)**:**- Irrigation.

- **Mr A. Gutter:** Theunissen - (farmer)**:**- processing and manufacturing of mushrooms.

Secondly an investigation of a holistic DSM programme applicable to the TBP feeder and selected customers was also conducted (interventions opportunities). The measurements at the substation for the whole feeder were taken concurrently with those of the selected customers for a period of seven days. The reason for this was to be able to identify and quantify the actual collective baseline (actual feeder's profile consumption) within five working days for processing and manufacturing customers and another additional two weekend days for irrigating and pumping customers and also to be able to perform the analysis for daily, monthly, seasonal and yearly consumption.

Thirdly, the proper feasible DSM programme was investigated from the perspective of all the customers. The TBP feeder has a specific energy demand before the potential DSM programme can be implemented. These energy demands would potentially be reduced by certain amounts after the future implementation of the programme. In order to demonstrate whether the programme was valid, potential measurements and verifications will be conducted for further research. This is done by applying M&V activities which are presented in Chapter 6.

The TBP has slight residential characteristics, which mostly comprise farm workers and the owner's houses and the office's usage of appliances. The farm workers' houses for all these selected customers are electrified through the government and owners' initiatives. They also consume electricity from the existing customer's transformers, but some of them still use wood, as a source of energy especially during winter, which has a negative impact on the environment. If the energy on the TBP feeder can be used optimally, the farm workers will stop cutting trees to use wood as a source of energy. The TBP feeder comprises mostly industrial customers and is therefore classified as an industrial network feeder.

The criterion used in developing and evaluating the relevant data process methodology was based on the following aspects:

Simplicity, obtainable parameters, simple user-friendly and transparent formulas, relevant model simulation software programme and uniform acceptance for future implementation.

Data process is evaluated and methodological results are performed as follows: Correct assumptions made and compromises reached by all parties that include researcher and customers. Pragmatic approach to develop data collection, theoretical, numerical and practical analysis of results.

4.2 Research Parameters and Methods Used for Data Collection

Interviews with farmers, plant supervisors, rural communities and experts were conducted. Questionnaires were circulated among end-users and local rural communities. Relevant courses/conferences were attended. Historical data, photographs, written work, observations, relevant documents sources and data-capturing equipment (Net-loggers) were used.

4.3 Technical Data Needed According to DSM Interventions

- ***Strategic-Growth**:* Customer's class/ segmentation, number of electricity-using devices per customer on year-duration, growth and development per plant.
- ***Energy-Efficiency**:* Types of technology and equipment used and to be used, operation efficiency, change of equipment and market share, new technology demand, rated electricity consumption on the equipment.
- ***Load-Shifting**:* Energy-shifting of kW / day, kW / month, kW / season and kW / year per hours of possible equipment / transformer operations and different scenarios.

All the interventions information is discussed per case study

4.4 **Segmentation/Class of TBP Feeder and Selected Customers**

- ***Residential Classes***: single family, duplex, and two families, mobile homes, apartment buildings.
- ***Commercial Classes***: shopping centres, hospitals, schools, office buildings, service orientated businesses.

◙ ***Industrial Classes**:* large manufactures, small manufacturing, mining, food processing, water pumping.

The TBP feeder is segmented into an industrial network (plant) because of the type of customers on it. Most of the customers on the TBP feeder use motors for water pumping, irrigation, food processing and manufacturing purposes. The weather information for the Theunissen area is gathered for the purpose of peak-load projecting. This includes the summer and winter loads on the TBP feeder and per selected customer. It was built in 1984 and has 82 customers. Figures 4.1, 4.2 & 4.3 give typical load curves for industrial load patterns for different seasons.

4.4.1 Typical Industrial Daily Load Curves in the U.S.A. (a) Winter, (b) Summer.

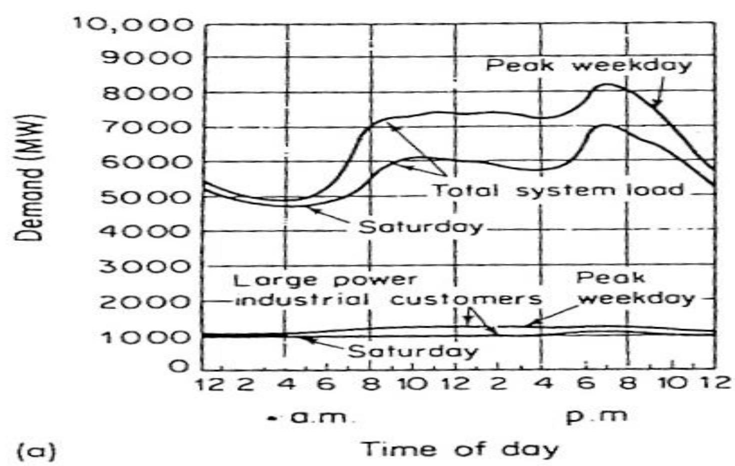


Figure 4.1: Typical industrial customer patterns in winter within a period of 24hours

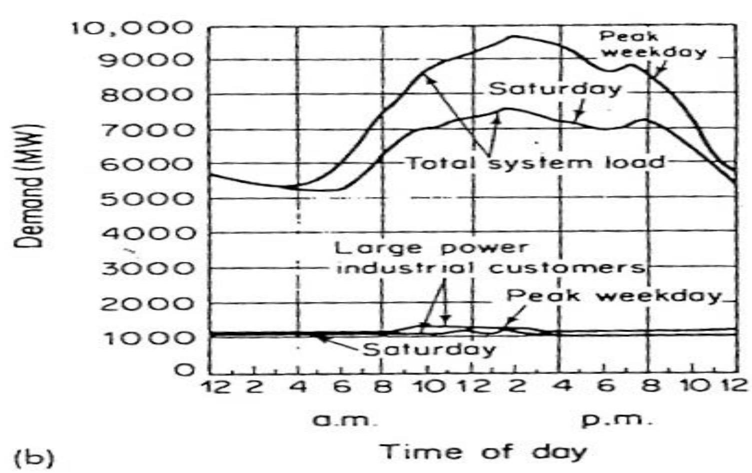


Figure 4.2: Typical industrial customer patterns in summer within a period of 24hours.

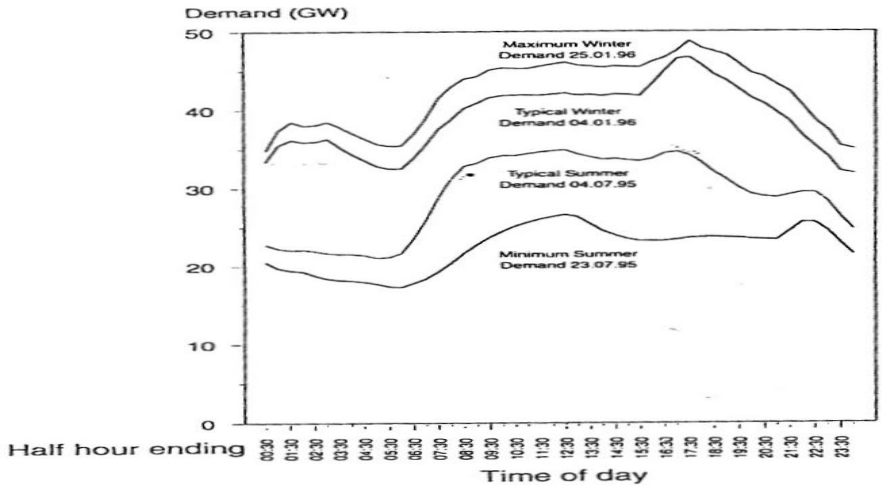


Figure 4.3: Comparison of industrial customer patterns in summer and winter within 24hours.

Figures 4.1, 4.2 and 4.3 represent typical industrial load patterns in the U.S.A utility. It is clear that most of the industrial loads are fairly constant during peaking loads. Comparison of Figures 5.3, 5.6, 5.8, 5.9 & 6.2 for the TBP and selected customers' baseline reduction representations in relation to Figures 4.1, 4.2 and 4.3 reflect similar trends in the demand-load patterns.

4.5 The TBP Feeder's Characteristic Descriptions

Customers with the largest transformer sizes were considered. The total number of customers on the TBP feeder were also scanned through. About sixty to seventy percent (60%-70%) of the customers on the feeders comprise industrial characteristics. The Theunissen-Brandfort Pumps feeder is situated in the Theunissen area. Theunissen-town is +/-110km outside Bloemfontein, and geographically located at 16º longitude and 84º latitude. The Theunissen-Brandfort feeder was built in 1984 and is 174km in length. The average temperature during winter and summer is 10ºc and 32ºc respectively. The installed demand-load on the feeder comes mainly from farmers and the pump station for Theunissen, Brandfort and the surrounding rural areas. It supplies 82 customers. The Erfnis Dam supplies water to most of the communities (farmers, rural communities) of Theunissen-Masilo and Brandfort-Majwemasweu communities via the stream-canal running on the outskirts of Theunissen town to the Eastern part of the Free State province. The Eskom's customers that will mostly benefit from this study are the local farmers, the local municipalities of Theunissen-Masilo, Brandfort-Majwemasweu as well as other surrounding rural communities.

4.6 List of Selected Customers

Table 4.1**:** Selected customers on the Theunissen-Brandfort Pumps feeder

DESCRIPTION	TYPE OF POWER USER	POLE NUMBER	KVA
Brandfort Municipality-Brandfort	Large	TBP126-34-1A	315
Gelukfontein 390 – Mr A. Gutter Theunissen	Large	TBP140-63-15	100
Koppiesfontein 11 District Theunissen	Small	TBP158-63-15	50
Purification Plant-Theunissen Municipality Theunissen	Large	TBP132-5	2x200

4.6.1 Description of Selected Customers

The potential DSM programme is deduced from information derived from case studies. These were performed on the Eskom's 11kV TBP rural feeder in the Theunissen area. There were approximately 82 customers. Most customers used motors for water pumping, irrigation, food processing and manufacturing. Meters were installed on selected customers and the TBP feeder (at the sub-station) for seven days, thus 5 weekdays and 2 weekend-days at 5-minute intervals (Refer to Figures 5.3, 5.6, 5.8, 5.9, 6.2. and Appendix I).

4.7 Block Diagram of a Typical TBP Electrical System (Machine)

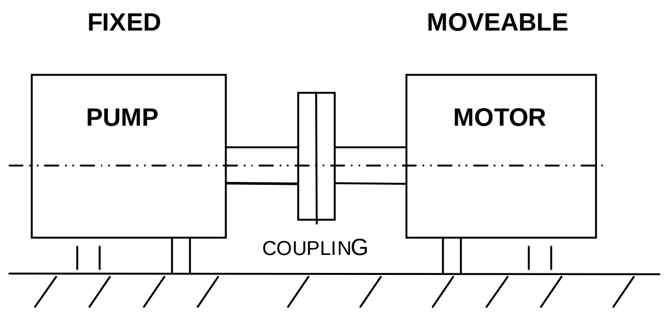


Figure 4.4: Block diagram of typical machine set comprising motor and pump

4.8 Scenarios Considered During Investigations

Two basic scenarios were considered. The first was that no measurements were taken to reduce the forecast energy consumption of the TBP feeder and per selected customer. The second considered the effect of the potential DSM programme applicable to the TBP feeder. The scenario without a potential DSM programme consists of the basis when load energy data and peak loads for the study period were as originally forecast.

The scenario involving the potential DSM programme considered that the programme has its peculiarity concerning its mode of implementation and acceptability, especially by customers during their periods of operation and dissemination. Each measure will have its own penetration factor determined by the set of factors linked to technical, market economic, environmental and mostly, human behaviour (customers' agreements) variables.

4.9 Conclusion

The best-practice of case studies was achieved by following and undertaking the basic principles of pollution-prevention and resource efficiency-energy audit protocol's goal and objectives, thus identifying energy-sources and costs, establishing profiles of energy use, consumption intensity and patterns, compiling energy use inventories and undertaking comparative analysis and identifying energy saving opportunities per facility or plant. All these are performed in the following Chapter.

CHAPTER 5: CASE STUDIES

This Chapter describes the TBP feeder's best practice-pollution prevention and efficiency-energy (EE) audit protocol goal and objectives achieved per selected TBP feeder's worksite. The following aspects are considered: measuring energy consumption and efficiency, monitoring and evaluating energy savings, technology and energy-savings opportunities. All these are achieved by performing relevant worksite case studies.

5.1 CASE STUDY 1: PURIFICATION PLANT

5.1.1 Plant Energy Audit Methodology Approach

This customer is composed of two electrical machines systems (Figures 5.1 and 5.2).

5.1.2 Identify Energy Source and Costs

Electricity is the only source of energy for the Purification Plant. The cost review of energy source for the last 12 months so as to establish the pricing structure in Rand per unit of energy, the cost of 30.578c/kWh/yr is averaged, considering the annual and seasonal cyclic load factors and variables.

Table 5.1: Purification plant energy sources intensity profile

ENERGY SOURCE	ENERGY USAGE(kWh)	PERCENT USAGE /ENERGY SOURCE	COST
Electricity	339.864kWh/day	100%	30.578c/kWh(Averaged)
Petroleum fuels	0units	0%	0 c/units
Miscellaneous	0units	0%	0 c/units
Total Purchased /yr	89,724.1kWh/yr	100%(30.578c/kWh)	R 27,435.834 (Averaged /Weekdays/yr)

The process flow diagram indicating all energy input and output points on the Purification machines, refer to Figures 5.1 and 5.2 and Table 5.2. Energy consumption and intensity profile for each energy source (electricity) over a typical 24 hour period with production records for the corresponding periods.

5.1.3 Purification Plant Energy Intensity Prior to Introduction of DSM Interventions

For an analysis of energy intensity and potential DSM interventions for the Purification-Plant, refer to Figure 5.3 of baseline-reduction presentation.

5.1.4 *Energy Usage Inventory*

The major energy users within the Purification facility are the motors, refer to Table 5.2.

5.1.4.1 Motors: Energy-User

Motor sizes are 300kW and 132kW greater than 3.5kW and are used to drive the pumps. They are standard efficient motors. The power drawn at maximum operating conditions is 178kW and is mainly from motor one, with a capacity of 300kW. The number of hours per year during which these motors operate constitute ≤¾ of load for 300kW motor one, viz : 16 hours within a day, and <½ load for 132kW for machine two, the reason being that the 132kW motor idles most of the time.

5.1.5 Energy Usage Patterns

Electrical energy consumption was estimated over 24 hours using measured results of the Purification Plant's wide-assessment. Percentage utilisation factor (%Utilisation) = 178 x 11.57 hours / 16hours x 178 = 0.725 ≈ **73%** daily. The profile graph of energy consumption applies to both machines one and two against the production periods over 24 hours. The electricity peak demand on the graph as well as the volume of production over relevant periods is shown on Figure 5.3. The following data are discussed from the graphs of Figure 5.3.

Load during none or low-production period is less than 20kW for light loads at the plant itself and the Plant supervisor's house. These loads are mainly consumed during the night. Production is mainly affected by the population density variable in Theunissen-Town and Masilo Township. Equipment start-up and shut-down and impact-on-demand is from 06:00 in the morning until 22:00 at night-refer to Figure 5.3. Interactions between systems have no major impact on the plant production. The problem was identified with the motor switches of the large machine one with 300kW capacity, and that was identified from maintenance report together with the Plant supervisor.

5.1.5.1 Peak-Load Reduction.

The plant does not show any electrical failure, largely because of proper maintenance, but there are no alternative sources of energy in-the case of failure of Eskom's supply site. All the other unlisted interacting loads are also essential, viz: for lights and other small motors, and less than 0,7kW for support of the Plant's purification-process. The utilisation or load factor for the Purification-Plant is approximately 73%. The only means of increasing the load factor for the benefit of the utility (ESKOM), is coupled with a density increase of the area's population. Therefore, with a load factor of 73%, there is a potential opportunity for load reduction on this facility.

5.1.6 Comparative Analysis

The industry's average energy-consumption patterns for different activities of the Purification-Plant can be compared in Figures 4.1, 4.2 and 4.3, were the peaking load is fairly constant from 06:00 in the morning until 22:00 at night.

5.1.7 Purification Plant's Energy-Efficiency and Load-Shifting Machine Analysis

The separate energy-efficiency and load-shifting analysis were firstly conducted methodologically on the motors, then on the pump applications and lastly, concluding with the whole electrical machines system of the plant. This customer is composed of two electrical system machines.

5.1.8 Plant's Electrical System (Machine Details) Inventory

Table 5.2: Machine technical details for the Purification plant

MACHINE ONE	**MACHINE TWO**
MOTOR (LARGE)	**MOTOR (SMALL)**
Power rating = 300 kW	Power rating = 132 kW
Current rating = 533 A	Current rating = Not available
Voltage rating = 380 V	Voltage rating = 380 V
Revolutions per minutes =1450 rpm	Revolutions per minutes =1468 rpm
KSB COUPLER	**KSB COUPLER**
MULTIFLO CENTRIFUGAL PUMP	**MULTIFLO CENTRIFUGAL PUMP**
Impeller diameter =360 mm	Impeller diameter =Not available
Year =1997	Year = Not available
H(horizontal mounting)	H(horizontal mounting)
Revolutions per minute =1450 rpm	Revolutions per minute = Not available

5.1.9 Purification Plant Machine Energy-Efficiency Analysis

This refers to section 2.4 of Chapter 2: for energy-efficiency description. The calculation of efficient energy use for this customer was based on observations during site visits, in maintenance reports, expense profile maintenance report, and machine history. The analysis included ISO standards 2372 & 3145 table, table for allowable vibration velocity forces on electrical motors, electrical analysis report of motor failure and a pumps analysis report. The logical conclusion is drawn from machine improvement report and suggestions. All these facts were based on inferences and stipulations for baseline-adjustment purposes, and most importantly, the pollution prevention and resources efficiency-energy audit protocol methodology was followed.

5.1.9.1 Energy-Efficiency for Purification Plant by Referring to Photo-Diagrams.

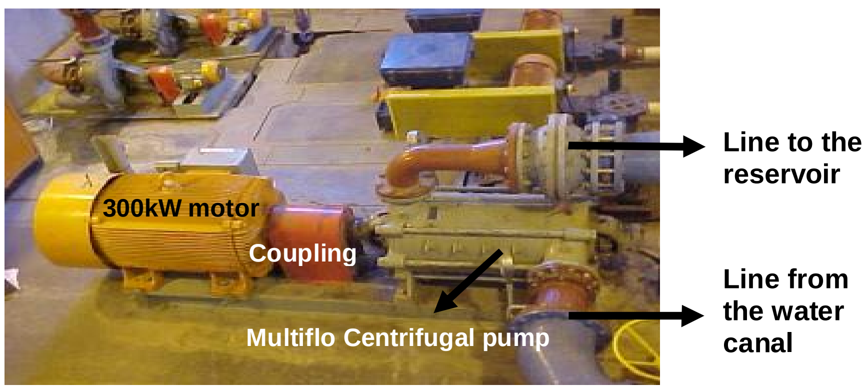


Figure 5.1**:** Machine one (large machine) for Purification Plant.

