CHAPTER 1: INTRODUCTION

1 Introduction

1.1 Background

1.1.1 The South African Dilemma

Thomas Edison was the person to discover the electricity generating power distribution system in the United States of America in the year 1882 [1]. The primary role for this was to provide electrical power for lighting in the Manhattan area [2].

Electricity has since been the most preferred form of energy and is used all over the world in households, production processes, hospitals, offices etc. The reason is that electrical energy can be supplied at a reasonable cost and high efficiency [2].

South Africa is the main electricity producer on the African continent and provides more than half of the continent's electricity [3]. Historically, South Africa has had the highest electricity reserve margins, with a margin of 25% in 2002 [4]. Figure 1 illustrates that this reserve decreased drastically subsequent to 2002, which can be attributed to the robust economic growth in South Africa since 1994 [3].

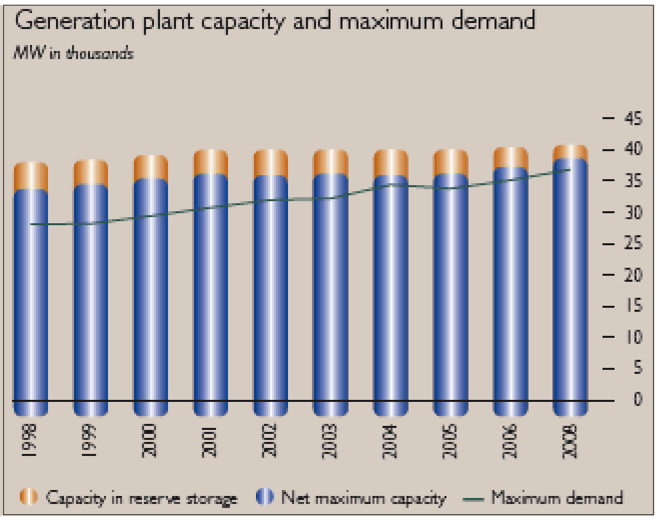

Figure 1: South Africa's historic electricity reserves [5]

It is estimated that the electricity consumption in South Africa is increasing by approximately 1 000 MW per year [6]. Figure 2 illustrates that the country's maximum demand capacity was reached in 2008. According to the National Energy Regulator of South Africa (NERSA), this resulted in an annual economic loss of R 50bn as production in most companies was dragged to a halt [7].

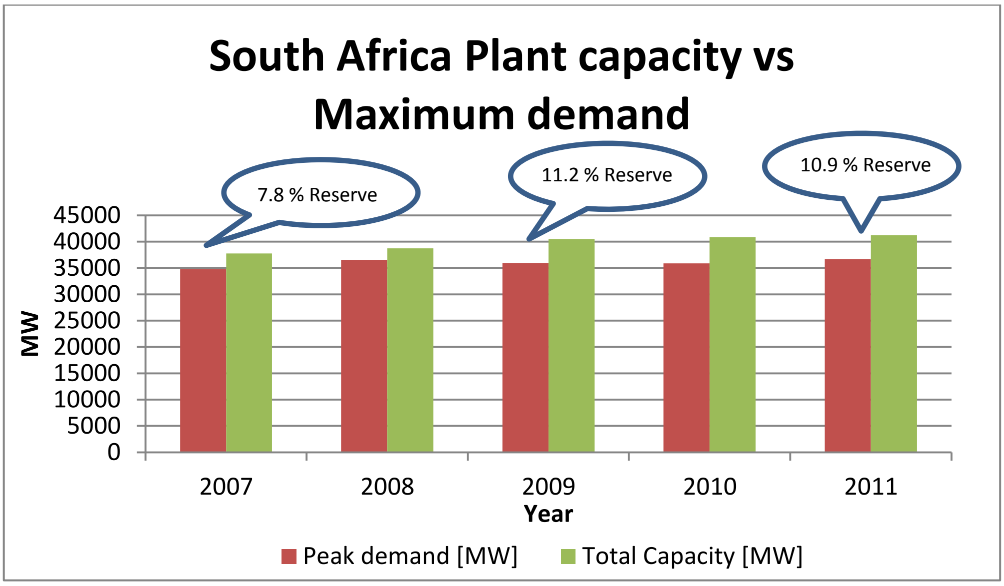

Figure 2: Eskom Maximum Plant capacity vs. Maximum demand [8]

An additional matter for concern is the peak-time demand between 18H00 and 20H00 during winter periods. Figure 3 indicates the electricity demand patterns for the year 2008 and has been included in this dissertation to illustrate the power consumption of consumers during a 24-hour period. The figure distinctly illustrates that most of the electricity is consumed during the period between 18H00 and 20H00.