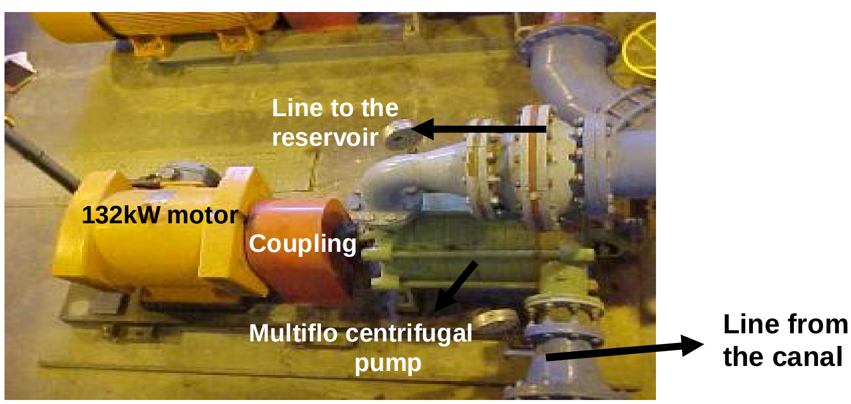


Figure 5.2**:** Machine two (small machine) for Purification Plant

5.1.9.1.1 Energy-Efficiency for Plant Motors Using Standard Allowable Vibration Table (Appendix F)

(a) Large Motor

Considering the motor size of 300kW of Figure 5.1 and referring to Appendix F.

The motor group is the letter N: the kW range is 315, and the motor actual kW is 300. The speed rpm is 1450. The motor can drive up to 13 staged horizontally mounted pumps at an average vibration speed (velocity) of 2.1mm/s and the number of existing pump stages is 3. Therefore analysis of the motor vibration velocity is within the required range of 2.1mm/s for less than 13 staged pumps. The logical conclusion drawn from the findings on the machines are inferred and stipulated as efficient. Both the inference and stipulation DSM activities show the strongest feasibility for vibration analysis on this machine.

(b) Small Motor

Considering the motor size of 132 kW of Figure 5.2 and referring to Appendix F:

The motor group is the letter I, kW range is 110, and the motor's actual kW is 132, speed rpm is 1479. The motor can drive up to 3 staged horizontally mounted pumps; therefore the motor vibration velocity is within the required range of 2.55mm/s. The logical conclusion of findings are inferred and stipulated as efficient. The vibration analysis show the DSM activities (load-shifting) by inferring and stipulating and are strongly feasible on this machine.

5.1.10 Energy-Efficiency Analysis Utilising the Motor Failure Theoretical Report

(a) Large Motor and Small Motor

Considering motor sizes of 300kW and 132kW, observations and theoretical electrical analysis for motor failures:

- Winding shorted phase-to-phase fault is minimal but likely to occur and this is reduced by a clean and well-maintained plant, no dust and dirt but other foreign substances such as moisture (water) leakages which usually occur at any time during water pumping. All these might cause the above fault and it is the customer's responsibility and cannot be considered as grounds for warranty.

- ◙ Winding shorted turn-to-turn fault is likely to occur (the effects are the same as in the above fault).

- ◙ Winding damage by voltage surge is likely to occur; the occurrence of lightning in the Theunissen area is high.

Since the above motors' electrically theoretically analysed faults are likely to occur , the motors are inferred as still being efficient but will probably be rewound or replaced by new and more efficient technology in the near future. The analysis from the motor failure report shows that the inferred EE (DSM activity) is the strongest feasible activity.

5.1.11 Pumps Analysis from Applications Report.

The customer uses the multiflo centrifugal pump. It is suitable for high pressure application and is marketed for municipal water supply, irrigation, heating, air conditioning, fire fighting and boiler feed. Since water has to be pumped for an approximate distance of 10km to the reservoirs in Theunissen town, it was the correct choice of pumps for the application and the pumps will endure for a much longer period and are correctly marketed for water pumping. Therefore the application is inferred and stipulated as efficient.

*5.1.12 Energy-Efficiency Analysis by using ISO Standards 2372 & 3945 Table (***Appendix E)**

(a) Machine One

Considering machine one with a motor size of 300kW and referring to Appendix E:

Machine class vibration severity is III (B), it is a large prime mover mounted on heavy rigid foundation frame. The vibration range rms velocity is 2,8mm/s with the required average movement during operation of 0,11 inches x 25,4mm = 2,794mm, therefore the class acceptance is satisfactory.

The vibration effect on machine one is acceptable due to a firm, rigid foundation, and proper and good plant maintenance. The machine still satisfies the specification requirements. According to ISO standards 2372 and 3945, the machine vibration is acceptable, therefore the vibration-severity analysis of the machine is inferred and stipulated as still being reliable and efficient.

(b) Machine Two

Considering machine two with a motor size of 132kW and referring to Appendix E:

Machine class vibration severity is III (B); it is a large prime mover mounted on a heavy rigid foundation frame. The ranges of vibration rms velocity is 2,8mm/s with required average movement during operation of 0,11 inches x 25,4 mm = 2,794mm, therefore the acceptance of class is satisfactory.

The vibration effect on the machine is acceptable due to its firm, rigid foundation, and proper and good plant maintenance. The machine still satisfies the specifications requirements. According to ISO standards 2372 and 3945 the machine vibration is acceptable, therefore the vibration-severity analysis of the machine is inferred and stipulated as still being reliable and efficient.

5.1.13 Energy-Efficiency Deduction Using the Machines History Maintenance Report

Table 5.3: Machine historical and maintenance records for Purification Plant

PLANT/CUSTOMER :	**Purification Plant & Water Supply**
MOTOR CLASS/ NUMBER : Large motor , switches were replaced with an amount of R40,000.00	
DATE OF FAILURE : 1997	
FURTHER COMMENTS : No repairs since 1997(machine was installed in 1990)	
DEFECT/S : Switches	
DATE OF REPLACEMENT : 1997	
COUPLER	
DATE OF FAILURE :	
FURTHER COMMENTS: No repairs(well maintained)	
DEFECT/S : No defects	
DATE OF DEFECT/S :	
Reported by: KC Motlohi **Diagnosed by**: KC Motlohi **Assisted by**: Plant Supervisor **Fault detected date**: 1994 **Repair Completion Date:** 1997 **Justification:** Prevented further replacement of switches on motors. Pumps still show no defects.	

5.1.14 Energy-Efficiency Analysis on Machines by Using Table 5.4

Table 5.4: Machine improvement and suggestion table report for Purification plant.

PLANT/CUSTOMER :	**Purification Plant & Water Supply**	
TYPE OF BUSINESS:	Municipal Water Supply	
EQUIPMENT TYPE:	Motors	
PROBLEM:	Energy-Efficiency Analysis	
REPAIR/S : No indication of immediate rewind or replace on motors for short-term		
ELECTRICAL MOTOR NUMBER/SERIAL NUMBER: Not available		
	ACTUAL COST	HISTORICAL COST
PARTS/ MATERIAL		Not available
LABOUR		Not available
TRANSPORT		Not available
TOTAL		
REPAIR SAVINGS : Potential energy-savings due to rewinding and replacement of motors		

PUMP AND MOTOR COUPLER

PLANT/CUSTOMER :	**Purification Plant & Water Supply**	
TYPE OF BUSINESS:	Municipal Water Supply	
EQUIPMENT TYPE:	Pumps	
PROBLEM:	Energy-Efficiency Analysis	
REPAIR/S: No indication of possible repairs on pumps		
PUMP NUMBER/SERIAL NUMBER : Not available		
	ACTUAL COST	HISTORICAL COST
PARTS/ MATERIAL		Not available
LABOUR		Not available
TRANSPORT		Not available
TOTAL		
REPAIR SAVINGS : Potential energy-savings due to correct choice of application		
Reported by: KC Motlohi **Diagnosed by**: KC Motlohi **Assisted by**: Plant Supervisor **Fault detected date**: **Justification:** Prevented further bearing wear and possible failures on motor and pumps		

5.1.15 Conclusion on Energy-Efficiency Analysis for Purification Plant

The analysis based on all the above mentioned theoretical, numerical and observational information for this particular customer, shows that the customers' machines are still efficient and in good condition. Therefore the machines are inferred and stipulated as efficient and capable of enduring for longer periods. Rewinding or replacing motor opportunities analysis was done in order to foresee the potential effects.

5.1.16 Purification Plant Machines' Load-Shifting Analysis

The deduction of efficient use of energy by shifting-load for this customer was done based on observations during site visits in which results were measured, along with the availability of plant's labour force. The operation sequence of this customer is deduced by observation and during these operations, the results were measured on site.

The analysis of load-shifting is by reducing load from 06:00 in the morning until 22:00 at night and this was performed by stipulating and inference, based on the measured results (refer to Figure 5.3). The load is stipulated and inferred to be shifted from peak to off-peak. The load-profile of Figure 5.3 represents the baseline, and the final logical conclusion for the potential effect of the DSM programme by shifting-load can be presented as in the machines' executive table report (Table 5.5).

5.1.16.1 Executive Sheet-Table Report for Purification Plant-Load Shifting

Table 5.5: Executive sheet-table for Purification Plant analysed actual time of use

DATE & TIME	**From: To:**
CUSTOMER'S NAME:	PURIFICATION PLANT
TRF NUMBER:	TBP 132-5
TRF SIZE:	2 X 200kVA Transformers paralleled
	MACHINE DESCRIPTION
MOTOR /PUMP ONE	300kW Motor driving pump
MOTOR /PUMP TWO	132kW Motor (Back Up) driving pump

CURRENT ENERGY USAGE - MOTOR /PUMP ONE			
Peak Time On	**Peak Time Off**	**Duration**	**Usage Description**
6:00h	22:00h	16hours/day	The customer switches on at 06:00h to 22:00h.Standby usage after 22:00h until 06: the next morning

POTENTIAL ENERGY USAGE REDUCTION ACCORDING TO TARIFF(DEFINED TIME OF USE)- MOTOR /PUMP ONE			
Std Time On	**Std Time Off**	**Duration**	**Usage Description**
20:00h	07:00h [11hours] & 10:00-18:00 & 7:00 [11hours] & anytime between 12:00-18:00 [5hours]	16h/day	20:00-7:00[11hours] & anytime between10:00-18:00[5hours] during weekdays. 20:00-7:00[11hours] & anytime between 12:00-18:00 [5hours] during Saturdays. Anytime during Sundays.

CURRENT ENERGY USAGE - MOTOR /PUMP TWO			
Peak Time On	**Std-Time Off**	**Duration**	**Usage Description**
			Used as back -up

POTENTIAL ENERGY USAGE REDUCTION ACCORDING TO TARIFF(DEFINED TIME PERIODS)-- MOTOR /PUMP TWO			
Std Time On	**Std Time Off**	**Duration**	**Usage Description**
			Suggested use when there is no great demand.

Reported by: KC Motlohi
Diagnosed by: KC Motlohi
Assisted by: Plant Supervisor
Execution date:
Justification: Load-shifting of existing machines classes for selected customers by stipulating and inferring for adjustments on customer's baseline.

5.1.16.2 Conclusion on Load-Shifting Analysis for Purification Plant

The load-shifting analysis activity depends on the efficiency of the customer's electrical system. It is then conducted based on the actual consumption in the customer's measured results profiles. The maximum load is 255kW within the period of seven days. Load-shifting activity analysis is shown in Table 5.5.

a) The profile shows the customer's possible defined time of the operational periods. The load-shifting activity can be stipulated and inferred from peak to off-peak for this customer to benefit from low energy costs when utilising less energy (Figure 5.3).

5.1.17 Purification Plant Profile Analysis of 2X200kVA /TBP 132-5 for Potential DSM Programme

The inference and stipulating analysis show the strongest penetration as the DSM activities for the plant. Figure 5.3 shows the potential DSM programme (activities) for this customer: Energy-efficiency and Load-shifting is conducted through stipulating and inference.

These potential DSM activity effects will only be experienced when the physical implementation stage of the process takes place to determine the decrease of load consumption profile for this customer.

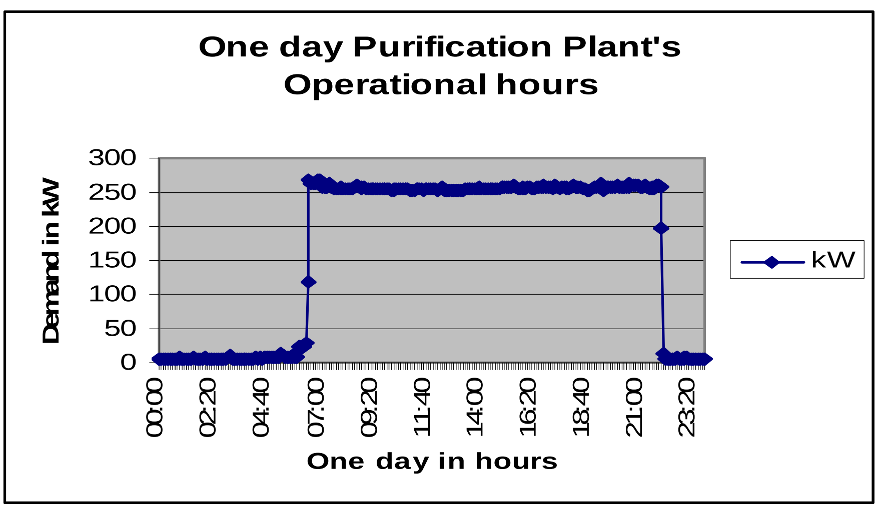


Figure 5.3: Baseline reduction representation for Purification plant

Figure 5.3 shows the measured results over a one day period. This customer segmentation is industrial in nature due to constant patterns. The highest peak load is averagely constant at 255kW during water pumping periods (peaks) for approximately 16 hours continuously, and the Off-peak load is less than 20kW for light loads at the plant. The customer's installed capacity is 2x200 kVA transformers. It is very clear that, within the period of a day, the load reduction (load shifting) should be from 06:00 until 22:00. Therefore, in the case of this customer, the load has to be adjusted from peak to off-peak for the benefit of the utility, whilst the customer will also benefit financially by having cheaper energy if he consumes less electricity.

The pre-implementation profile of Figure 5.3 represents the current system before the implementation stage and will be used as a baseline. The operational hours with reference to Figure 5.3 of the time of use (TOU) tariff (Ruraflex) represent load reduction due to the potential DSM activities (load-shifting) and this would represent the post-implementation stage to be used as the actual load reduction (impact) in the future. The main focus time of use for Purification Plant with reference to the ruraflex tariff, will be the load reduction during peak defined time periods from 06:00 to 22:00 within 24 hour (day) period (see Figure 5.3).

5.1.17.1 Conclusions on the Purification Plant for Potential DSM Programme.

The logical conclusions for the energy-efficiency and load-shifting of this customer for electrical machines are drawn based on the relevant and applicable theoretical and numerical analyses, observations, maintenance reports, manufacturer's, and supplier's information. The actual daily operational sequences of the machines are deduced from the measured results and tariff. The feasibility of potential DSM activities to experience the actual savings effect (impact) is evident; therefore the DSM programme can be implemented in the future.

The potential annual energy and cost savings for the Purification Plant due to the identified opportunities (projects) of motor replacement and rewinding are presented in Chapter 7. The emissions reduction is also pointed out. A simulation programme called the International Motor Selection and Savings analysis (Version 1.0.11:07 November 2005 was used. Energy-efficiency saving opportunities for Purification Plant, viz: rewinding and replacement of motors are prioritised according to their feasibility and viability. They are analysed in Chapter 7.

5.2 CASE STUDY 2: THEUNISSEN-BRANDFORT PUMPS PLANT

5.2.1 Plant Energy Audit Methodology Approach

This customer is composed of two electrical line systems, one old and one new (Figures 5.4 & 5.5).

5.2.2 Identification of Energy Source and Costs

Electricity is the only source of energy for this Plant. The costs review of the energy source for the last 12 months is implemented to establish the pricing structure in Rand per unit of energy; the cost of 30.578c/kWh is averaged ruraflex tariff, considering the seasonal and annual cyclic load factors and variables.

Table 5.6: Theunissen-Brandfort Plant's energy source intensity profile

ENERGY SOURCE	ENERGY USAGE(kWh)	PERCENT USAGE /ENERGY SOURCE	COST
Electricity	277.389kWh	100%	30.578c/kWh(Averaged)
Petroleum fuels	0units	0%	0 c/units
Miscellaneous	0units	0%	0 c/units
Total Purchased /yr	73,230.70kWh/yr	100%(30.578c/kWh)	R22,392.50(Avaraged /Weekdays/yr)

The process flow diagram which indicates all energy input and output points on the Theunissen-Brandfort Pumps machines, is presented Figures 5.4 and 5.5 and Tables 5.7 and 5.8. This also reflect the energy consumption and intensity profile for each energy source (electricity) over a typical 24 hour period with production records for the corresponding periods.

5.2.3 Theunissen-Brandfort Plant Intensity Prior to Introduction of DSM Interventions.

For an analysis of energy intensity and potential DSM interventions for the Theunissen-Brandfort pumps Plant, refer to Figure 5.6 of baseline reduction presentation.

5.2.4 Energy Usage Inventory

The major energy users within this facility are the motors please refer to Tables 5.7 and 5.8.

5.2.4.1 Motors: - Energy User

Motors sizes for both old and new lines are 110kW greater than 3.5kW and are used to drive the horizontally mounted centrifugal pumps. They are standard efficient motors. The power drawn at maximum operating conditions is 185kW and comes from the old line of 2x110kW motors pumping continuously, refer to Figure 5.6. The number of hours per year during which these motors operate is >¾ of load for 2x110kW of old line, thus >18 hours within a day and <½ load for 2x110kW for a new line; the reason being that the new line machine idles most of the time.

5.2.5 Energy Usage Patterns

Electrical energy consumption was estimated over 24 hours by using the measured results of the Theunissen-Brandfort Pumps Plant's wide-assessment. The utilisation factor is 64.3% daily. The profile graph for energy consumption of the old and new lines, measured against the production periods, is over 24 hours. The electricity peak-load, as well as the volume of production over relevant periods is shown on Figure 5.6.

The following data discussed are drawn from the graphs of Figure 5.6:

Load during non-and low-production periods is less than 10kW and this applies to light loads pumping as well as at the plant's housing itself, which includes including the Plant supervisor's house. These loads are mainly consumed during the night. Production is mainly affected by the population density in Brandfort-town and Majwemasweu Township. Equipment start-up and shut-down impact on demand is from 00:00 to 13:00, and re-start again from 14:00 to 24:00. Refer to Figure 5.6. Interactions between both lines have no major impact on the plant production, this happens only when there is a high demand for water where both lines have to pump at the same time. Problem areas arise from the old line not being well maintained, and this brings the potential opportunity within the facility.

5.2.5.1 Peak Load Reduction.

The plant's old line shows potential electrical failure, because of poor maintenance. There are no alternative sources of energy in the event of a failure on Eskom's supply site. The opportunities for the rewinding and replacement of the motors on the old line, are analysed in Chapter 7. There are no essential interacting production loads, besides those for light loads which come from the Plant's supervisor's house. The utilisation or load factor for Theunissen-Brandfort Pumps Plant is approximately 64.3%. The only means of increasing the load factor for Eskom's benefit will be the area's population density increase.

5.2.6 Comparative Analysis

The industry average energy consumption patterns for different activities of the Theunissen-Brandfort Pumps Plant can be compared in Figures 4.1, 4.2 and 4.3, where the peaking load is fairly constant but the current time of use differs. The time of use for Figures 4.1, 4.2 and 4.3 is cyclic, thus from 06:00 in the morning until 22:00 at night and that of the Plant is from 00:00 to 13:00 for 13 hours and 14:00 to 18:40 for 4 hours.

5.2.7 Analysis of the Theunissen-Brandfort Plant's Energy Efficiency and Load-Shifting Machines

It should be noted that separate energy-efficiency and load-shifting analyses are firstly conducted methodologically on the motors, and lastly conclude the whole electrical machines system of the Theunissen-Brandfort pumps plant. This customer is composed of two electrical line systems, the old and the new.

5.2.8 Theunissen-Brandfort Pumps Plant Electrical System (Machines) Inventory

Table 5.7: Standards for old machine lines

MACHINE ONE	**MACHINE TWO**
MOTOR ONE	**MOTOR TWO**
Power rating = 110 kW	Power rating = 110 kW
Current rating = Not available	Current rating = Not available
Voltage rating = 380 V	Voltage rating = 380 V
Revolutions per minutes =1450rpm	Revolutions per minutes =1468rpm
KSB COUPLER	**KSB COUPLER**
MULTIFLO CENTRIFUGAL PUMP	**MULTIFLO CENTRIFUGAL PUMP**
Impeller diameter =360mm	Impeller diameter = Not available
Year =1997	Year =Not available
H(horizontal mounting)	H(horizontal mounting)
Revolutions per minute =1450 rpm	Revolutions per minute =Not available

Refer to Figure 5.5 of the old line machine for Table 5.7. The lines are old and not well maintained when compared to the new lines.

Table 5.8: Standards for new machine lines

MACHINE ONE	MACHINE TWO
MOTOR	**MOTOR**
Power rating = 110 kW	Power rating = 110 kW
Current rating = 533 A	Current rating = Not available
Voltage rating = 380 V	Voltage rating V = 380 V
Revolutions per minutes =1480 rpm	Revolutions per minutes =1480 rpm
KSB COUPLER	**KSB COUPLER**
CENTRIFUGAL PUMP	**MULTIFLOCENTRIFUGAL PUMP**
Impeller diameter =360mm	Impeller diameter =Not available
Year =1997	Year = Not available
H(horizontal mounting)	H(horizontal mounting)
Revolutions per minute =1450 rpm	Revolutions per minute =Not available

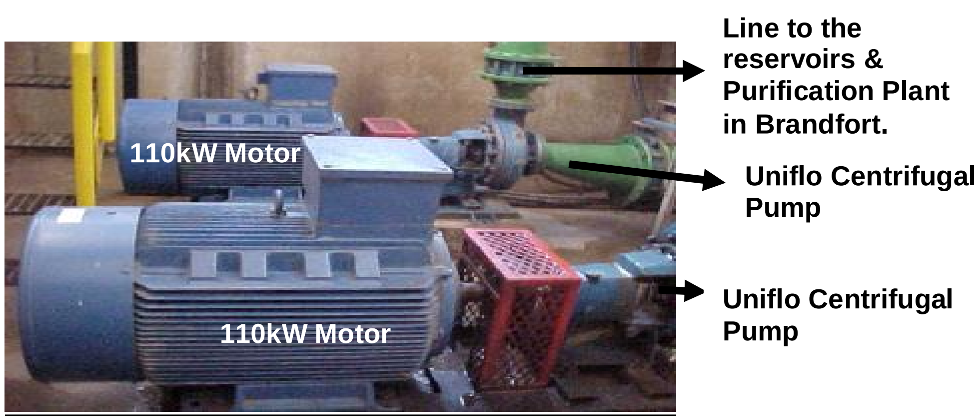
Refer to Figure 5.4 of the new line machine for Table 5.8. The lines are new and well maintained when compared to the old lines.

5.2.9 Analysis of Plant Machine Energy Efficiency

The deduction of efficient energy use for this customer was based on observations during site visits, a maintenance report and the machines' history. ISO standards 2372 and 3145 tables, for allowable vibration (velocity forces) on electrical motors, an electrical analysis report of motor failure and a pumps analysis selection report are also available. The logical conclusion is drawn from the machines improvement report and suggestions. All these facts were based on inferences and stipulations for energy-efficiency baseline adjustment purposes.

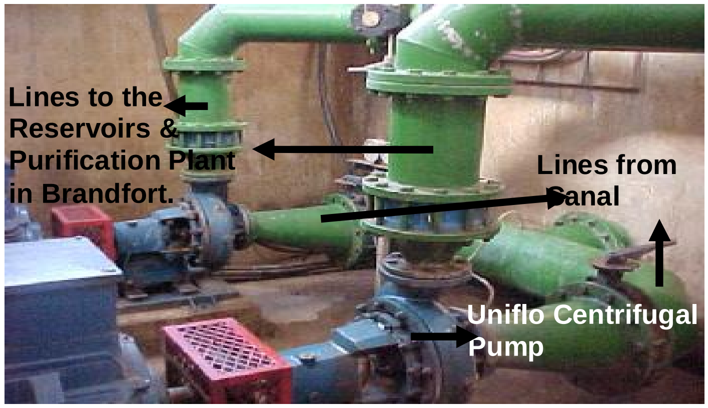
5.2.9.1 Efficient Energy Use for Theunissen-Brandfort Pumps Plant Machines.

(a) New Machine Line (2X110kW Motors)



(a)

Figure 5.4**:** New machine line (2x110kW) for Theunissen-Brandfort Pumps Plant



(b)

Figure 5.4**:** New machine line (2x110kW) for Theunissen-Brandfort Pumps Plant

(b) Old Machine Line (2X110kW Motors)

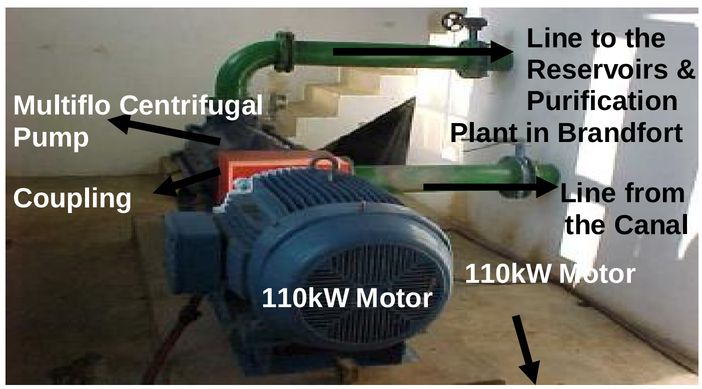


Figure 5.5**:** Old machine line (2 x 110kW) for Theunissen-Brandfort Pumps Plant.

5.2.10 Energy-Efficiency Deduction for Plant Motors Using Allowable Vibration Table **(Appendix F)**

(a) Motor One and Two (New Line)

Considering the motors with sizes of 110kW and referring to Appendix F:

The motor group is the letter I, kW range is exactly 110, and the actual motor kW is 110, the speed rpm range is 1479 and the actual 1480 rpm. Each motor can drive up to 3 staged horizontally mounted pumps at an average vibration speed (velocity) of 2.55mm/s. The number of existing pump stages is 3; therefore the motor vibration velocity is within the required range of 2.55mm/s velocity. The logical conclusion and findings of vibration on the motor are inferred and stipulated as being efficient.

(b) ***Motor One and Two (Old Line)***

Considering the motor size of 110kW and referring to Appendix F:

The motor group is the letter I, kW range is exactly 110, and the motor actual kW is 110, the speed rpm range is 1479 and the actual are 1450 rpm and 1468 rpm. Each motor can drive up to 3 staged horizontally mounted pumps at an average vibration speed (velocity) of 2.55mm/s. The number of existing pump stages is 3; therefore the motor vibration velocity is within the required range of 2.55mm/s velocity.

The conclusion of findings on motors are inferred and stipulated as efficient but more attention should be given to proper maintenance.

5.2.11 Use of the Electrical Motor Failure Theoretical Report as a Guideline for Energy Efficiency

(a) ***Motor One and Two (New and Old Lines)***

Considering both motor sizes of 110kW, and the electrical theory analysis of motor failures, the following findings are offered:

◙ Winding shorted phase-to-phase fault is high and likely to occur and this will be increased by lack of labour manpower; there is only one worker for the plant and there is evidence of dust and dirt on the motors and other foreign matter such as moisture (water) leakages which usually occur at any time during water pumping. This might cause the above fault. This is viewed as the customer's responsibility and the fault cannot be considered as covered by warranty.

◙ Winding shorted turn-to-turn fault is likely to occur (The effects are the same as in the above fault).

◙ Winding shorted-coil fault is likely to occur (The effects are the same as with the above fault).

- Phase damage due to overload is likely to occur on the old line motors, if the whole new line will be operative for a prolonged period of time, it is therefore likely to occur on the old line, as the new line was built in response to an increased demand for water supply in the Brandfort area to support the old line. The old line could not handle the water supply demand, consequently this fault cannot be considered as covered by warranty.

- Winding damage by voltage surge is likely to occur; the occurrence of lightning in the Theunissen area is pronounced.

Since the above motors' electrically analysed faults are unlikely to occur on the new line and the likely faults are minimal, the new line is inferred as being efficient; conversely, the motors (old line) are inferred to be inefficient (new motors and / or high maintenance expenses will be needed) because the housing is not well maintained, and there are no properly closed doors, which means that rain water can reach the motors easily. There is dust around the motors, new and more efficient technology in the near future is needed for the old line. The analysis from the motor failure report shows that the EE (DSM activity) by inference is the strongest feasible activity, especially on the old line.

Motors on the new line – inferred and stipulated as efficient according to motor failure analysis theoretical report**.**

Motors on the old line – motors are inferred and stipulated to be inefficient in the near future according to the motor failure analysis theoretical report.

5.2.12 Deductions on Pumps from Applications Analysis Report

(a) Pumps on the New and Old Lines

The customer is using the uniflo centrifugal pumps. The pumps are suitable for high pressure and harsh application. It is marketed for agriculture, domestic and general industry.

Since water has to be pumped for an approximate distance of 42km to the reservoirs in Brandfort town, it was the correct choice of pump application, and it will sustain itself for much longer periods due to the highly pressured and harsh conditions. They are marketed for general industry. The pump's application is inferred and stipulated as correct and efficient.

5.2.13 Deduction on Machine Energy-Efficiency in Terms of ISO Standards 2372 & 3945(Appendix E)

(a) Machines One and Two (New Line)

Considering machines one and two for new line with motor size of 110kW and with reference to Appendix E:

Machine class vibration severity is III (B). It is a large prime mover mounted on heavy, rigid foundation frame. Vibration range rms velocity is 2,8mm/s, which requires an average movement of 0,11 inches x 25,4(mm) = 2,794mm during operation, therefore the acceptance of class is satisfactory.

The vibration effect on the machine is acceptable due to proper maintenance. The machine still satisfies the specification requirements. According to ISO standards 2372 and 3945, the machine vibration is acceptable, therefore the machine is inferred and stipulated as still being reliable and efficient.

(b) Machines One and Two (Old Line)

Considering machines one and two for old line with motor size of 110kW and with reference to Appendix E:

Machine class vibration severity is III (B). It is a large prime mover mounted on a heavy, rigid foundation frame. Vibration range rms velocity is 2, 8 mm/s which requires an average movement of 0, 11 inches (mm) x 25, 4 (mm) = 2,794mm during operation, therefore the acceptance of class is satisfactory.

The vibration effect on the machine is not acceptable due to improper maintenance. The machine is likely not to satisfy the specification requirements. According to ISO standards 2372 and 3945, the machine vibration is acceptable, but because of some other factors such as dirt, moisture and insecure machine housing, this machine line is inefficient and will soon be worn out. The machines are inferred and stipulated as still being unreliable and inefficient.

5.2.14 Energy-Efficiency Using the Machines History from Maintenance Report

(a) Machines One and Two (New Line & Old Line)

Table 5.9: Old and new machine maintenance and inspection reports

PLANT/CUSTOMER :	**Theunissen-Brandfort Pumps Plant & Water Supply**
MOTOR CLASS/ NUMBER : Old machines were installed 20 years ago	
DATE OF FAILURE :	
FURTHER COMMENTS : New efficient machine technology is needed urgently & no repairs on new line(well maintained)	
DEFECT/S :	
DATE OF REPLACEMENT :	
COUPLER	
DATE OF FAILURE : Old machines were installed 20 years ago	
FURTHER COMMENTS: New efficient machine technology is urgently required for old line, no repairs on new line(well maintained)	
DEFECT/S : No fault detected	
DATE OF DEFECT/S :	
Reported by: KC Motlohi **Diagnosed by**: KC Motlohi **Assisted by**: Plant Supervisor **Fault detected date**: No fault detected **Repair Completion Date:** Not available **Justification**: No justification	

5.2.15 Machines Improvement and Suggestion Report

Table 5.10: Machines improvement report and suggestion for Theunissen-Brandfort Pumps plant

PLANT/CUSTOMER :	**Theunissen-Brandfort Pumps Plant & Water Supply**	
TYPE OF BUSINESS:	Municipal Water Supply	
EQUIPMENT TYPE:	MACHINE ONE AND TWO (NEW LINE & OLD LINE) MOTOR SIZES: 2x110 kW / LINE	
PROBLEM:	Energy-Efficiency Analysis (Old line machines not well maintained)	
REPAIR SAVINGS: Indication of immediate rewind or replacement on motors old line and new line machines still in good conditions		
ELECTRICAL MOTOR NUMBER/SERIAL NUMBER: Not available		
	ACTUAL COST	HISTORICAL COST
PARTS/ MATERIAL		
LABOUR		
TRANSPORT		
TOTAL		
REPAIR SAVINGS : Potential energy-savings due to rewinding and replacement of motors (Old line machines)		

COUPLER

PLANT/CUSTOMER :	Water Pumping Plant	
TYPE OF BUSINESS:	Municipal Water Supply	
EQUIPMENT TYPE:	Pumps	
PROBLEM:	Energy-Efficiency Analysis	
REPAIR SAVINGS: No indication of possible repairs on pumps. Further potential energy-savings due to correct choice of application		
PUMP NUMBER/SERIAL NUMBER : Not available		
	ACTUAL COST	HISTORICAL COST
PARTS/ MATERIAL		
LABOUR		
TRANSPORT		
TOTAL		
REPAIR SAVINGS :		
Reported by: KC Motlohi **Diagnosed by**: KC Motlohi **Assisted by**: Plant Supervisor **Fault detected date**: **Repair Completion Date:** **Justification:** Prevented further bearing wear and possible failures on motor and pumps		

5.2.16 Theunissen-Brandfort Pumps Plant Profiling for Energy-Efficiency

(a) Machines One and Two (New Line)

The deduction is obtained from the overall report of energy-efficiency for the Theunissen-Brandfort pumps plant. The existing machines one and two for the new line are inferred as being efficient. This customer's maximum load is 185kW from the measured results actual site

(b) Machines One and Two (Old Line)

The deduction is obtained from the overall report of energy-efficiency for Theunissen-Brandfort Pumps plant. The existing machines one and two for the old line are inferred as being inefficient. This customer's maximum load is 185kW and is constant according to the profile (Figure 5.6), of the measured results. The transformer will also not be overloaded in the near future according to the measured results.

New efficient technology is recommended for the old line so that the load is inferred for the benefit of both customer and the utility.

5.2.17 Conclusions on the Theunissen-Brandfort Plant Energy- Efficiency

The logical conclusions on energy-efficiency for this customer's electrical machines are drawn based on the relevant theoretical analysis above, as well as observations, maintenance reports, manufacturer and supplier's information. Inference and stipulation are obtained based on this thorough analysis. The new-line machine's house building is well maintained and well built. A rigid and firm foundation limits the machines' vibration movements. There is an existence of foreign matter, therefore water leaks during operation might influence the efficiency of the machines.

The machine's old line house building is old and not well maintained. This has a major influence on the machine's efficiency due to foreign matter like dust and dirt, water rain and the access of people and animals. Foundations are still firm and rigid for vibration limitations. This line, when compared to the new line has many factors which influence the efficiency of the machine. The old line is therefore, inferred as inefficient. Recommendations for this machine are that it be ***replaced*** soon with new technology, or that it be ***rewound*** and the existing house building needs to be refurbished.

5.2.18 Theunissen-Brandfort Pumps Plant Machines Load-Shifting Analysis

The deduction of the efficient use of energy by shifting-load for this customer was based on observations during site visits, measured results and workers' availability. Since this customer's maximum load is 185kW and is constant, the measured results show that the transformer will not be overloaded in the near future. The operation sequence of this customer is deduced from observations and measured results.

Load is stipulated and inferred to be shifted from peak to off-peak. The final logical conclusions which will determine the effect by load-shifting are drawn from the machines executive sheet table report (Table 5.11).

5.2.18.1 Executive Sheet Table Report for Theunissen-Brandfort Pumps Load-Shifting

Table 5.11: Theunissen-Brandfort Pumps Plant analysed actual time of use

DATE & TIME		**From: To:**	
CUSTOMERS NAME:		THEUNISSEN BRNDFORT PUMPS PLANT	
TRF NUMBER:		TBP 126-34-1A	
TRF SIZE:		315 kVA	
		MACHINE DESCRIPTION	
MOTOR /PUMP (OLD)		Old line- 2X110 kW motors driving pumps	
MOTOR /PUMP(NEW)		New line-2X110 kW motors driving pumps	
CURRENT ENERGY USAGE - MOTOR /PUMP ONE			
Peak Time On	**Peak Time Off**	**Duration**	**Usage Description**
6:00	22:00	16hours	Starts switching on at 6:00 in the morning, stops at 22:00 at night until 6:00 in the next morning
POTENTIAL ENERGY USAGE REDUCTION ACCORDING TO TARIFF(DEFINED TIME PERIODS)- MOTOR /PUMP ONE			
Std Time On	**Std Time Off**	**Duration**	**Usage Description**
20:00	07:00h[11hours] & 10:00-18:00 & 7:00 [11hours] & anytime between 12:00-18:00 [5hours]	16hours	20:00-7:00 [11hours] & anytime between 10:00-18:00 [5hours] during weekdays 20:00-7:00 [11hours] & anytime between 12:0018:00 [5hours] during Saturdays. Anytime during Sundays.
Reported by: KC Motlohi **Diagnosed by**: KC Motlohi **Assisted by**: Plant Supervisor **Justification:** Load-shifting of existing machines classes for selected customers by stipulating and inferring for adjustments/reduction on loads			

These facts were based on inferences and stipulations for potential baseline reduction due to load-shifting.