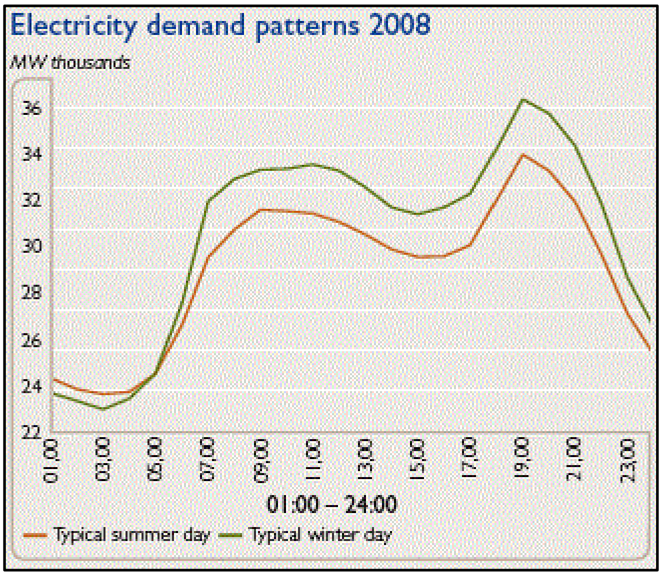

Figure 3: Eskom average national hourly electricity demand [51]

As a result of the negative consequences load shedding will encompass on both the economy and the community, Eskom has embarked on a short term solution which could significantly ease the present demand problem in South Africa. This is also known as Eskom's Demand Side Management (DSM) programme [9].

1.2 Eskom and Demand Side Management

Eskom was established in 1923 as the Electrical Supply Commission and is the main provider of electrical energy in South Africa [10]. With a maximum generation capacity of 41 194 MW in the year 2012, Eskom generates approximately 95% of the electricity used in South Africa and roughly 45% of the electrical energy used in Africa [11].

The electrical energy usage of the country is rapidly increasing. This could be attributed to the present economic growth and the pressure exerted on the mining industry to produce more in a lesser amount of time. Without DSM intervention, in order to meet the demand, a requirement for additional generation plants would have been necessitated in 2007 [12]. However, by introducing different tariff billing structures for large energy consumers, Eskom has succeeded in encouraging consumers to reduce the demand during peak periods. These tariff structures act as incentive for companies to save energy during peak periods.

1.2.1 Eskom tariff structures

The Eskom tariff structures are intended to differentiate between the seasons of the year as well as the different times of day. Furthermore, these structures vary by location as well as type of industry. For example, applying the Mega flex tariff, the cost of one unit consumed during winter peak-hours will be eight times greater than that used during summer off-peak periods [13].

Eskom has defined the winter months, through June to August, as the high demand season. The summer months, September until May, have been designated as Low demand season for applying the different tariff structures.

1. **Nightsave Rural**

   This tariff is for rural customers with a high load factor, a Notified Maximum Demand (NMD) from 25 kVA at a supply voltage of less than 22 kV [13]. Nightsave has the following charges:

   - Seasonally differentiated active energy charges;
   - seasonally and Time of Use (TOU) differentiated energy demand charge;
   - two TOU periods; peak- and off-peak periods;
   - a bundled network access charge;
     - an environmental levy charge;
     - a service charge;
     - an administration charge.

   Figure 4 shows the Nightsave TOU peak- and off-peak periods.