5.2.19 Theunissen-Brandfort Pumps Plant Load Profile and Load Management Analysis

Transformer size and pole number: 315kVA /TBP 126-34-1A

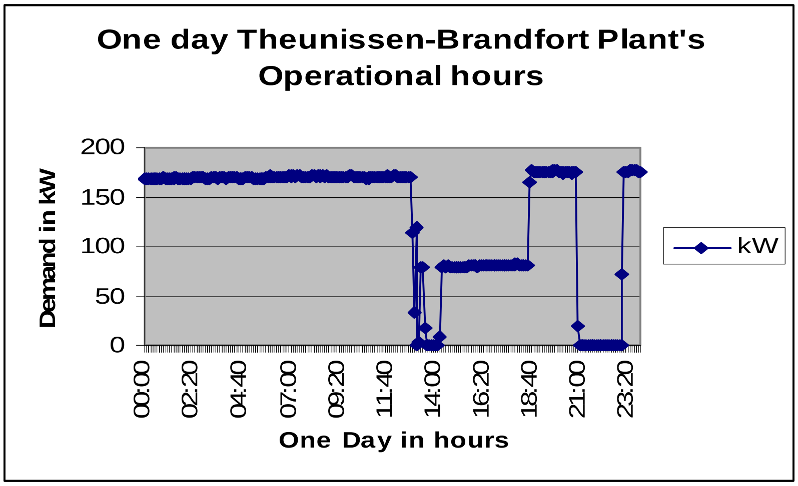


Figure 5.6: Baseline reduction representation for Theunissen-Brandfort Pumps plant

Figure 5.6 shows the measured results over a one-day period. This customer segmentation is industrial due to fairly constant patterns. The highest peak load is averagely constant at 185kW during water pumping periods (peaks) between 00:00 to 13:00 for approximately 13hours. The standard peak period load is from 14:00 to 18:40 with approximately 80kW, and the Off-peak load is less than 10kW for light loads at the plant. The customer's installed capacity is 315 kVA transformers. The load pattern is within 24-hour period; the load reduction focus (load shifting) must be from 00:00 to 13:00, therefore, this customer requires the load to be adjusted from peak to off-peak within the peaking periods, for the benefit of the utility. The customer will also benefit financially by having cheaper energy if he consumes less electricity.

The Theunissen-Brandfort Pump Plant has certain operational hours and certain peak demand over a period of one week. The pre-implementation profile of Figure 5.6 represents the current system before the implementation stage and will be used as a baseline. The operational hours with reference to Figure 5.6 of the TOU tariff (Ruraflex) represent load reduction due to the potential DSM activities and this would represent the post-implementation stage to be used as the actual load reduction in the future. The main focus time of use for Theunissen-Brandfort Pump Plant with reference to the ruraflex tariff, will be the load reduction during peak-defined time periods from 06:00 - 22:00 for of 24 hour (day) period (Refer to Figure 5.6).

5.2.19.1 Conclusions on the Theunissen-Brandfort Pumps Plant Shifting of Load

The final and logical conclusions of load-shifting of this customer on electrical machines are drawn from observations during site visits, measured results, increased population density in Brandfort-Majwemasweu and the availability of the labour force for night-shift operations (refer to Table 5.11).

The profile (Table 5.11) shows the customer's possible defined time of the operational periods. The load-shifting activity can be stipulated and inferred for peak to off-peak for this customer to benefit from low energy costs when utilising less energy.

5.2.20 Deducing Potential DSM Programme for Theunissen- Brandfort Pumps Plant

Inference and stipulating analysis show the strongest feasibility as the DSM activities for the plant, the energy-efficiency and load-shifting are inferred and stipulated for this customer: The following is the DSM programme for this customer: Replacement with new technology or rewinding is recommended. This recommendation depends on the customer's reluctance, knowledge of new technology, the availability of funds or loans for customers, the country and area's economic stability, and the need of the customer to supply more water for Brandfort-Majwemasweu.

5.2.21 Conclusions on Theunissen-Brandfort Pumps Plant Potential DSM Programme

The logical conclusions drawn regarding the energy-efficiency and load-shifting of this customer for electrical machines are drawn based on the relevant and applicable theoretical analysis, observations, maintenance reports, manufacturer's, supplier's information, the actual daily operational sequences of the machines are deduced from the measured results and tariff. The realisation of potential DSM activities which would allow the customer to experience the potential savings effect (impact) is presented in Chapter 7.

The potential annual energy and cost savings for Theunissen-Brandfort pumps Plant due to the identified opportunities of replacing or rewinding (projects) are presented in Chapter 7. The emissions reduction is also pointed out. A simulation programme called International Motor Selection and Savings analysis (Version 1.0.11:07 November 2005) was used. Energy savings opportunities are prioritised according to their feasibility.

5.3 CASE STUDY 3: KOPPIES PLANT

5.3.1 Plant Energy Audit Methodology Approach

This customer is composed of a one-machine electrical system.

5.3.2 Identify Energy Source and Costs

Electricity is the only source of energy for the Koppies Plant. The costs review of the energy source for the last 12 months used to establish the pricing structure in Rand per unit of energy. The cost of 30.578c/kWh/yr is averaged ruraflex tariff, considering the annual and seasonal cyclic load factors and variables.

Table 5.12: Koppies Plant's energy source intensity profile

ENERGY SOURCE	ENERGY USE(kWh)	PERCENT USAGE /ENERGY SOURCE	COST
Electricity	11.662kWh/day	100%	30.578c/kWh(Averaged)
Petroleum fuels	0units	0%	0 c/units
Miscellaneous	0units	0%	0 c/units
Total Purchased /yr	3,078.77kWh/yr	100%(30.578c/kWh)	94,142.57c (Averaged/Weekdays/yr)

The process-flow diagram indicates all energy input and output points on the Koppies machine, refer to Figures 5.7 and Table 5.13. Energy consumption and intensity profile for each energy source (electricity) over a typical 24-hour period with production records for the corresponding periods.

5.3.3 Koppies Energy Intensity Prior (baseline) DSM Interventions.

For the analysis of energy intensity and potential DSM interventions for the Koppies-Plant, refer to Figure 5.8 of baseline reduction presentation.

5.3.4 Energy Usage Inventory

The major energy users within the facility of water pumping are the motors, as shown in Table 5.13.

5.3.4.1 Motor: Energy User

Motor size is 22kW greater than 3.5kW and is used to drive the pumps. It is a standard efficient motor. The current power draw at maximum operating conditions is 21kW within 6hours. The number of hours per year during which these motors operate are <¾ of load for 50kVA transformer, thus for 6 hours within a day.

5.3.5 Energy Usage Pattern

Electrical energy consumption was estimated over 24-hours and the measured results of the Koppies Plant's wide-assessment were used. Percent %Utilisation = 40% daily.

A graph of energy consumption for 22kW machine against the production periods of 24-hour, is presented in Figure 5.8. The electricity peak demand on the graph and the volume of production over relevant periods is shown in Figure 5.8.

The following are discussed from the graphs of Figure 5.8. Load during none-and low-production periods are less than 3kW, and this is the case for light loads at the plant itself as well as at the customer's house. These loads are mainly consumed during the day until the next day. Production is mainly affected by irrigation during the planting season. Equipment start-up and shut-down and impact on demand is from 00:00 until 07:00 in the morning. Refer to Figures 5.7 and 5.8, problem areas relate mainly to the maintenance of machines.

5.3.5.1 Peak Load Reduction.

Plant analysis shows that the motors are being poorly maintained. There are no alternative sources of energy in the event of a failure on Eskom's supply site. All the other interacting loads which are not listed are also essential, viz: for customer's household's usage, like lights and others. Utilisation or load factor for the Koppies-Plant is approximately 40%, including these and other low loads. The only means of increasing the load factor is when the customer irrigates.

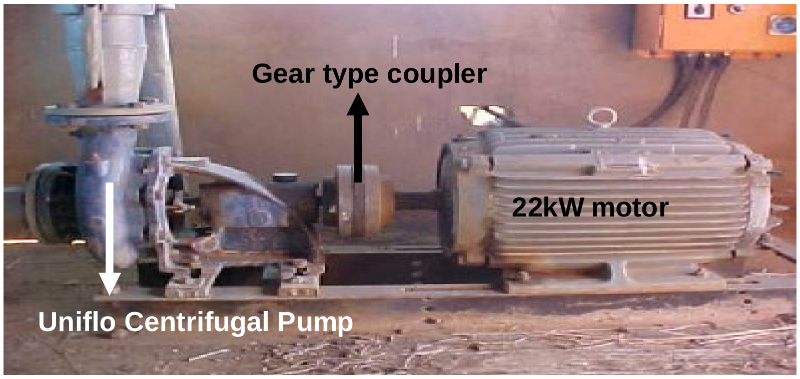
5.3.6 Comparative Analysis

The averaged industrial energy consumption patterns for different activities of the Koppies Plant are compared in Figures 4.1, 4.2 and 4.3; where the peaking load is fairly constant but the current times of use differ. The time of use for Figures 4.1, 4.2 and 4.3 is cyclic through-out the year, viz: from 06:00 until 22:00 and that of the Plant is from 00:00 to 07:00 for 7 hours and a light load of 3kW from 07:00 until 00:00 the next day.

5.3.7 Koppies Energy-Efficiency and Load-Shifting Machine Analysis

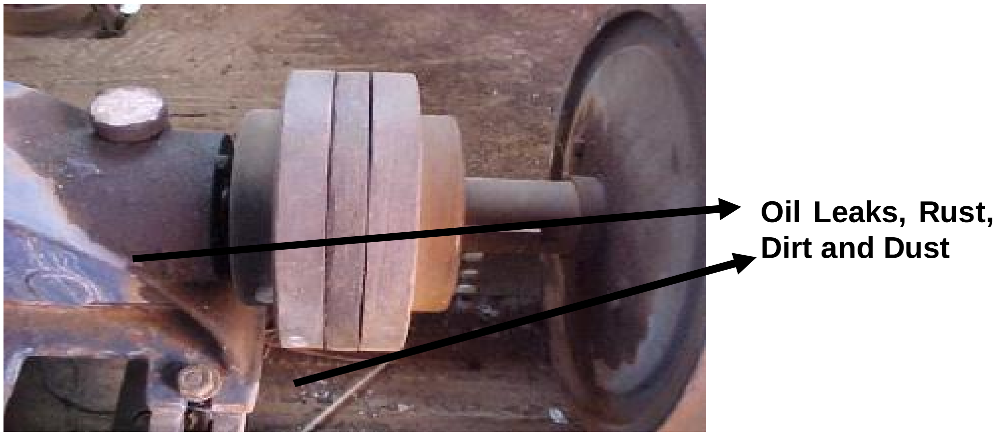
Table 5.13: Machine standards for Koppies customer

MOTOR (Induction)
Power rating = 22 kW
Current rating = 44 A
Voltage rating = 380 V
Revolutions per minute =2940 rpm
COUPLER
PUMP(Centrifugal)
Type :KSB
Year :1995
Serial no:46329-431



(a)

Figure 5.7**:** Machine site photo for Koppies.



(b)

Figure 5.7**:** Machine site photo for Koppies.

Figure 5.7 shows that this electrical system is not well maintained; soon the customer will have to replace or rewind the existing machine in order to implement the potential DSM activities. Transformer size and pole number are: 50kVA /TBP 158-63-15.

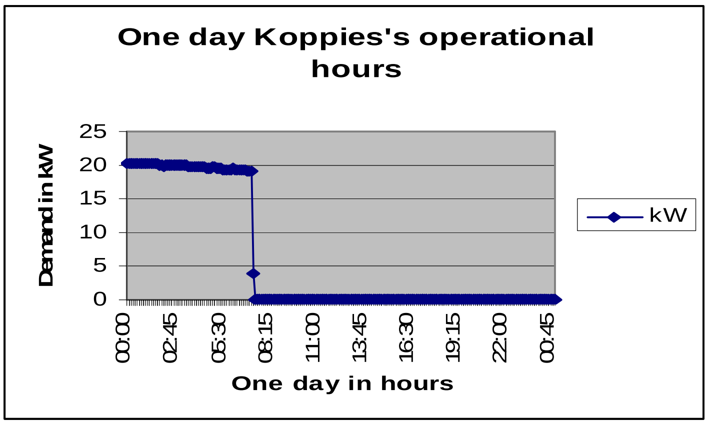


Figure 5.8: Baseline reduction representation for Koppies plant

This customer load is constant; therefore the segmentation is also industrial. Figure 5.8 shows the highest peak load at 21kW from 00:00 to 07:00 which then drops to 3kW. The low peak load is less than 3kW and is from 07:00 to 00:00[17hours]. This type of pattern for the customer is caused solely by irrigation. The customer's installed capacity is 50kVA and the recorded peak load within a day is 21kW. The customers' time periods are already defined as nocturnal consumption (time of use-TOU) when most of Eskom's customers are not consuming. With reference to the customer's machine in Figure 5.7, found to be poorly maintained. The customer urgently needs to buy new, advanced and efficient technology so as to be able to implement DSM programme (activities) in the future.

5.3.8 Conclusions on Koppies Plant's Potential DSM Programme.

The logical conclusions drawn regarding the energy-efficiency and load-shifting assessment of this customer for electrical machines are based on the relevant and applicable theoretical analysis, observations, maintenance reports, manufacturer's, and supplier's information. The actual daily operational sequences of the machines are deduced from the measured results and tariff.

The potential annual energy and cost savings for the Koppies Plant due to the identified opportunities (projects) are presented in Chapter 7. The potential emissions reduction is also pointed out. A simulation programme called International Motor Selection and Savings analysis (Version 1.0.11:07 November 2005) was used. Energy savings opportunities for Koppies customer are prioritised according to their feasibility and viability, viz: motor replacement and rewinding and are analysed in Chapter 7.

5.4 CASE STUDY 4: Mr A.GUTTER'S PLANT

5.4.1 Plant Energy Audit Methodology Approach

Note: This customer terminated his transformer point immediately after measurements were taken, due to his business scaling down. Therefore, further and more complete analysis could not be carried out. The analysis for Gutter is thus incomplete.

5.4.2 Load-Profile Analysis

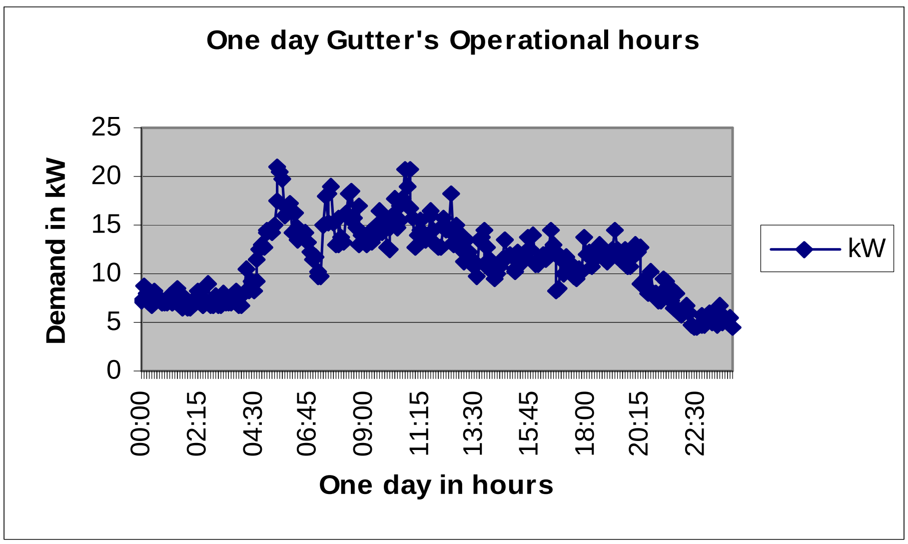


Figure 5.9: Baseline reduction representation for Gutter plant

This customer is segmented / classified as heterogeneous, i.e. a mixture of different classes. He is a mixture of commercial and industrial and, to some extent, residential classes. There are ten houses for the workers, and the customer's house is supplied from the same transformer point which includes the plant. His load is not constant due to different types of classes. Figure 5.9 shows the highest peak load at 23kW, which then drops to 10kW. The standard peak load is at 8kW from 00:00 to 05:00[5hours]. The type of pattern relevant to this customer is established by air conditioners on the plant and other household and office equipment. The customer's installed capacity is 100kVA and the recorded peak load within a week is 24.154kVA. It is very clear that within a period of a day, the maximum peak load must be increased. From site observation and several site visits to this customer, it was evident that the business was scaling down. This was the reason for the customer consuming significantly reduced quantities of power.

CHAPTER 6: THE TBP PLANT-WIDE BEST PRACTICE ASSESSMENT

This describes the whole plant-wide (TBP feeder's) best-practice pollution prevention and energy-efficiency (EE) audit assessment achieved. The following aspects were considered: trapezium rule application for collective average baseline determination, pollution prevention and EE audit model, identification and quantification potential of energy-saving opportunities (projects). Demonstrate how to achieve and implement feasible TBP potential DSM programme. How to determine its potential impacts for future implementation, How was the tariff structure achieved, and finally how to determine the collective potential savings of energy-efficiency and the Load-shifting opportunities. All these are achieved by considering the whole TBP plant best-practice assessment.

6.1 CASE STUDY 5: THE TBP WHOLE PLANT ENERGY AUDIT METHODOLOGY

The TBP feeder is composed mainly of (60-70%) typical motor driving pumping customers (refer to Figure 4.4).

6.2 Identification of Energy Source and Costs

Electricity is the major source of energy for the TBP feeder. The percentage intensity for other energy sources on the TBP feeder is approximately zero. The costs review for electricity as an energy source for the last 12 months is implemented to establish the pricing structure in Rands per unit of energy. The cost of 0.1991R/kWh/yr is averaged miniflex tariff, considering the annual and seasonal cyclic load factors and variables.

Table 6.1: The TBP feeder's energy source intensity profile

ENERGY SOURCE	ENERGY USAGE(kWh)	PERCENT USAGE /ENERGY SOURCE	COST
Electricity	419.9 kWh	100%	19.19c/kWh(Averaged)
Petroleum fuels	0 units	0%	0c/unit
Miscellaneous	0 units	0%	0c/unit
Total Purchased R/yr	110,853.6 kWh/yr	100%(19.19c/kWh)	R 21,272.81(Ave /Weekdays/yr)

6.2.1 *Energy Intensity (baseline) Prior to Introduction of Conservation Measures (DSM Interventions)*

For the analysis of profiling and potential EE and LS for the TBP feeder, refer to Figure 6.2 for potential baseline reduction presentation.

6.2.2 Energy Usage Inventory

The major energy users within the TBP feeder as a facility are motors.

6.2.2.1 Motors: Energy User

The largest motor sizes on the TBP feeder are ≥300kW greater than 3.5kW. The average draw at maximum operating conditions is 800kW. The number of hours for highest peak per year during which these motors operates are >¾ of load more than 1000kW, viz: approximately 16 hours within a day for all 82 customers.

6.2.3 Energy Usage Pattern

Electrical energy consumption was estimated over 24 hours by using measured results of the TBP Plant's wide assessment. The percent (%) utilisation = 72.7% daily. Graph of energy consumption for the entire feeder against the production periods of 24 hours. The electricity peak demands on the graph as well as the volume of production over relevant periods are shown in Figure 6.2.

The following are discussed from the graph of Figure 6.2;

Loads during low-production periods are approximated to ≥300kW. These loads are mainly consumed during the night. Production is mainly affected by the population densities variables in Theunissen-Town and Masilo Township, Brandfort-Town and Majwemasweu Township and surrounding rural areas. The feeder's peaking load and impact on demand is from 06:00 until 22:00. Problem areas are located with a few customers who do not maintain their machines well with consequent effect on the efficient energy usage on the entire feeder.

6.2.3.1 *Peak Load Reduction.*

The feeder shows future electrical failure due to some other customers' machines which are not well maintained. There are no alternative sources of energy in the event of a failure on the Eskom's supply site. Utilisation or load factor for the TBP-Plant wide is approximately 72.7%. The load factor can only be increased in relation to population rate increase in the areas, due to urbanisation.

6.3 Trapezium Rule for Baseline Determination

For the trapezium rule refer to [3]:

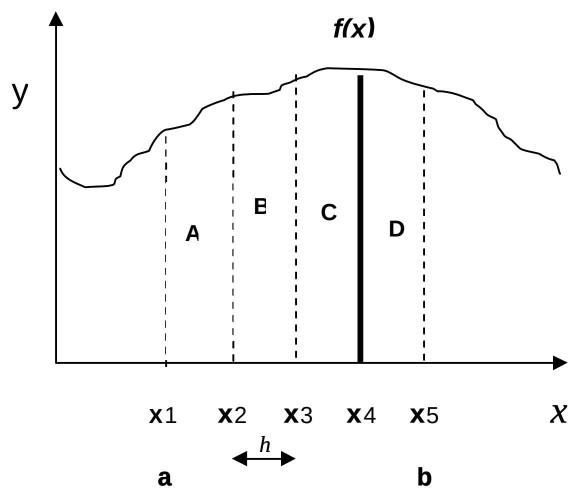


Figure 6.1: The approximate curve *f(x)* by series of straight lines forming trapeziums

$$\int_a^b f(x)\,dx = h\left(\tfrac{1}{2} f_1 + \tfrac{1}{2} f_2\right) \ldots\ldots \textbf{\textit{A-area}}$$

$$+\, h\left(\tfrac{1}{2} f_2 + \tfrac{1}{2} f_3\right) \ldots\ldots \textbf{\textit{B-area}}$$

$$+\, h\left(\tfrac{1}{2} f_3 + \tfrac{1}{2} f_4\right) \ldots\ldots \textbf{\textit{C-area}}$$

$$+\, h\left(\tfrac{1}{2} f_4 + \tfrac{1}{2} f_5\right) \ldots\ldots \textbf{\textit{D-area}} + 0\left((b-a)^3 f''/N^2\right)$$

h or (x3-x2) - The width of a single interval (5-minutes interval or 5/60-hour interval).

x - Values per time interval (5-minutes).

y - Values per averaged demand (calculated) in kW.

f(x) - Averaged function, which gives the total area under the curve.

The main aim of applying this rule is to average the measured results within twelve iterations of 5-minute intervals which make-up one hour, and to obtain the averaged collective TBP's baseline consumption as shown in Figure 6.2*.* To make this rule useful, the curve is broken and integrated into many small intervals (small-h). Summing up the area of these trapeziums, gives an approximation of the total area under the *f(x)* (curve) between ***a*** and ***b***. The curve in this instance is considered as the potential averaged baseline [3].

6.3.1 Application of Trapezium Rule for Obtaining Potential Collective Baseline

Table 6.2: Results calculated using trapezium rule within 24 hours

kWh	**317.668**	314.13	309.716	312.021	347.416	386.67	635.073	659.63
Time	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00
kWh	720.912	747.48	708.081	692.882	656.51	651.107	651.61	698.108
Time	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00
kWh	685.005	707.662	705.854	680.648	647.468	410.997	347.269	338.23
Time	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00

The baseline in kWh within 24 hours is calculated. Below is an example of how the values in Table 6.2 were calculated using the trapezium rule [3]:

h=5-minutes interval/60≈ **0, 0833... hour**

Total usage (kW) from 00:00 to 01:00 ≈ 5/60 {½ f(x1) **+** ½ f(x2)**)** **+** *h* (½ f (x2) **+** ½ *f(x*3))

+...... up to last term.

≈ 5/60{½ (341.787) **+** ½ (339.646)} **+** 5/60 ½

(339.646) **+** ½ (357.105)}

≈ 317.668kWh

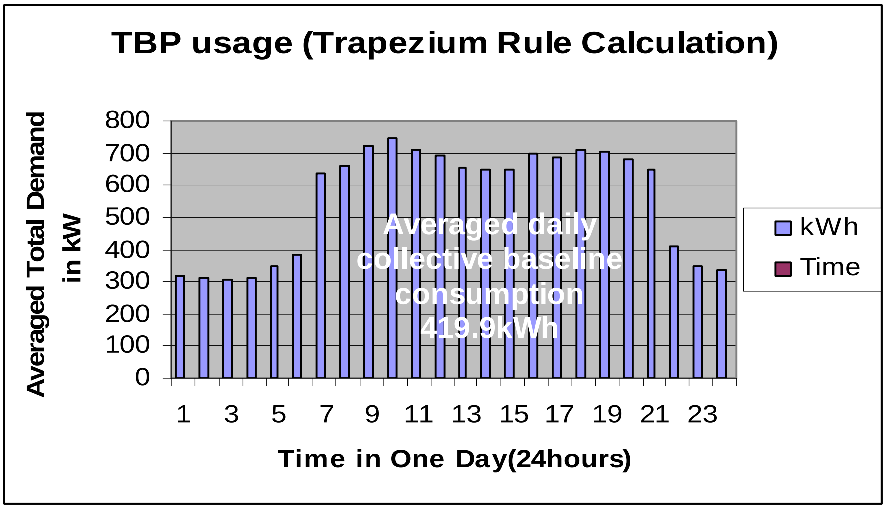


Figure 6.2: TBP potential baseline reduction EE and TOU implementation.

The profile in Figure 6.2 represents results as tabulated in Table 6.2.

h=5-minutes interval/60≈ 0, 08333/60X24 ≈ **0.0333... hours (24-hour-interval)**

Total usage (kWh) area under the curve **(**Figure 6.2**),** ***for period of 00:00 to 24:00***

≈ 0.0333{½ *f(x1)* + ½ *f(x2)* **+** *h* **(**½ *(fx2***)** + ½ *f(x3))* +........up to last term}

≈ 0.0333{½ (**317.668**) + ½ (314.13) + 5/60 (½ (314.13) + ½ (309.716) +.....up to last term}

≈ 419.9kWh daily averaged potential collective baseline

6.3.2 Comparative Analysis

The energy consumption is 419.9kWh for the daily averaged collective baseline. The daily measured results pattern as shown on Figure 6.2 was compared to Figures 4.1, 4.2 and 4.3, which represent typical daily load curves showing industrial pattern component of a U.S.A utility for high and low demand seasons. It can be seen that the trends of these profiles are almost the same, where high-peaking time is from 6:00 until 22:00 and the standard-peaking time from 22:00 to 6:00.

6.3.3 Operational Hours for TBP Feeder and Customers' Loads Reduction due to Potential DSM Programme Activities

By referring to the averaged profile baseline results of the whole feeder (Figures 6.2), it was deduced that the TBP feeder which comprise few types and a mixture of commercial and residential type of customers, does not have a profile of 100% purely industrial load. The industrial penetration factor is about sixty to seventy percent due to fact that most of the customers on the feeder use motors and pumps. The Theunissen-Brandfort Pumps feeder, however, must be classified as an industrial electrical system because most of the customers' patterns are constant, which typifies industrial patterns.

Figure 6.2 represents the TBP feeder's typical operation during a period of 24 hours. The peak load is averaged at 800kW from 06:00 until 22:00. The load peaks steadily from 330kW to 810kW for about 6 hours, thus from 22:h00 to 6h:00, then peaks averagely between 810kW and 700kW from 06:00 until 22:00 for 16 hours, then drops steadily to 330kW from 22:00 until 06:00(8hours) the next morning (standard peak). Most of the selected customers' water pumping operational hours high-peak patterns are also from 06:00 to 22:00 and standard peaks are from 22:00-06:00. Referring to Figure 6.2, it is clear that the high load-peaking and standard-peaking trends and patterns of the TBP feeder occur during 06:00 to 22:00 and 22:00-06:00 respectively within the period of 24 hours. It is also evident that the implementation stage of a potential LS programme (activities-time of use) on the TBP feeder can be performed from 06:00 to 22:00 for high peak load, and 22:00-06:00 for standard loads to reduce the entire feeder load. Table 6.6 shows Eskom's defined time of periods for both miniflex and ruralflex tariffs. All the customers on this feeder have to be motivated to optimally consume less energy between 06:00 to 22:00 of high peaking periods to standard peaking periods of 22:00-06:00. They will also benefit financially if they reduce their consumption.

The focus of the TBP load reduction must be between 06:00 to 22:00 and 22:00-06:00 for weekdays, Saturdays and Sundays. Most of the customers' machines were stipulated and inferred as still being efficient, therefore the potential proposed defined time of use (TOU) for the whole TBP feeder is presented in Table 7.10. The aim of this survey is to indicate the potential of shifting loads (time of use) for the feeder.

In the case of TBP, a defined time of period can be defined by implementing the potential usage of efficient machines and load shifting. The TBP potential LS programme activities and are summarized in Table 7.10.

The daily measured results pattern (trapezium rule calculation) as shown Figure 6.2 was compared to Figures 4.1- 4.3 which represent typical daily load curves showing the industrial pattern component of a U.S.A utility for high and low demand seasons. It can be seen that the trends of these profiles are almost the same, where high-peaking time is from 6:00 until 22:00 and the standard-peaking time from 22:00 to 6:00.

6.4 Expected Savings Report for the TBP

The potential savings per year are determined on the basis of the energy-efficiency (EE) opportunities analysis performed using the simulation programme and the load-shifting of peak load to standard and low peak electricity consumption on the customer's water pumping machines with applicable assumptions. The expected potential EE savings that are measured in rand value and kWh per year are analysed in Chapter 7 (refer to Tables 7.1- 7.9).

6.4.1 Potential Savings Determination for TBP

To determine the baseline (what the energy usage would be prior to implementation) for the TBP feeder, it was necessary to quantify the following:

- The actual measured pumping load in kW before implementation.
- The actual operational hours of machines and the entire feeder before potential implementation (Figure 6.2).

These are the parameters needed to be quantified for potential TBP DSM activities in order to determine the impact of implementation (retrofitting).

6.4.2 Potential Savings for TBP's Due to Opportunities Identified through the Analysis of Inefficient Customers' Machines

The energy-efficiency analysis of the following customers' geared-coupled machine types was deduced as inefficient. If new, more efficient and identical machine sizes and features are to be installed (replaced), whilst the old, inefficient machines are to be rewound, there will be potential energy savings due to efficient energy usage.

Table 6.3: Inefficient machines to be rewound and replaced by efficient technology

DESCRIPTION	DEDUCTIONS	NUMBER OF MACHINES
Koppies	Inefficient	1X22kW
Theunissen-Brandfort Pumps Plant	Inefficient	2X110 kW (old line)

The following assumptions were made:

- Estimated installed load on the TBP is more than 1MVA. It supplies approximately 82 customers. The penetration factor (confidence level) for all industrial customers on the TBP is approximately 60%-70%. The DSM options are stipulated and inferred. Profile for Figure 6.2 is used as a baseline.

- Calculation of sample size using Table 6.4 and equation 6.1 [2]

Table 6.4: Confidence levels metered systems with identical characteristics to those found in Previous Studies

CONFIDENCE LEVEL (Penetration Factor)	Z* (Z-Statistics)
50.0%	0.674
60.0%	0.841
70.0%	1.036
80.0%	1.282
90.0%	1.645
95.0%	1.960
96.0%	2.054
98.0%	2.326
99.0%	2.576

$$n_k = (z^*.\ \sigma / m)^2 \qquad \textbf{\textit{(Eq 6.1)}}$$

- z^* –statistics of 0.841 obtained from Table 6.4 with the specified corresponding confidence level of 60%.
- m-standard deviation (gradient) with the default value of 0.5 or 50.0% was considered.
- σ - default precision or margin error of 0.1 or 10% was considered.

n_k (sample size) represents the potential population value of TBP customers using inefficient gear-coupled machines.

n_k (sample size) = $(z^*.\ \sigma / m)^2 = (0.841 \cdot 0.1/0.5)^2 = 0.0283\% \approx$ **3 customers**

The main aim of demonstrating equation 6.1 and Table 6.4 is to show the potential penetration factor (confidence level) of 82 TBP industrial customers who are using inefficient geared-coupled machine types. The values on Table 6.4 were calculated using equation 6.1, and were drawn from previous studies that have metered the operation of electrical systems with similar characteristics [2].

Confidence level of sample size for potential customers using **inefficient machines** is **≈ 3 customers**

Table 6.5: List of potential rewound and new efficient machines size technology

DESCRIPTION	OLD INEFFICIENT MACHINES SIZE	NEW EFFICIENT MACHINES SIZE
Koppies	1X22 kW	**1**X22kW
Theunissen-Brandfort Pumps Plant	2X110 kW	**2**X2X110 kW

Assumptions for potential TBP's sample size of 0.0283 % ≈ **3** % = 82 x 3 % = 2.46 ≈ **3 customers** are conditional upon the follows:

- Provided Koppies (customer) can replace and/or rewind (retrofit) his machines as inferred and stipulated (old inefficient machine size of 22kW) and provided new efficient machine technology is implemented.

- Provided Theunissen-Brandfort Pumps Plant customer replaces (retrofits) and/or rewinds machines as inferred and stipulated (inefficient old machine line with 2x110kW geared-type machines) and new efficient technology of same machine sizes is implemented.

- Provided any other customer/s within 82 agree/s that his/her/their machine/s need to be replaced and rewound with new efficient 1x110kW consumption.

Thus, the total, potential full load for new efficient electricity consumption for sampled size of 3 customers will be 1x110kW + 1x22kW + 2x110kW + 60% confidence level of other existing potentially inefficient machines within 82 customers = **352kW at constant full load for 24 hours.** For the TBP's actual consumption to be calculated, another set of measurements has to be established after the retrofitting (implementation) of new efficient machine technology.

6.5 TBP Profile Analysis and Selected Customers' Tariff Structures

Miniflex and Ruraflex tariffs are suitable for the TBP feeder and selected customers who are able to manage their energy consumption and maximum demand according to Eskom's specified schedule (Table 6.6 relates to Figure 6.3). These tariffs are applicable once a satisfactory contract has been negotiated between Eskom and the customers.

Miniflex: This is the correct choice of tariff for the TBP feeder. It is a tariff applicable to customers with supplies of 100kVA to 5MVA and who can shift their load to defined time periods. The TBP feeder's substation transformer size is 5MVA and the installed load is more than 1MVA.

Ruraflex: This is the correct choice of tariff for the selected customers. It is a tariff applicable to the three-phase rural customers who take supply from 400V up to and including 22kV and who can shift their load to a defined time period.

6.5.1 Eskom's Defined Time Periods of Miniflex and Ruraflex Tariffs (TOU)

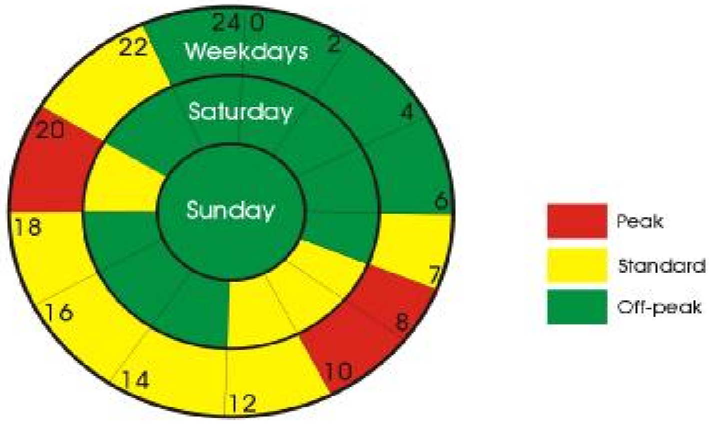


Figure 6.3: Miniflex and Ruraflex tariffs time of use share [4]

Table 6.6: Miniflex and Ruraflex tarrifs defined periods

DAYS	PEAK	STANDARD	OFF-PEAK
Weekdays	7:00-10:00,18:00-20:00	6:00-7:00,10:00-18:00,20:00-22:00	22:00-6:00
Saturday	None	7:00-12:00,18:00-20:00	12:00-18:00,20:00-7:00
Sunday	None	None	None

It should be noted that the above Table 6.6 relates to Figure 6.3.

Table 6.7: Standardised active energy charge-Miniflex charges

ACTIVITY DESCRIPTION	HIGH DEMAND SEASON(June- August)	LOW DEMAND SEASON(September-May)
Maximum demand in kW	Peak : 57.92c/kWh Standard:16.77c/ kWh Off-Peak:8.06c/ kWh	Peak : 17.86c/kWh Standard:11.83c/ kWh Off-Peak:6.99c/ kWh

It should be noted that the rates from Table 6.7 also relate to defined periods in Figure 6.3.

6.6 TBP Potential Electricity Consumption Savings Impact due to EE Programme

The trapezium rule calculation was used for TBP's baseline verification [3]. The EE programme implementation shows the potential impact (Figure 6.4).

Potential TBP collective averaged electricity consumption baseline = **419.9kWh** according to the trapezium calculation results.

Estimated kWh TBP potential savings impact, i = $\left\{ \text{kWh TBP averaged area}_{\text{potential baseline, } i} \right\} - \left\{ \text{kWh averaged area}_{\text{potential actual, } i} \right\}$

= (419.9 **–** 352.00) kWh

= 67.9kWh within 24-hour (one day)

The potential energy-efficiency electricity consumption-savings impact profiles for collective baseline and potential EE impact are presented in Figure 6.4.[5]

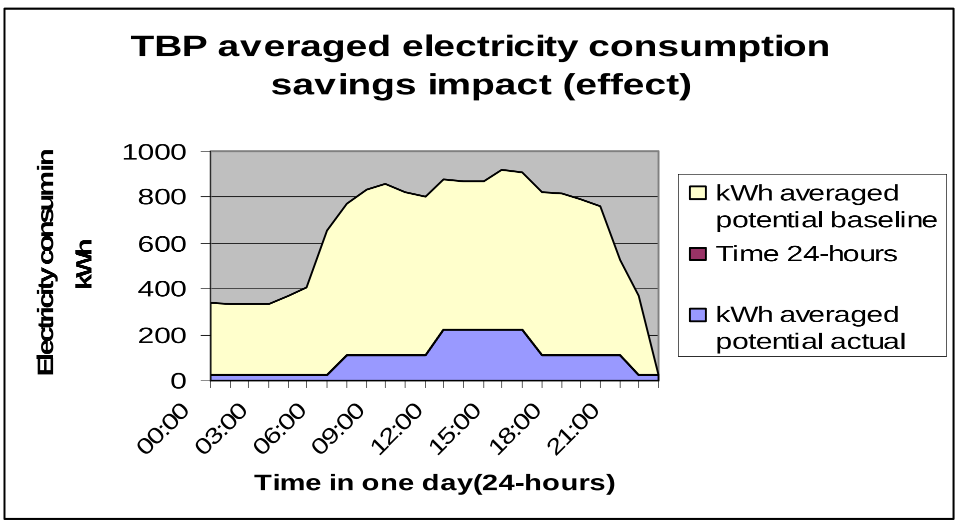
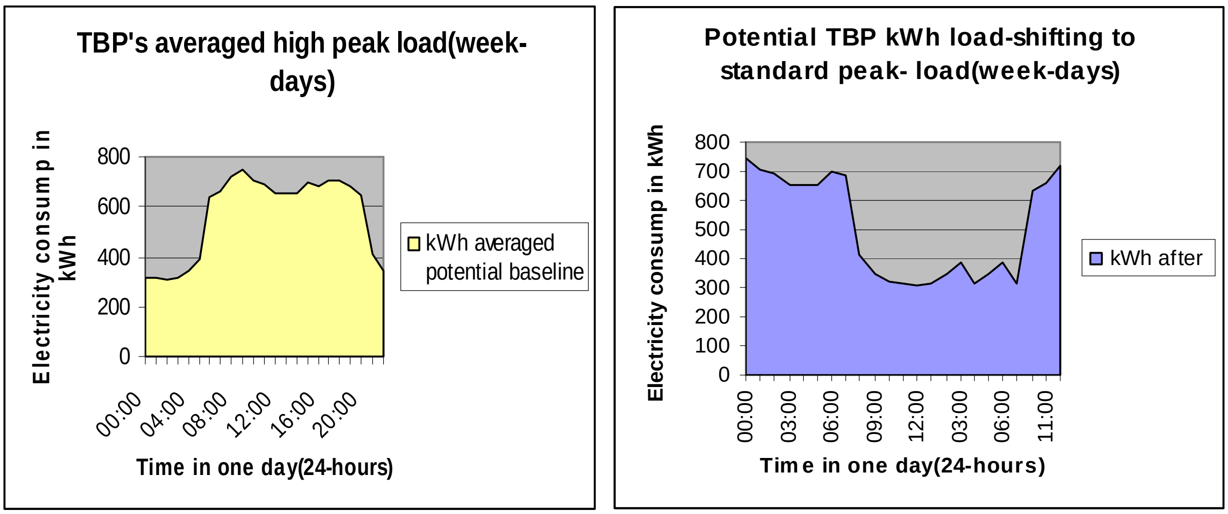


Figure 6.4: TBP usage for potential energy-efficiency implementation.