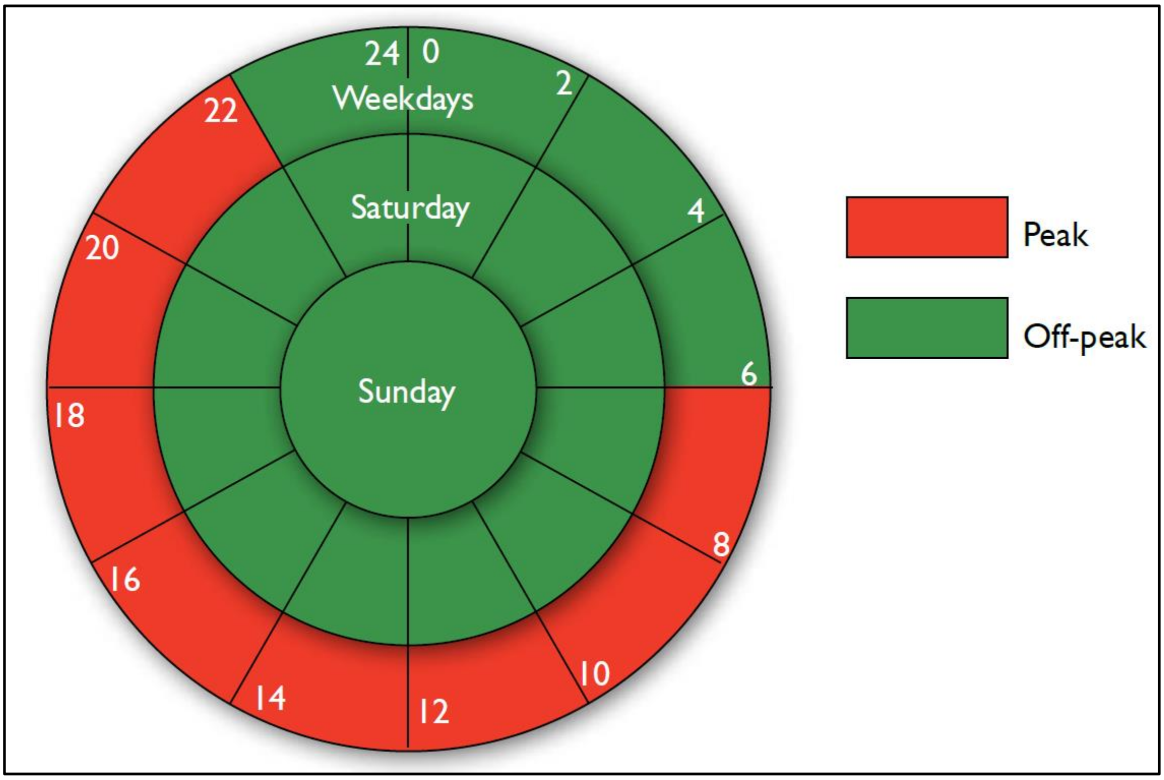

Figure 4: Eskom Nightsave Rural TOU periods [14]

Billing rates for all the different tariff structures, as supplied by Eskom, are illustrated by Appendix A.

2. Ruraflex

This TOU electricity tariff is for rural customers with dual- and three-phase supplies with an NMD in excess of 25 kVA and a supply voltage greater than 22 kV [13]. Ruraflex has the following charges:

- TOU and seasonally distinguished active energy charges;
- TOU periods are divided into peak-, standard- and off-peak periods;
- an environmental levy charge;
- a service charge;
- an administration charge;
- a reactive energy charge.

Figure 5 illustrates the peak-, standard- and off-peak periods of the day for both the Ruraflex and Megaflex tariff structures.

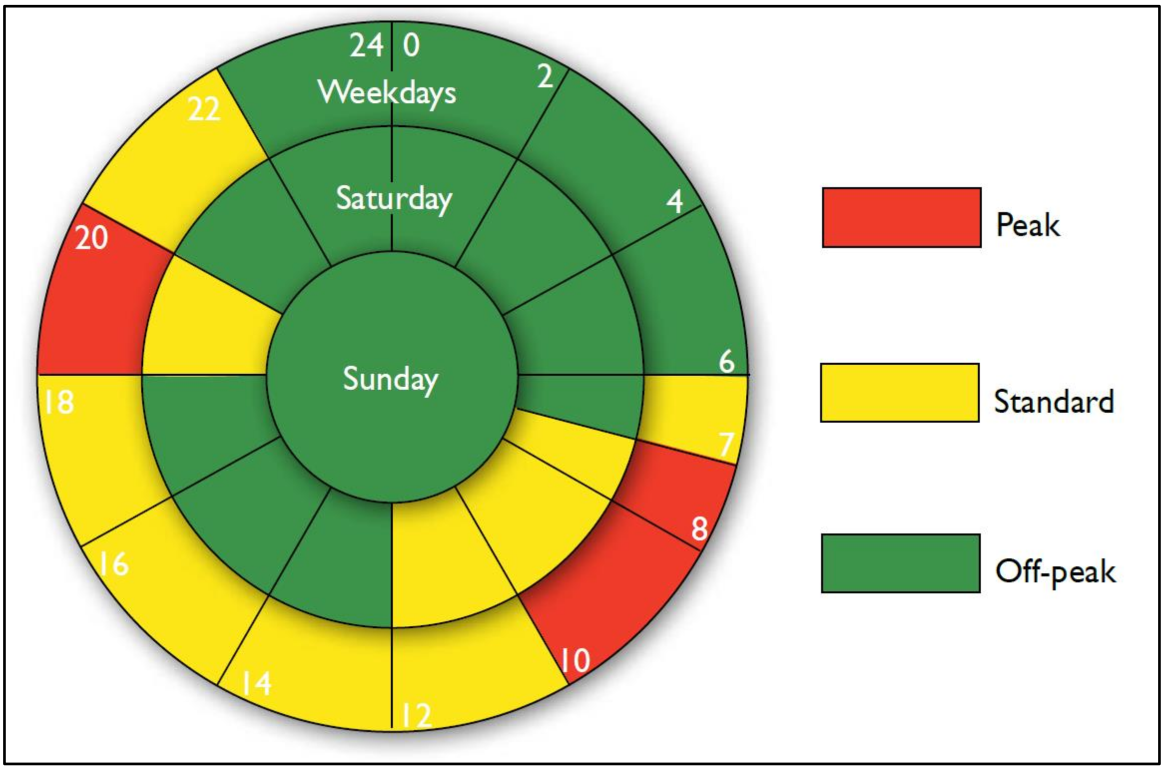

Figure 5: Rura- and Megaflex TOU tariff structures [14].

3. Megaflex

Megaflex is a TOU electricity tariff for urban customers with a NMD greater than 1 MVA and who are able to shift load [13]. Industries on the Megaflex tariff structure have the following charges:

- TOU and seasonally differentiated active energy charge;
- a transmission network charge;
- a distribution network access charge;
- an electrification and rural subsidy;
- an environmental levy charge;
- a service charge;
- an administration charge;
- a reactive energy charge.

These tariff structures are mentioned briefly due to their relevancy, the projects rural setting and the implications of switching to a different tariff structure. There are however other tariff structures but these are of no use in the scope of this study. The complete Eskom tariff structure is shown in Appendix A.

1.2.2 Demand Side Management (DSM)

With the launch of the Eskom DSM program, customers who wish to reduce electricity or shift load out of the peak periods, qualify for having either part, or the total cost of such a project financed by Eskom. Three types of DSM projects namely Peak clipping, Energy Efficiency and Load shifting are generally utilised.

Peak clipping is achieved by simply reducing energy consumption during the Eskom peak demand period without shifting this energy demand to an alternate time [15]. Figure 6 shows that the maximum energy consumption is reduced only during the peak demand time frame.