6.7 Potential Average TBP Feeder Time of Use (Load-Shifting) Programme

The main aim of choosing these tariffs is because they suit all the customers on the TBP feeder. The tariffs are explained in section 6.5 of this Chapter. The load-shifting activities of 60%-confidence-level customers on the TBP feeder can be performed based on potential averaged baseline (Figure 6.2). For potential TOU implementation, refer and compare the LS programme summary inTable 7.10 and Table 6.8 in relation to Figures 6.5(a) and (b).



(a) **(b)**

Figure 6.5: TBP seasonal usage after potential load-shifting implementation.

Figure 6.5 present the potential week-days load-shifting (LS) activity programme for TBP feeder's from highest-peak load to standard-peak load. The TBP's load-shifting activities for Saturday and Sunday are basically the same as those of week-days according to the measured results. For the results on Table 6.8, refer to Figure 6.5 (b) for shifting load from highest-peak load to standard-peak loads for week-days, thus from 20:00-7:00 [11hours] and anytime between 10:00-18:00 [5hours].

Table 6.8: Potential load-shifting programme results (TOU) for TBP feeder

kWh after Potential LS Implementation	747.48	708	692.882	657	651	652	698	685.005
Time 24-hours	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00
kWh after Potential LS Implementation	410.997	347	317.668	314	310	312	347	386.67
Time 24-hours	08:00	09:00	10:00	11:00	12:00	01:00	02:00	03:00
kWh after Potential LS Implementation	312.021	347	386.67	314	635	660	721	
Time 24-hours	04:00	05:00	06:00	07:00	08:00	11:00	11:55	

6.8 Potential DSM Programme for the TBP Feeder

Both inferential and stipulatory analyses show the strongest penetration for DSM programme of the whole plant (feeder). The potential DSM programme; namely: energy-efficiency by rewinding and replacing motors and load-shifting by time of use from peak to standard and Off-peaks (refer to Figures 6.2, 6.4 and 6.5)

Simulations: A simulation software programme was used to check the potential energy-efficiency programme, (The reports are presented in Chapter 7) [3].

6.9 Potential Effect of M&V Programme Using the Applicable Tariff Rates Structure

The tariff structures were chosen according to types of identified customers and the feeder as a whole. The individual selected customers would pay for ruraflex tariff rates. The whole feeder (TBP) pays for miniflex tariff rates. Services charge per account are based on th sum of monthly utilised capacity, the maximum demand charge measured in kW demands are measured during peak and standard periods. The active energy charge is measured in kWh.

6.10 Active Energy Charge (kWh)

The savings (adjustments) will be due to the activity energy charges calculations and assumptions, according to a day and one week's measured results. This provides the conclusion that the potential DSM programmes should influence the customer to use less energy for the benefit of the utility and savings, and that would also benefit the customers in terms of cheaper electricity and environmental benefits. Furthermore, the M&V programme can be used to measure and verify after actual implementation in the future.

The following factors must be considered:

a) The active energy in kWh adjustment will be performed only when the DSM programme becomes invisible.

b) The customers (TBP) daily average time of operation.

c) The estimated averaged daily electricity consumption is determined.

d) Weekday's and week-ends average time of operation.

e) There are four Saturdays and 22 weekdays in a month.

f) No load-shifting on Sundays (Off-peak).

All this information was obtained from the measured results and calculations and the following parameters can be calculated using the above information:

- Averaged energy-savings for weekdays and weekend-days (Saturdays) within a month.

- Total of monthly and yearly averaged energy-savings.

6.11 Potential Billings (Verifications) Calculations for the TBP Feeder

The following formula, assumptions and Table 6.6 will be used:

TBP Electricity Costs= Energy Charge(c/kWh) x Energy Consumed (kW) hours (h)

Calculation assumptions for future verification will be done as follows:

In one week day during high demand season for peak, standard and off- peak, multiply by 22 days. In one weekend day during high demand season for peak, standard and off-peak, multiply by 4 days. In one week day during low demand season for peak, standard and off-peak, multiply by 22 days. In one weekend day during low demand season for peak, standard and off-peak, multiply by 4 days. In one year weekdays for peak, standard and off-peak demand seasons, multiply by 22 days x 12 months and multiply by 4 days x 12 months for weekend days and then add to give the annual results.

Monthly bill for high demand season: **[**energy cost in rands**]** x **[**actual number of days of consumed energy**]**

Monthly bill for low demand season: **[**energy cost in rand**]** x **[**actual number of days of consumed energy**]**

Further calculations would be done on average monthly and yearly billings.

The monthly and yearly cost savings and emission reduction impact are calculated.

6.12 Conclusion for TBP Feeder Profile Analysis

The analysis of all the customers was based on the measured data taken more or less at the same time, within 5-minute intervals for the period of one week. The measured results of each customer depict a sequence of operations. It is clear that the Theunissen-Brandfort Pumps feeder is an industrial electrical system because most of the customers' patterns are constant, which typifies industrial patterns. It is also clear that if the potential EE, load-shifting (DSM programmes) for the entire system can be implemented to adjust the load from peaks to standard and off-peaks for the benefit of Eskom, its infrastructural financial investment in assets developments will be delayed, the electricity bills will be reduced for the customers and the emissions will be reduced. At this point in time the actual savings will only be realised if these potential DSM measures/activities are implemented in future.

6.13 References/Bibliography

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[3] Trapezium rule numerical integration (1998). {http://www.damtp.com.ac.uk/user/fdl/ people/sd/lectures/nummeth98/intergration.htm}.

[4] Eskom tariffs and charge booklet, 2005/6.

[5] Energy Efficiency Task Force Report To The Clean Diversified Energy Advisory Committee of The Governors Association: Final Report November 18 2005: *The Potential for More Efficient Electricity Use in The Western United States.*

CHAPTER 7: POTENTIAL SAVINGS

This Chapter provides the potential energy and cost savings resulting from the identified and quantified EE opportunities (projects) on the selected customers and the TBP feeder as a whole. These potential opportunities would also assist Eskom with regard generation capacity demand reduction, and South Africa, as far as potential green-house gas (GHG) mitigations are concerned.

7.1 Introduction

Whenever any measurement and verification project report is implemented, the first question to ask is: How are the potential savings achieved? An engineer, professional or any layperson would ask such a question to the researcher. This is an easy question to ask. However, it is not an easy question to answer, especially if the savings cannot be measured immediately, but can only be measured and seen after some time; at best, they can be calculated.

The aim of this Chapter is to provide potential savings achieved through the use of quantified and identified potentially feasible EE programme (opportunities) applicable to the Theunissen-Brandfort Pumps feeder as a whole. The aim is to show and enable the potential quantification and assessment of the energy savings resulting from the DSM programmes and to prove that they can be sustainable.

In order to determine the savings, the potential averaged baseline reductions per customer and the entire TBP feeder were developed. The baseline is what the energy consumption would have been if the system underwent no changes. The collective baselines were developed with measured Theunissen-Brandfort Pumps feeder data prior to any changes made to the system using the trapezium rule. In order to determine the potential savings, the baseline reduction of the daily pattern was first analysed.

The effects of the DSM measures would result in potential energy savings, which in turn would be quantified, measured and verified in the future. The potential saving effect would also carry environmental benefits. Thus for every kWh of energy saved, one less emission reduced would occur and one litre of water would be saved. An overview of M&V programme (activities) comprises the follows: Project scoping, M&V plan and development.

Baseline development report implementation and assessment involves an M&V post-implementation report, M&V metering installation and commissioning. For the potential savings results due to potential DSM programme implementation, refer to the summary of the project for EE and LS opportunities table results.

7.2 The TBP M&V Project Activities

The M&V scoping report and the M&V plan and process for this project were developed as presented in Chapter 3. Chapter 4 involved a detailed description of the TBP network, locations and selected customers' equipment. Chapter 5 provided case studies per selected customer. The relevant project information, the manner in which the collective baseline was developed, which data would be used, applicable tariff structures, the energy-efficiency and the LS activities as presented in Chapter 6, the calculation of potential savings results and the presentation of Figures 6.4 and 6.5, viz: the potential project impact and the evaluation EE analysis, are set out in Chapter 7. Annual potential savings analysis reports are drawn up by using the international selection and savings analysis software programme (IMSSA).

7.3 The Basic Approach for Potential Impact Determination

The basic M&V options that can determine the baseline reduction at the TBP feeder can be thoroughly tested by real implementation for future research (results), especially for a typical industrial TBP load in order to determine what (impact) actual effect would have been if it were fully implemented. The following potential M&V options derived from the IMPVP protocols [2] (refer to reference one of Chapter two) were used:

- **Option A:** A partially measured retrofit isolation of selected customers' machines with maximum consuming electricity capacity was separated from the rest of their facilities.

- **Option B: Whole TBP feeder:** The involvement of the meter to assess the energy performance of the total TBP feeder was used by installing meters at the substation for a period of a week. This option was implemented with the aim of determining the potential collective baseline. The savings due the energy-efficiency and DSM activities for the TBP feeder, which exhibits a complex, and highly developed integration process are analysed by using the simulation programme (IMSSA).

- **Option C: Simulation:** Research analysis is performed on the potential opportunities for savings analysis using the relevant simulation programme(IMSSA).

- **Option D:** The savings determination is the same as that of option A, except that stipulation and inference are allowed, full measurements are required. Short-term or metering is used.

7.4 The Potential Collective Baseline and M&V Savings Impact on the TBP

The feasible M&V programme analysis for the particular electrical system will be performed by potential energy-efficiency and load management. The amount saved would be deduced using the best M&V programme. Customers' and utility benefits are only seen when actual savings are determined. Other benefits like socio-economical and environmental benefits would also be determined after the potential amount saved was calculated.

7.5 Opportunities (Projects) for Selected Customers and the TBP Feeder

The quantified and identified opportunities on the selected customers' motors are the same. The EE potential opportunities' savings are analysed using the calibrated simulation programme *(IMSSA)*.

7.6 IMSSA Simulation Programme Features:

Figure 7.1: Snap-shot of international motor selection and savings analysis software Programme

The IMSSA supports motor management functions at commercial and institutional facilities, water supply and wastewater treatment systems, irrigation districts, medium-sized and large industrial facilities. Designed for utility auditors, energy managers, and plant or consulting engineers, *IMSSA* supports motor and motor systems improvement planning through identifying the most efficient action (opportunity) for a given repair or motor purchase decision. *IMSSA* can be used to compute the energy and demand savings associated with the purchase of a new motor instead of a standard or improved Efficiency motor model or evaluate the cost-effectiveness of replacing a failed motor with an efficient motor. *IMSSA* operates under Microsoft Windows and includes an online help system. The programme is menu-driven, with ample help on-screen. Below are the opportunities analysed per customer and also for the entire TBP feeder using the *IMSSA programme software.*

7.7 *Purification Plant Potential EE Opportunities (Projects) Analysis*

Table 7.1: Purification Plant project opportunities analysis for 300kW motor

Motor Savings Analysis - Replace Existing — Page: 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor>:		EFF3 Standard Efficiency Motor <Default EFF3 motor>:	
Size (kW) / Speed (RPM) (Poles):	300.0 kW:	1500 RPM	300.0 kW:	1500 RPM
Degree of protection /Voltage (Volts):	IP55	380 Volts	IP55	380 Volts
Load (%):	75.0		75.0	
Efficiency (%):	94.2		94.6	
Full load RPM:	1450 RPM		1450 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%):	0.4			

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4,571	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	182	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5760	5760		

RESULTS – POTENTIAL SAVINGS

Description:	Existing Motor:	EFF3 Standard Efficiency Motor:	Energy Savings:	
Differential cost (R):		4,753	Energy (kWh/yr):	5,665
Energy use (kWh/yr):	1339469	1333803	Demand (kW):	1.0
Energy cost (R/yr):	409,609	407,877	Energy savings (R/yr):	1,732
Demand charge (R/yr):	13,953	13,894	Demand savings (R/yr):	59
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1,791
South Africa (Free State):	West Virginia	tonnes CO2/yr: 5, 09	Simple payback (yrs):	2, 7

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Motor Savings Analysis - Rewind — Page: 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor<Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	300.0 kW:	1500 RPM	300.0 kW:	1500 RPM
Degree of protection /Voltage (Volts):	IP55	380 Volts	IP55	380 Volts
Load (%):	75.0		75.0	
Efficiency (%):	94.1		94.6	
Full load RPM:	1450 RPM		1450 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%):	0.5			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4,571	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5760	5760		

RESULTS – POTENTIAL SAVINGS

Description:	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings:	
Differential cost (R):		-132	Energy (kWh/yr):	7,089
Energy use (kWh/yr):	1340892	1333803	Demand (kW):	1. 4
Energy cost (R/yr):	410,045	407,877	Energy savings (R/yr):	2,168
Demand charge (R/yr):	16,433	16,346	Demand savings (R/yr):	87
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	2,255
South Africa (Free State):	West Virginia	tonnes CO2/yr: 6.37	Simple payback (yrs):	0.0

Above are the existing 300 kW motor *replacement* with more efficient motor and existing 300 kW motor *rewinding* projects opportunities analysis.

Table 7.2: Purification Plant project opportunities analysis for 132kW motor

Motor Savings Analysis - Replace Existing

Page: 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor> :		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	132.0 kW:	1500 RPM	132.0 kW:	1500 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	73.0		73.0	
Efficiency (%):	94.9		95.1	
Full load RPM:	1468 RPM		1468 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%):	0.2			

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	5,645	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	486	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5760	5760		

RESULTS – POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor;	Energy Savings :	
Differential cost (R):		6,131	Energy (kWh/yr):	1,231
Energy use (kWh/yr):	585067	583837	Demand (kW):	0.2
Energy cost (R/yr):	178,914	178,537	Energy savings (R/yr):	376
Demand charge (R/yr):	6,094	6,083	Demand savings (R/yr):	13
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	389
South Africa (Free State):	West Virginia	tonnes CO2/yr: 1.11	Simple payback (yrs):	15.8

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Motor Savings Analysis - Rewind

Page: 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	132.0 kW:	1500 RPM	132.0 kW:	1500 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	73.0		73.0	
Efficiency (%):	94.6		95.1	
Full load RPM:	1468 RPM		1468 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%):	0.5			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	5,645	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5760	5760		

RESULTS POTENTIAL SAVINGS

Description	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings	
Differential cost (R):		3,160	Energy (kWh/yr):	3,087
Energy use (kWh/yr):	586923	583837	Demand (kW):	0.5
Energy cost (R/yr):	179,481	178,537	Energy savings (R/yr):	944
Demand charge (R/yr):	6,114	6,082	Demand savings (R/yr):	32
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	976
South Africa(Free St:	West Virginia	tonnes CO2/yr: 2.77	Simple payback (yrs):	3.2

Above are the statistics for the existing 132 kW motor *replacement* with more efficient motor and the existing 132 kW motor *rewinding* projects opportunities analysis.