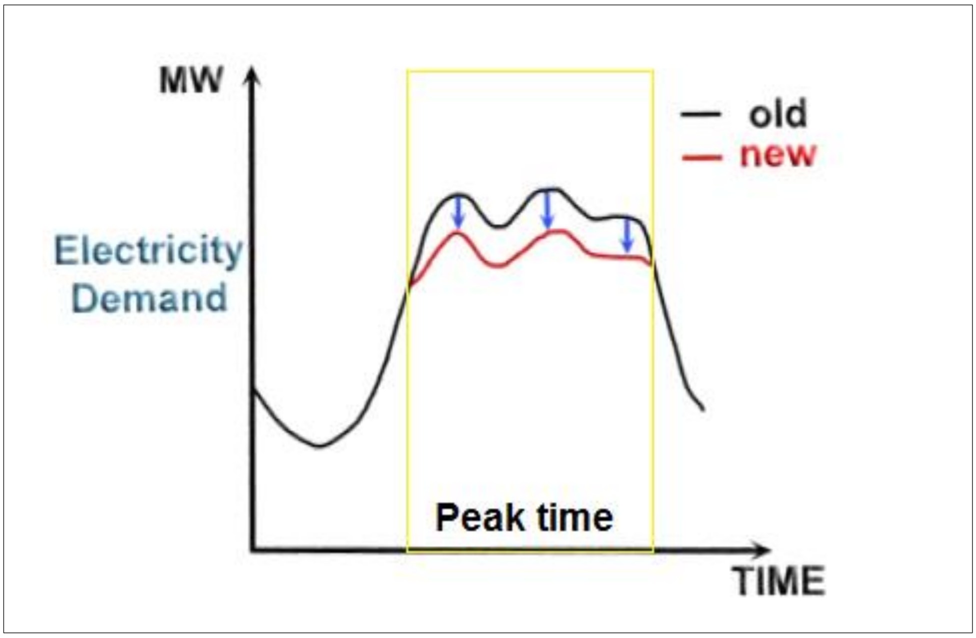

Figure 6: Peak clipping [16]

Another common DSM strategy followed by consumers is the Energy Efficiency (EE), strategy shown in Figure 7. When implementing EE, the overall power profile is reduced and less energy will be consumed daily.

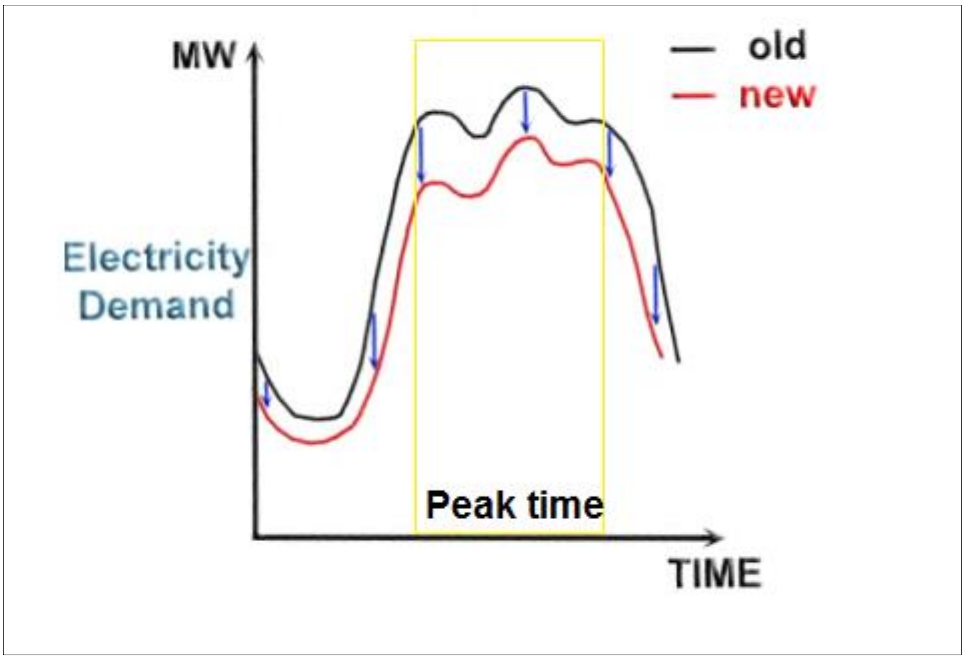

Figure 7: Energy efficiency [16]

The DSM strategy applicable to this study is load shifting (LS). Figure 8 illustrates the power profile as a result of LS where the load is shifted out of the Eskom peak demand periods into the Eskom off-peak periods.

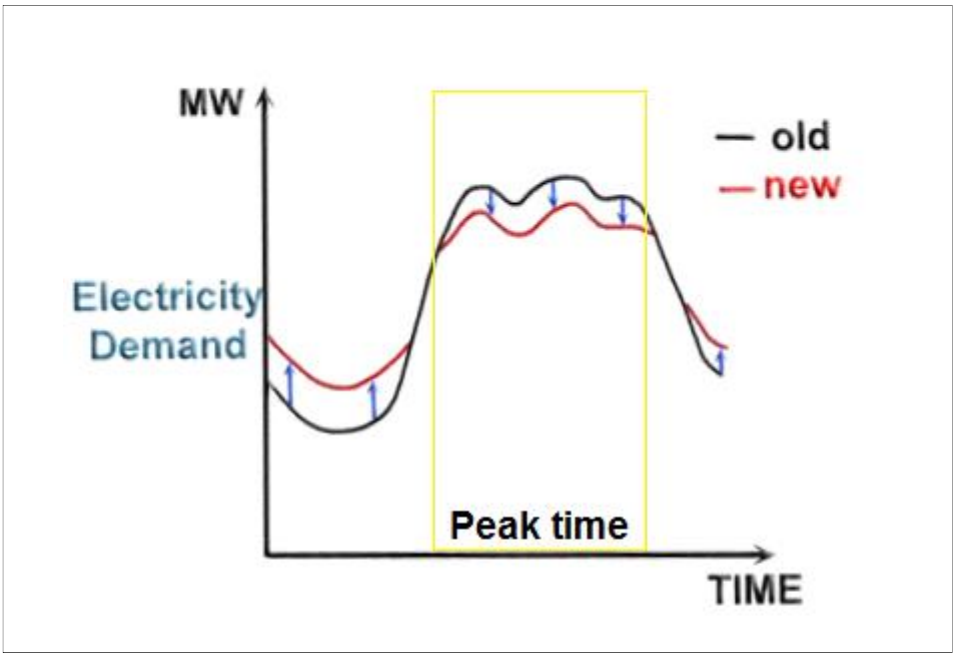

Figure 8: Load shift [16]

Load shifting reduces the demand during peak periods and will ease the strain on the Eskom reserve margins. Eskom TOU tariff structures can also result in substantial financial savings for a client if load shifting strategies can be successfully applied [17]. Both Energy Service Companies, (ESCo), and consumers find this a very attractive option since Eskom subsidises all the capital expenditure for a load shifting project, whereas it only subsidises 50% of the cost of a viable energy efficiency project [18].

The most notable difference between load shifting and the other methods is that load shifting results in the same daily energy usage, while the other interventions reduce the daily energy consumption.

1.2.3 Energy Service Companies

An ESCo is a profit-making business, providing a wide range of energy solutions. These include strategies and applications of energy management interventions to large energy consumers [19]. An ESCo uses its own capital to initiate technical interventions or energy efficiency projects for the client. After successful DSM implementation the ESCo receives an income proportional to the energy savings achieved by the consumer [20].

The ESCo firstly identifies the necessity, potential or opportunity where savings could be realised [21]. When this has been completed the ESCo conducts an energy audit to determine the type, quantity and rating of all the related energy consuming systems. The possible savings the DSM intervention could realise are calculated using this information. Figure 9 shows the process cycle of an ESCo.