7.8 Theunissen-Brandfort Plant EE Potential Opportunities (Projects) Analysis

Table 7.3: Theunissen-Brandfort Plant opportunities analysis for 110kW (old line) machine one motor

Motor Savings Analysis - Replace Existing Page: 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor> :	EFF3 Standard Efficiency Motor <Default EFF3 motor>
Size (kW) / Speed (RPM) (Poles):	110.0 kW: 1500 RPM	110.0 kW: 1500 RPM
Degree of protection /Voltage (Volts):	380 Volts	380 Volts
Load (%):	64.3	64.3
Efficiency (%):	95.8	91.9
Full load RPM:	1450 RPM	1450 RPM
Centrifugal load:	True	
Old Motor Efficiency Loss (%):	0.5	

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4,254	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	445	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5040	5040		

RESULTS POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor:	Energy Savings :	
Differential cost (R):		4,699	Energy (kWh/yr):	4274
Energy use (kWh/yr):	379811	375637	Demand (kW):	0.8
Energy cost (R/yr):	116,177	114,870	Energy savings (R/yr):	1,307
Demand charge (R/yr):	4,523	4,472	Demand savings (R/yr):	51
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1,358
South Africa (Free State):	West Virginia	tonnes CO2/yr: 3, 84	Simple payback (yrs):	3. 5

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Motor Savings Analysis - Rewind Page: 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>	EFF3 Standard Efficiency Motor<Default EFF3 motor>
Size (kW) / Speed (RPM) (Poles):	110.0 kW: 1500 RPM	110.0 kW: 1500 RPM
Degree of protection /Voltage (Volts):	380 Volts	380 Volts
Load (%):	64.3	64.3
Efficiency (%):	95.8	91.3
Full load RPM:	1450 RPM	1450 RPM
Centrifugal load:	True	
Rewind efficiency loss (%):	0.5	

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4, 254	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5040	5040		

RESULTS POTENTIAL SAVINGS

Description	Rewound Motor	EFF3 Standard Efficiency Motor	Energy Savings:	
Differential cost (R):		2, 052	Energy (kWh/yr):	2, 014
Energy use (kWh/yr):	379911	377897	Demand (kW):	0.4
Energy cost (R/yr):	116, 177	115, 561	Energy savings (R/yr):	616
Demand charge (R/yr):	4, 535	4, 499	Demand savings (R/yr):	24
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	640
South Africa(Free State):	West Virginia	tonnes CO2/yr: 1, 81	Simple payback (yrs):	3. 2

Table 7.4: Theunissen-Brandfort Plant opportunities analysis for 110kW (old)machine two motor

Motor Savings Analysis - Replace Existing

Page: 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor> :		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	110.0 kW:	1500 RPM	110.0 kW	1500 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	64.3		73.0	
Efficiency (%):	93.8		94.3	
Full load RPM:	1468 RPM		1468 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%):	0.5			

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4,254	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	445	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5640	5640		

RESULTS POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor:	Energy Savings :	
Differential cost (R):		4, 699	Energy (kWh/yr):	2 , 253
Energy use (kWh/yr):	425139	422885	Demand (kW):	0.4
Energy cost (R/yr):	130,007	129,318	Energy savings (R/yr):	689
Demand charge (R/yr):	4,523	4, 499	Demand savings (R/yr):	24
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	713
South Africa (Free State):	West Virginia	tonnes CO2/yr: 2.02	Simple payback (yrs):	6.6

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Motor Savings Analysis - Rewind

Page: 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor<Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	110.0 kW:	1500 RPM	110.0 kW:	1500 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	64.3		64.3	
Efficiency (%):	93.8		94.3	
Full load RPM:	1468 RPM		1468 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%):	3.5			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	4, 254	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5640	5640		

RESULTS POTENTIAL SAVINGS

Description:	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings:	
Differential cost (R):		2, 052	Energy (kWh/yr):	2, 253
Energy use (kWh/yr):	425139	422885	Demand (kW):	0.4
Energy cost (R/yr):	130, 007	129, 318	Energy savings (R/yr):	689
Demand charge (R/yr):	4, 523	4, 499	Demand savings (R/yr):	24
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	713
South Africa(Free St:	West Virginia	tonnes CO2/yr: 2.02	Simple payback (yrs):	2. 9

Above are the existing 110 kW motor *replacement* with more efficient motor and existing 110 kW motor *rewinding* projects opportunities analysis on old line machines, one and two motors

Table 7.5: Theunissen-Brandfort Plant opportunities analysis for 110kW (New line) machine one

Motor Savings Analysis - Replace Existing

Page: 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor> :		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	110.0 kW.	1500 RPM	132.0 kW.	1500 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	61.3		61.3	
Efficiency (%):	94.3		94.1	
Full load RPM:	1480 RPM		1480 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%).	0			

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%).	N/A	35	Energy price (R/kWh).	0.3058
Purchase price (R):	N/A	4,251	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	445	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5640	5640		

RESULTS – POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor:	Energy Savings :	
Differential cost (R).		4,698	Energy (kWh/yr).	0
Energy use (kWh/yr):	422865	422585	Demand (kW):	0.0
Energy cost (R/yr):	129,318	129,318	Energy savings (R/yr):	0
Demand charge (R/yr):	4,499	4,499	Demand savings (R/yr):	0
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	0
South Africa (Free State):	West Virginia	tonnes CO2/yr: 0.00	Simple payback (yrs):	0.0

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Motor Savings Analysis - Rewind

Page. 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor<Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	110.0 kW:	1500 RPM	132.0 kW:	1500 RPM
Degree of protection /Voltage (volts):		380 Volts		380 Volts
Load (%):	61.3		61.3	
Efficiency (%):	94.3		94.3	
Full load RPM:	1480 RPM		1480 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%).	0			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R).	N/A	4,234	Demand charge (R/kW/mo.).	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr.	5640	5640		

RESULTS – POTENTIAL SAVINGS

Description:	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings	
Differential cost (R):		2,052	Energy (kWh/yr):	0
Energy use (kWh/yr):	422885	422885	Demand (kW):	0.0
Energy cost (R/yr):	129,318	129,318	Energy savings (R/yr):	0
Demand charge (R/yr):	4,499	4,499	Demand savings (R/yr):	0
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	0
South Africa(Free State):	West Virginia	tonnes CO2/yr: 0.00	Simple payback (yrs):	0.0

Existing 110 kW motor *replacement* project opportunity with more efficient motor and existing 110 kW motor *rewinding* project opportunity analysis. **Note: Analysis for another** 110kW motor for new line machine two is the same as the above [Table 7.5].

7.9 Koppies EE Potential Opportunities (Projects) Analysis on 22kW Motor

Table 7.6: Koppies Plant project opportunities analysis for 22kW motor

Motor Savings Analysis - Replace Existing Page. 1

INPUTS

Motor Characteristics Description:	Existing Motor <Default EFF3 motor> :		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	22.0 kW:	3000 RPM	22.0 kW:	3000 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	40.0		40.0	
Efficiency (%):	84.2		89.6	
Full load RPM:	2940 RPM		2940 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%):	0			

Costs/Use	Existing Motor:	EFF3 Standard Efficiency Motor :	Utility Data :	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	1,653	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	109	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5040	5040		

RESULTS POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor:	Energy Savings:	
Differential cost (R):		1,762	Energy (kWh/yr):	3,187
Energy use (kWh/yr):	52705	49517	Demand (kW):	0.6
Energy cost (R/yr):	16,117	15,142	Energy savings (R/yr):	975
Demand charge (R/yr):	627	589	Demand savings (R/yr):	38
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1,013
South Africa (Free State):	West Virginia	tonnes CO2/yr: 2.86	Simple payback (yrs):	1. 7

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Motor Savings Analysis - Rewind Page: 1

INPUTS

<u>Motor Characteristics Description</u>	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor<Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	22.0 kW:	3000 RPM	22.0 kW:	3000 RPM
Degree of protection /Voltage (volts):		380 Volts		380 Volts
Load (%):	40.0		40.0	
Efficiency (%):	83.2		89.6	
Full load RPM:	2940 RPM		2940 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%):	1			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	1,653	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr:	5040	5040		

RESULTS – POTENTIAL SAVINGS

Description:	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings:	
Differential cost (R):		980	Energy (kWh/yr):	3,821
Energy use (kWh/yr):	53338	49517	Demand (kW):	0.8
Energy cost (R/yr):	15,311	15,142	Energy savings (R/yr):	1,169
Demand charge (R/yr):	635	589	Demand savings (R/yr):	45
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1,214
South Africa (Free State)	West Virginia	tonnes CO2/yr:: 3.43	Simple payback (yrs):	0. 8

Existing 22 kW motor *replacement* project opportunity with more efficient motor and existing 22 kW motor *rewinding* project opportunity analysis

7.10 The Whole Plant Assessment Potential EE Opportunities (projects) Analysis on Total of 352 kW of Inefficient Motor Identified.

Table 7.7: TBP Plant wide motor ***replacement*** opportunities analysis for 352kW quantified load

Motor Savings Analysis - Replace Existing Page. 1

INPUTS

Motor Characteristics Description	Existing Motor <Default EFF3 motor>		EFF3 Standard Efficiency Motor <Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	355.0 kW:	3000 RPM	355.0 kW:	3000 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	72.7		72.7	
Efficiency (%):	94.9		96.2	
Full load RPM:	2940 RPM		2940 RPM	
Centrifugal load:	True			
Old Motor Efficiency Loss (%):	0.5			

Costs/Use	Existing Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R):	N/A	23, 400	Demand charge (R/kW/mo.):	5
Installation cost (R):	N/A	0	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr.	5760	5760		

RESULTS POTENTIAL SAVINGS

Description:	Existing Motor	EFF3 Standard Efficiency Motor.	Energy Savings :	
Differential cost (R):		17, 308	Energy (kWh/yr):	8, 067
Energy use (kWh/yr):	1552715	1544616	Demand (kW):	1, 4
Energy cost (R/yr):	309, 115	307, 539	Energy savings (R/yr):	1, 606
Demand charge (R/yr):	16, 174	16, 090	Demand savings (R/yr):	84
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1, 690
South Africa (Free State):	West Virginia	tonnes CO2/yr: 7. 24	Simple payback (yrs):	10.2

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Table 7.8: TBP Plant wide motor ***rewind*** opportunities analysis for 352kW quantified load

Motor Savings Analysis - Rewind Page: 1

INPUTS

Motor Characteristics Description	Rewound Motor<Default EFF3 motor>		EFF3 Standard Efficiency Motor<Default EFF3 motor>	
Size (kW) / Speed (RPM) (Poles):	355.0 kW:	3000 RPM	355.0 kW:	3000 RPM
Degree of protection /Voltage (Volts):		380 Volts		380 Volts
Load (%):	72.7		72.7	
Efficiency (%):	95.7		96.2	
Full load RPM:	2940 RPM		2940 RPM	
Centrifugal load:	True			
Rewind efficiency loss (%):	0.5			

Costs/Use	Rewound Motor	EFF3 Standard Efficiency Motor	Utility Data	
Dealer discount (%):	N/A	35	Energy price (R/kWh):	0.3058
Purchase price (R).	N/A	23, 400	Demand charge (R/kW/mo.).	5
Installation cost (R):	N/A	1, 335	Power factor (%):	N/A
Motor rebate (R):	N/A	0	Rebate program:	<None>
Peak months:	12	12	Simple payback criteria, yrs:	10
Hours use/yr.	5760	5760		

RESULTS – POTENTIAL SAVINGS

Description:	Rewound Motor:	EFF3 Standard Efficiency Motor	Energy Savings:	
Differential cost (R):		24, 735	Energy (kWh/yr):	8, 067
Energy use (kWh/yr):	1552713	1544646	Demand (kW):	1, 4
Energy cost (R/yr):	309, 145	307, 539	Energy savings (R/yr):	1, 606
Demand charge (R/yr):	16, 174	16, 090	Demand savings (R/yr):	84
Greenhouse Gas Emissions Reduction			Total savings (R/yr):	1, 690
South Africa(Free State):	West Virginia	tonnes CO2/yr:: 7.24	Simple payback (yrs):	14, 6

7.11 TBP Potential EE Programme

Table 7.9: Potential EE programme opportunity summary

FACILITY/PLANT Motor/s sizes in kW	REWIND & REPLACE : OPPORTUNITY SOLUTIONS ON MOTORS	POTENTIAL EE OPPORTUNITY IMPLEMENTATION SAVINGS RESULTS OVERVIEW/YEAR Potential: Annual Energy Savings. Annual Rand Savings. Annual Emissions Reduction & Annual Payback Time Per Opportunity Implementation
Purification 1. 300kW Motor: ►	•*Rewind* : Best Solution	•7,089kWh/yr. 2,255R/yr. 6,37CO_2/yr & Payback=0.0yr
	•*Replace*: Long-Term Solution	•5,666kWh/yr. 1,732R/yr 5,09CO_2/yr & Payback=2,7yr
2. 132kW Motor : ►	•*Rewind* : Best Solution	•3,087kWh/yr. 976 R/yr. 2,77CO_2/yr & Payback=3.2yr
	•*Replace*: Long-Term Solution	•1,231kWh/yr. 309 R/yr. 1,11CO_2/yr & Payback=15,8yr
Theunissen-Brandfort 1. 110KW(old line machine one motor) ►	•*Rewind* : Short-Term Solution	•2.014kWh/yr. 640R/yr. 1,81CO_2/yr & Payback=3,2yr
	•*Replace* : Best Solution	•4,274kWh/yr. 1,358R/yr. 3,84CO_2/yr & Payback=3,5yr
2. 110KW(old line -machine two motor) ►	•*Rewind* : Short-Term Solution	•2,263kWh/yr. 723R/yr. 2,02CO_2/yr & Payback=2,9yr
	•*Replace*: Long-Term Solution	•2,253kWh/yr. 713R/yr. 2,02CO_2/yr & Payback=6,6yr
3. 110KW(new line machine one motor) ►	•*Rewind* : Not Potential Solution	•0kWh/yr. 0R/yr. 0CO_2/yr & Payback=0yr
	•*Replace*: Not Potential Solution	•0kWh/yr. 0R/yr. 0CO_2/yr & Payback=0yr
4. 110kW(new line -machine two motor ►	•*Rewind* : Not Potential Solution	•0kWh/yr. 0R/yr. 0CO_2/yr & Payback=0yr
	•*Replace*: Not Potential Solution	•0kWh/yr. 0R/yr. 0CO_2/yr & Payback=0yr
Koppies 1. 22kW Motor: ►	•*Rewind* : Short-Term Solution	•3,821kWh/yr. 1,214R/yr. 3,43CO_2/yr & Payback=0.8yr
	•*Replace*: Long-Term Solution	•3.187kWh/yr. 1,013R/yr. 2,86CO_2/yr & Payback= 1,7yr
A. Gutter Motor/s: ►	No analysis performed	No analysis performed
Whole TBP feeder: 352kW Quantified TBP' Motor Load: ►	•*Rewind* : Short-Term Solution	•8,067kWh/yr. 1,606R/yr. 7,24CO_2/yr & Payback=10,2yr
	•*Replace*: Long Term Solution	•8,067kWh/yr. 1,606R/yr. 7.24CO_2/yr & Payback= 14,6yr

7.12 TBP Potential LS Programme

Table 7.10: Potential LS programme opportunity summary

IMPLEMENTATION	TBP CURRENT TIME-OF-USE	TBP POTENTIAL TIME-OF-USE IMPLEMENTATION
Days	**TBP High Peak-Load**	**Shift Load to Standard-Peak Load**
Weekdays	06:00 22:00[16hours]	20:00 7:00[11hours] & anytime between 10:00-18:00[5hours]
Saturday	06:00-22:00[16hours]	20:00-7:00[11hours] & anytime between 12:00-18:00[5hours]
Sunday	06:00-22:00[16hours]	Anytime of the day
Days	**TBP Standard-Load**	**Shift Load to Standard-Peak Load**
Weekdays	22:00-06:00[8hours]	22:00-06:00[8hours]operational hours remain the same
Saturday	22:00-06:00[8hours]	Anytime between 20:00-7:00[8hours]
Sunday	22:00-06:00[8hours]	Anytime of the day
Days	**TBP Off-Peak-Load**	**Shift Load to Standard-Peak Load**
Weekdays	None	None
Saturday	None	None

7.13 Energy-Efficiency Audit Parameters

Table 7.11**:** Efficient-energy audit parameters used for TBP EE opportunities analysis

DESCRIPTION	REWIND	REPLACE
1. Size kW/speed (rmp-poles)	355kW	355 kW
2. % Utilisation factor	72.70%	72.70%
3. Full load rpm	2940 rpm	2940 rpm
4. Centrifugal loads	yes/true	yes/true
5. Old motor/s efficiency loss	50%	50%
6. Hours of operation/yr	5760 hours	5760 hours
7. Averaged energy price(Utility)	0.1991c/kW/yr	0.1991c/kW/yr

The reason for using the above identical parameters for both EE opportunities analysis using the IMSSA programme was to identify the best feasible and viable opportunity solutions between motor rewinding and replacement for the entire feeder and the results show that both opportunities are viable. Moreover, it is evident that replacement is a long term (opportunity) solution and rewinding a short term one.

The EE and LS programmes assessment results are based on the purchase and replacement by new motors and rewinding of existing motors identified as iefficient not to be efficient with the same existing new motors' characteristics, viz: sizes, rpm enclosed fan- cooled motor, the facilities' percentage load hours of operation per year, utilization factors per year and averaged utility rate structure, (refer to Tables 7.9 and 7.10).

7.14 Conclusion

It is evident that if these potential energy-efficiency (EE) and load shifting (LS) activities are fully implemented on the TBP, their effects (impacts) and the actual savings achieved would be determinable. The actual EE and LS activities (DSM programme) and M&V can be implemented on the TBP feeder in future.

7.15 Bibliography

[1] Eskom tariffs and charge booklet, 2005/6. pp 1-37

[2] Trapezium rule numerical integration. (1998){http://www.damtp.com.ac.uk/user/fdl/ people/sd/lectures/nummeth98/intergration.htm}.

[3] http://www.epa.gov/asap

[4] http:// www.energyfinance.org. ©2006 energy finance org all rights reserved

[5] http:// www.plug-in.org

CHAPTER 8: CONCLUSIONS & RECOMMENDATIONS

This Chapter gives the potential energy and cost savings findings, resulting from the identified and quantified EE opportunities (projects) and conservation measures (Load-shifting programme) on the selected customers and the entire TBP feeder as a whole. Recommendations are also drawn on the basis of the evaluated potential EE and LS opportunities that show the greatest potential. Indications about how they would be pursued in the future are given, based on their individual and combined feasibility.

8.1 Similar Research

A vast body of research regarding Demand-Side Management has been published abroad and in South Africa from different backgrounds and varying scope compared to this particular project. Other aspects such as socio-economic and environmental benefits provide different scenarios on the subject.

8.2 Direct Results

The assessment of the TBP plant resulted in the identification and quantification of potential multiple cost savings opportunity projects per selected customers, the entire feeder and an appropriate strategy, for the pursuit of these aims in future. A total of nine potential projects (opportunities) within all the selected customers' facility plants were identified and are scheduled according to short-and long-term periods and three of them qualify as best solutions. These best alternative solutions are scheduled according to the immediate potential implementation. The LS activity opportunities were also assessed per customer and the entire feeder.

The potential projected annual energy and cost savings, resulting from the entire TBP potential EE opportunities implementation are 8,067kWh / yr and R 1,606 / yr for each opportunity. The potential CO_2 emission reduction of 7,24tonnes / yr per opportunity on the entire TBP facilities analysis, considering South Africa (Free State) as a whole, and was benchmarked against that of the state of West Virginia in the USA. The whole feeder payback periods per opportunity are 10, 2 yrs and 14, 6 yrs concurrently.

Short-term EE projects are scheduled in such a way that their average yearly implementation cost is approximately R 4,183.00, Long-term EE projects average a yearly implementation total expenditure of R 5,453.00. Best solutions average a yearly implementation total of R 4,589.00 and non-best solutions a total of R0,00, refer to Table 7.9.

a) The results throughout the study show that standard information would be used in future and this would be in line with Eskom's DSM standardisation process.

8.3 Indirect Results

DSM is a fairly new concept in South Africa and is therefore not well known. The study was based on simplicity in order to simplify the DSM subject for future research. By using a simple and user-friendly IMSSA software programme, quick, relevant results were obtained. The study played an important role in influencing and educating the customers about the importance of potential demand-side management concepts and objectives. The study compiled valuable information on potential EE, DSM and M&V that was previously unknown and, which will make it easy for future applications.

8.4 Limitations

Customers' disagreements and lack of knowledge are the main factors and limitations with regard to other important energy-efficiency and efficient energy conservation data that could have been collected on site. Data was mostly collected during customers' operations. It is very unpredictable for the TBP load consumption to be precisely determined due to daily changes in the feeder configuration.

8.5 ***Further Research***

The pre-implementation, post-implementation, commissioning, operation and maintenance stages of the programmes remain a concern aimed at achieving proper actual DSM measurable results. Further study should be carried out on these stages. It is evident from this study-with the introduction of the potential energy-efficiency (EE) and load-shifting (LS) for the TBP electrical system-that potential savings (adjustments) will be possible. Further research can be conducted by actual implementation of the TBP feeder's potential EE, LS and M&V programmes.

8.6 Recommendations for Identified Opportunities

It is recommended that all the motors identified as inefficient be rewound and replaced by new and efficient ones. It is also very important that the LS programme be implemented only after these EE opportunities are implemented to ensure the sustainability of resources and that the DSM objectives can be achieved.

For TBP customers to agree with the DSM programme, the following recommended initiatives may be pursued by the utility (Eskom):

a) Campaigns to replace and rewind inefficient motors.

b) Proper training of Eskom's meter reading and data management staff for reliable data collection.

c) Consultancy on purchase of energy-efficient equipment.

d) Appointments of energy services companies (ESCO's)

e) Energy labelling of equipment.

f) Informative electricity bills showing the development of electricity consumption for the individual consumer.

g) Loans and subsidies to customers to be implemented.