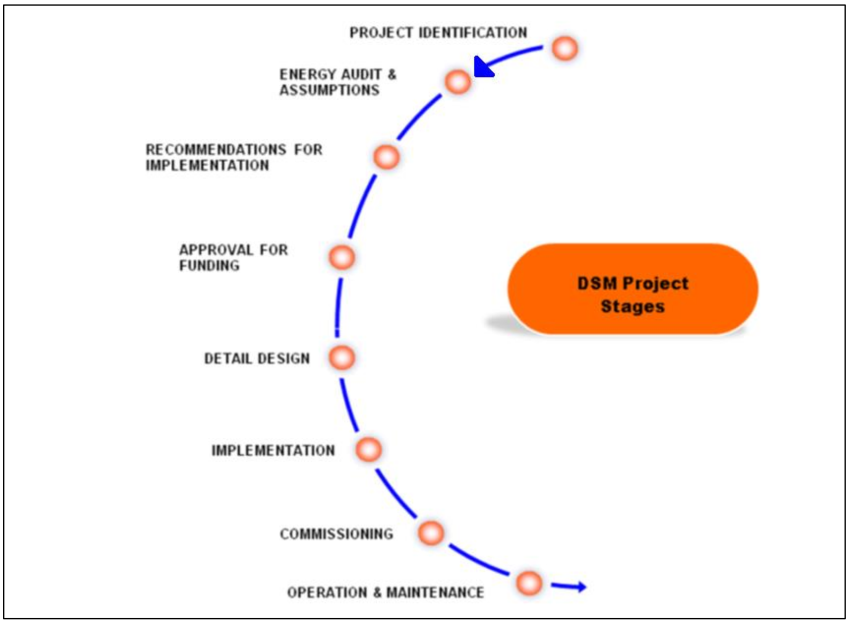

Figure 9: DSM project stages [21]

If positive results and potential for a project are identified, the ESCo will submit a recommendation for a DSM implementation to the client [22]. If the client accepts the recommendation, the ESCo will submit a proposal to Eskom DSM, who will then evaluate the practicality and feasibility of the submission. Eskom DSM will provide funding for the ESCo to implement the project, if it is believed to be cost effective and can realistically deliver acceptable results within the budget constraints[21].

After Eskom DSM has granted approval, the ESCo will compile the detail design and implement the DSM project. As soon as the implementation phase is completed the commissioning phase will commence. During this phase all the installed equipment is commissioned to verify that the equipment and systems are performing to the specified requirements. The client will be advised as to when the commissioning of the equipment has been successfully concluded.

Only when all these stages are completed, will the operation and maintenance stage commence. The system must be continuously monitored and maintained in order to ensure that the DSM activities deliver a sustainable level of performance as verified during commissioning. The maintenance can either be the responsibility of the ESCo or the client depending on the contractual agreement between the two parties [21].

Figure 10 shows the basic project stages of the energy efficiency and DSM projects.

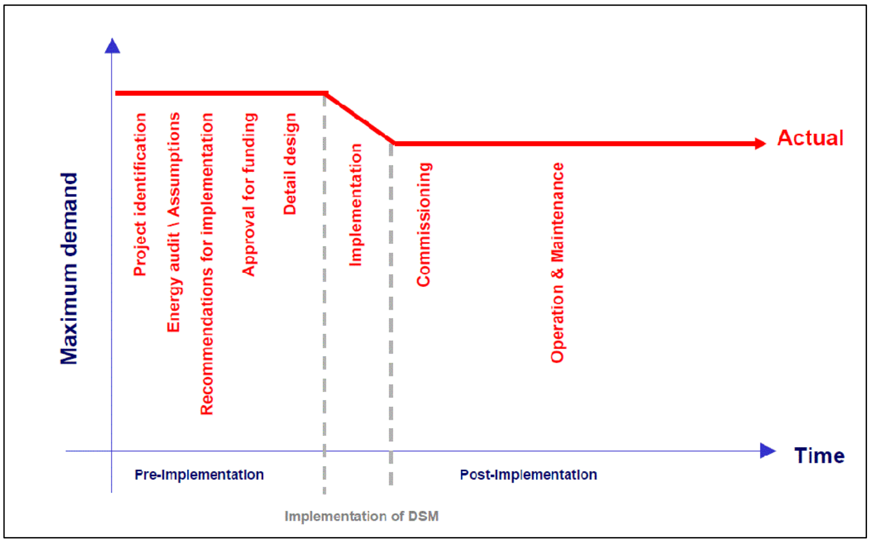

Figure 10: Basic DSM project stages transposed on project impacts [22]

1.2.4 Monitoring and verification

After the project has been implemented and commissioned, the savings claimed by an ESCo has to be verified. Eskom appoints a Measurement and Verification (M&V) team to each project to conduct performance audits and reports [23].