8.7 General Conclusion

Through the whole of this project and with reference to other similar projects of different background and scope, the correct interaction process design methodology was implemented for better potential savings results output. This set of data made it possible to proceed with the study where indirect and direct results were analysed and achieved. Consequently the study of actual energy saving, viz: actual implementation of EE and LS activities on the TBP feeder-would need more time in order to see even better results in the future. The actual results of any DSM project take time to be realised.

Recommendations are that the opportunities be implemented according to the category scheduling of the results, showing throughout the study that standard information would be used and this would be inline with Eskom's standardisation process.

8.7.1 Conclusion: Methodology

The integrated approach methodology stages within the DSM and M&V, together with the pollution prevention and resource efficiency-energy audit protocol processes were followed as is clearly set out in Chapter 3 (refer to Figure 3.1 and Table 3.1). The energy audit model (Appendix B) and the pragmatic assessment approach were performed on the TBP's worksite facilities and the whole TBP feeder, and the DSM programme potential implementation is feasible. It will now be possible to implement these methodology stages to show the potential implementation of DSM on the TBP.

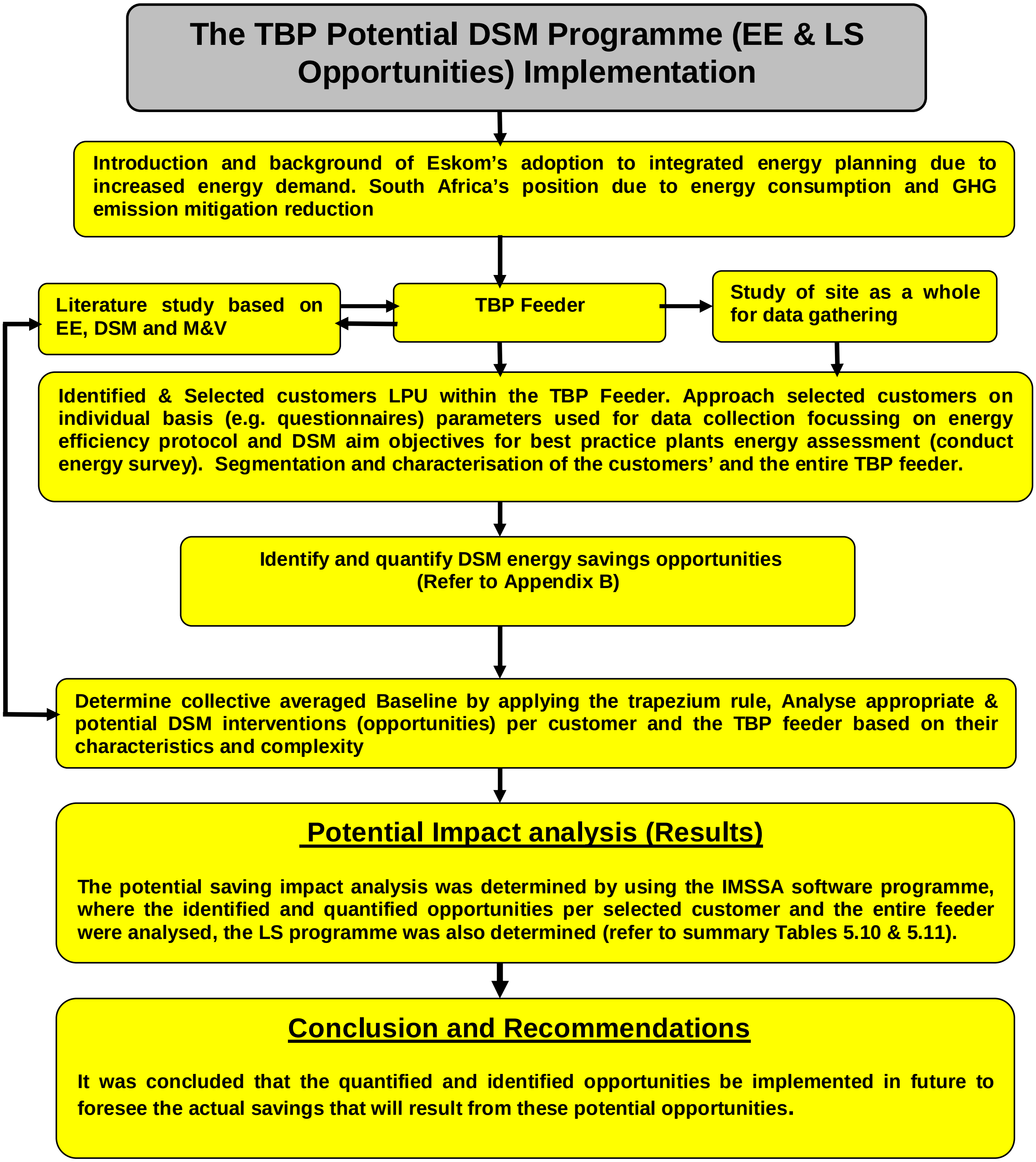
8.7.2 Conclusion: Case Studies

The case studies provided the potential EE and LS activities opportunities (DSM programme) according to their complexity and feasibility, and the fact that they can be measured and verified in future.

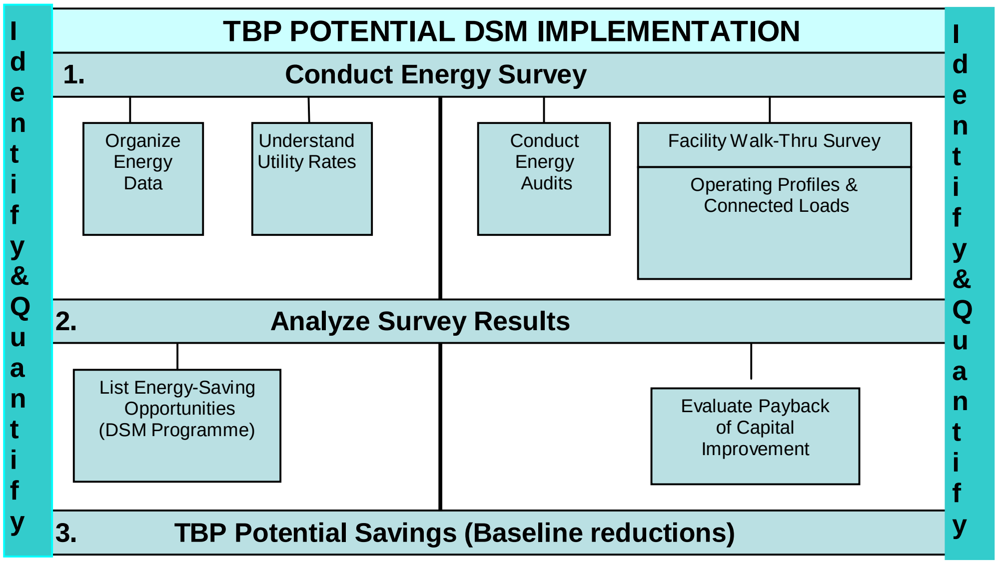
8.7.3 Conclusion: Baseline

The collective TBP baseline consumption was quantified and averaged from the reliable measured results using calibrated net-logger meters and accurate calculations using the trapezium rule. The potential implementation of the DSM programme, shows the potential baseline reductions, which result in potential savings which can be measured and verified in future.

APPENDIX A: BLOCK DIAGRAM OF STUDY DESIGN



APPENDIX B: POTENTIAL ENERGY-EFFICIENCY & DSM SAVINGS AUDIT MODEL



Tables diagnosed for data collection and the demonstration of potential EE, DSM & M&V programmes penetration levels:

APPENDIX C: MACHINE HISTORY AND MAINTENANCE REPORT TABLE

PLANT/CUSTOMER :	
MOTOR CLASS/ NUMBER :	
DATE OF FAILURE :	
FURTHER COMMENTS :	
DEFECT/S :	
DATE OF DEFECTS :	
PUMP AND MOTOR(MACHINE) COUPLER	

TYPE OF PUMP/ NUMBER :
DATE OF FAILURE :
FURTHER COMMENTS :
DEFECT/S :
DATE OF DEFECTS :

Reported by: …………………………..

Diagnosed by: …………………………..

Assisted by: **…………………………….**

Fault detected date:…………………….

Repair Completion Date:……………….

Justification: ……………………………..

APPENDIX D: MACHINES IMPROVEMENT AND SUGGESTION TABLE REPORT FOR EFFICIENCY ANALYSIS

PLANT/CUSTOMER :		
TYPE OF BUSINESS:		
EQUIPMENT TYPE:		
PROBLEM:		
REPAIR SAVINGS :		
ELECTRICAL MOTOR NUMBER/SERIAL NUMBER:		
	ACTUAL COST	**HISTORICAL COST**
PARTS/ MATERIAL:		
LABOUR		
TRANSPORT		
TOTAL		
REPAIR SAVINGS :		

PUMP AND MOTOR COUPLER

PLANT/CUSTOMER :		
TYPE OF BUSINESS:		
EQUIPMENT TYPE:		
PROBLEM:		
REPAIR SAVINGS :		
PUMP NUMBER/SERIAL NUMBER:		
	ACTUAL COST	**HISTORICAL COST**
PARTS/ MATERIAL:		
LABOUR		
TRANSPORT		
TOTAL		
REPAIR SAVINGS :		

Reported by: **…………………………………**

Diagnosed by:………………………………

Assisted by:………………….

Fault detected date:……………………….

Repair Completion Date:…………………

Justification: ………………………………

APPENDIX E: ISO STANDARDS 2372 &3945 FOR MACHINE VIBRATION SEVERITY

RANGES OF VIBRATION		**EXAMPLE OF VIBRATION SEVERITY FOR SEPARATE CLASSES OF MACHINES**			
RMS VELOCITY		**CLASS I**	**CLASS II**	**CLASS III**	**CLASS IV**
mm/s	**inches/sec**				
0.28	0.01				
0.45	0.02	A			
0.71	0.03		A		
1.12	0.04	B		A	
1.8	0.07		B		A
2.8	0.11	C		B	
4.5	0.18		C		B
7.1	0.28	D		C	
11.2	0.44		D		C
18	0.71			D	
28	1.10				D
45	1.77				

MACHINES CLASSES

CLASS I **-** Individual component, integrally connected with complete machine in its normal operating conditions.

CLASS II - Medium sized machines.

CLASS III - Large prime movers (motors) mounted on a heavy rigid foundation.

CLASS IV - Large prime mover (motors) mounted on a relatively soft light weight structure.

ACCEPTANCE OF CLASSES

A - Excellent

B **-** Satisfactory

C - Unsatisfactory

D **-** **Most** unsatisfactory

APPENDIX F: AVERAGE VIBRATION STANDARD TABLE FOR COUPLED ELECTRICAL MOTORS AND PUMPS (MACHINES)

MOTOR INFORMATION	PUMP INFORMATION

Motor Group/Class No :	kW Range	Speed rpm Range	Qty of stages	Horizontal or Vertical	AVERAGE SPEED(mm/s)
A (A1)	15	970	5	H	1.34
B (A2	15	2980	3	H	3.6
C (B)	45	1470	5	H	1.6
D (C)	55	980	1	H	1.83
E (C)	55	1480	5	H	1.4
F (D)	75	2990	2	H	4.7
G (E)	90	1476	2	H	2.2
H (F)	100	2990	2	H	7.8
I (G)	110	1479	3	H	2.55
J (H)	160	1485	6	H	2.43
K (I)	200	1483	6	H	2.4
L (J)	250	1483	3	H	1.45
M (K)	275	2990	3	H	4.4
N (L)	315	1490	13	H	2.1
O (M)	375	1488	3	H	1.76
P (N)	560	1480	4	V	2.3
Q (O)	650	484	2	V	3.5
R (P)	1900	987	6	V	1.6
(G	2400	985	4	H	1.34

APPENDIX G: EXECUTIVE SHEET TABLE REPORT FOR SELECTED CUSTOMERS' LOAD-SHIFTING

<table>
<tr><td>DATE & TIME</td><td colspan="4">From: To:</td></tr>
<tr><td>CUSTOMERS NAME:</td><td colspan="4"></td></tr>
<tr><td>TRF NUMBER:</td><td colspan="4"></td></tr>
<tr><td>TRF SIZE:</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="4">MACHINE DESCRIPTION</td></tr>
<tr><td>MOTOR /PUMP ONE</td><td colspan="4"></td></tr>
<tr><td>MOTOR /PUMP TWO</td><td colspan="4"></td></tr>
<tr><td>MOTOR /PUMP THREE</td><td colspan="4"></td></tr>
<tr><td>MOTOR /PUMP FOUR</td><td colspan="4"></td></tr>
<tr><td>MOTOR /PUMP FIVE</td><td colspan="4"></td></tr>
<tr><td colspan="5">USAGE - MOTOR /PUMP ONE</td></tr>
<tr><td>Time On</td><td>Time off</td><td>Duration</td><td colspan="2">Usage Description</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">POTENTIAL ENERGY USAGE REDUCTION ACCORDING TO TARIFF(DEFINED TIME PERIODS)- MOTOR /PUMP ONE</td></tr>
<tr><td>Time On</td><td>Time off</td><td>Duration</td><td colspan="2">Usage Description</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">USAGE - MOTOR /PUMP TWO</td></tr>
<tr><td>Time On</td><td>Time off</td><td>Duration</td><td colspan="2">Usage Description</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">POTENTIAL ENERGY USAGE REDUCTION ACCORDING TO TARIFF(DEFINED TIME PERIODS) - MOTOR /PUMP TWO</td></tr>
<tr><td>Time On</td><td>Time off</td><td>Duration</td><td colspan="2">Usage Description</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

Reported by……………………………………..

Diagnosed by:…………………………………….

Assisted by: **……………………………………..**

Execution date:**………………………………….**

Justification:…………………………………….

APPENDIX H: INVITATION FOR LOAD PROFILE MEASUREMENTS AT THEUNISSEN

TSI

Att.: Clement Motlohi

H Pienaar
Tel. (011) 629-5208
Fax (011) 629-5264

Load Profile Measurements at Theunissen

INVITATION TO QUOTE: LOAD PROFILE MEASUREMENTS AT THEUNISSEN

Thank you very much for giving us the opportunity to quote for the above-mentioned work.

As per your request the scope of work was defined as follows:

Scope of work:

1. Install 5 Netlog 2 loggers in the Theunissen area.
2. Measure kW, kWh kVArh, currents, voltages, power factor and provide load profiles for each measurement point.
3. Measurements to be done over a 7-day period per measurement point.

Assumptions:

1. That there is adequate space to install the loggers.
2. That there is connection points available to connect to (voltages).
3. Have access to all the panels and metering points.
4. All additional work will be done at R265-00/h and R1-65/km.

The service required from TSI can be structured as follows:

Theunissen			
Metering			
	Installation, removal and data manipulation		**R9 010**
	Equipment hire		**R4 900**
	Travelling / Transport		**R1 820**
		TOTAL	**R15 730**

For the scope of work defined above the price is R 15 730.00. (This excludes 14% VAT)
This quote is valid for a period of 30 days from the date of submission.

Yours faithfully

H PIENAAR (***ENERGY-EFFICIENCY SERVICES -EES***)

APPENDIX I: QUOTATION FOR JOB AGREEMENT

Page 1
(Customer copy)

TSI
JOB AGREEMENT

JOB TITLE: Theunissen profile Measurements

TSI DIVISION: EES

TSI TECHNICAL AREA

TSI COST CENTRE	TSI JOB NUMBER	TSI PROJECT CODE

CUSTOMER/COMPANY	CONTACT PERSON Clement Motlohi	Telephone: 051 404 2456 FAX 051 404 2263
Start Date: 21-05-2004......... End Date: 30-05-2004...........	PROJECT LEADER H Pienaar	Telephone: 011 629 5208 FAX 011 629 5264

Scope of work: Install 5 Netlog2 loggers to measure current, power, active power, reactive power and power factor. Extra trips will be charged at R1-65/km and all additional work will be charged at R265-00/h.

Output: Data and graphs in excel format.
....
....

OTHER TERMS & CONDITIONS

1. Does the customer require a ROI analysis?
   No

2. The Contact total exclude VAT

CUSTOMER Clement Motlohi
ADDRESS ……………………………
……………………………
Telephone: 051 404 2456
Fax:

ACCOUNTANT : ....
OCC NO : ....
DAC NO : ....
ORDER NO : ....
PROJECT CODE : ....

Manpower Cost : R 9 010
Material Cost : R 4 900
T & S : ....
Transport : .R1 820
Consultants : ....
Contract Labour : ....
Other : ....
CONTRACT TOTAL: R15 730

Progress payments:

Milestone	Amount
May 2004……	R16 220

TSI REPRESENTATIVE:

SIGNATURE : _______________________

Name ___________________________

(Please print)

Date: ____________________________

CUSTOMER REPRESENTATIVE:

SIGNATURE: ________________________

Name: ___________________________

(Please print)

Date: _____________________________

Page 2 (TSI copy)	**TSI JOB AGREEMENT**	TSI

JOB TITLE: Theunissen profile Measurements

TSI DIVISION: EES	TSI SECTION

TSI COST CENTRE	TSI JOB NUMBER	TSI PROJECT CODE

CUSTOMER/COMPANY	CONTACT PERSON Clement Motlohi	Telephone: 051 404 2456 FAX 051 404 2263
Start Date: 21-05-2004......... End Date: ...30-05-2004...........	PROJECT LEADER H Pioneer	Telephone: 011 629 5208 FAX 011 629 5264

Scope of work: Install 5 Netlog2 loggers to measure current, power, active power, reactive power and power factor. Extra trips will be charged at R1-65/km and all additional work will be charged at R265-00/h.

Output: Data and graphs in excel format.

....

....

OTHER TERMS AND CONDITIONS 1. Attach a pre-project cost benefit analysis on a separate sheet. 2. Does the customer require a ROI analysis **NO** **3. The Contact total exclude VAT**	CUSTOMER Clement Motlohi ADDRESS ……………………………. ……………………………. Telephone: 051 404 2456 Fax: ACCOUNTANT : .... OCC NO : .... DAC NO : .... ORDER NO : .... PROJECT CODE : ....

Manpower Cost: R9 010
Material Cost : . ..R4 900
T & S : ....
Transport : .R1 820
Consultants : ....
Contract Labour : ....
Other : ....
CONTRACT TOTAL: R15 730

GRADE	HOURS	RATE/HOUR	COST
EE/S3			
MU/PU			
ML/PL			
P0			
CU	35	265	9 010
CL			
BU			
		TOTAL	9010

TSI REPRESENTATIVE: CUSTOMER REPRESENTATIVE:

SIGNATURE : ___________

_____________ SIGNATURE:: KC MOTLOHI

Name ____________________________ (Please print)

Date: _____________________________

Name: KC MOTLOHI (Please print)

Date: ______________________________

All jobs must include a detailed job breakdown including Gantt chart and review dates. For contracts with customers external to Eskom, the conditions as in Model Form 1 of the Article and Conditions of Agreement for use by a Client and Consulting Engineer in respect of Engineering Works (South African Association of Consulting Engineers) shall apply as applicable.