A proposed average power saving expected from implementing all the DSM projects versus the actual results recorded by M&V teams during Eskom peak hours are seen in Figure 11. This figure shows that the M&V savings exceeded the Eskom target from 2008 and that on average, more than 2 500 MW has been saved by DSM implementations.

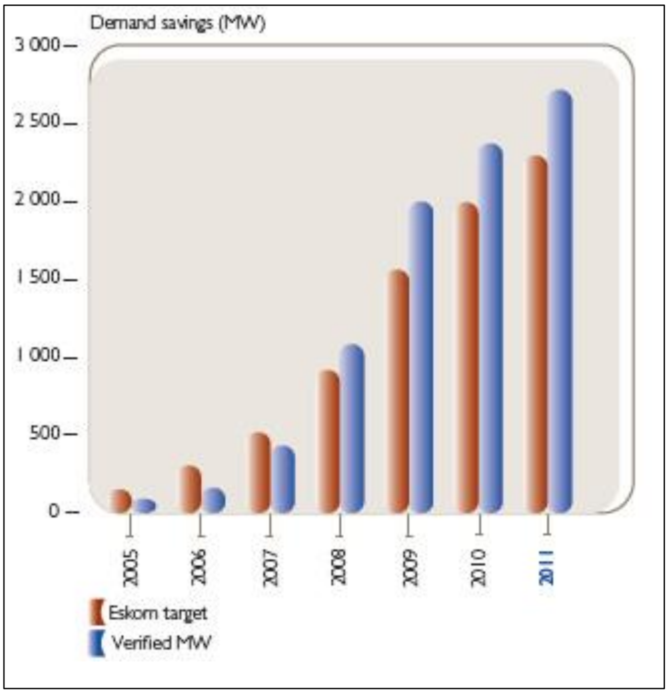

Figure 11: Eskom DSM MW target vs. actual saving [24]

1.3 Load shift on water pumping systems

Electricity energy usage in South Africa can be categorised into a number of different consumers. In Figure 12, the different electricity users and the percentage of energy each consume are illustrated.

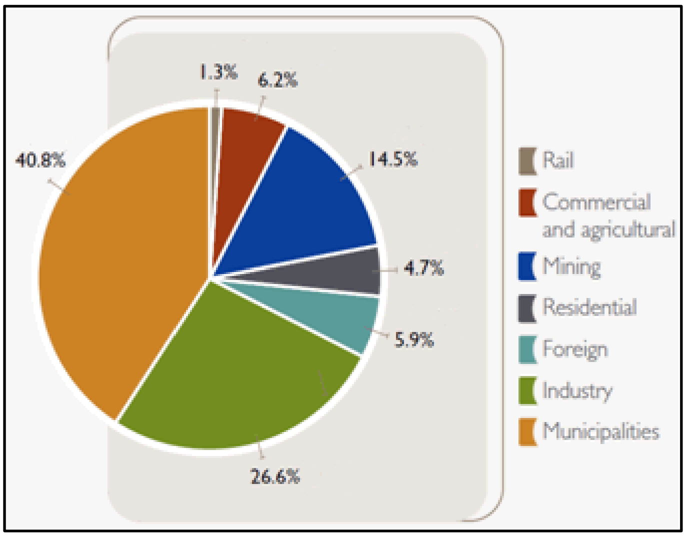

Figure 12: Eskom energy consumers 2011[24]

Figure 12 indicates that the three largest consumers of electricity in South Africa are: mining, the industrial sector and municipalities.

1.3.1 Mines

Combined, the industrial and mining sectors consume 41.1% of the total energy supply compared to the 40.8% of the municipalities. It is very likely that a South African mine could consume the same daily amount of energy as a small town. The number of mines in South Africa are much fewer than the number of towns and cities. Therefore, significant energy savings could be achieved from DSM projects implemented at the mines, compared to that of the residential sector [25].

DSM projects have already been implemented at various mines with great success. These projects include clear water pumping projects, compressed air projects and cooling systems projects [26] [27].

1.3.2 Municipalities

Due to the large electricity consumption by municipalities, the expectation was created that DSM implementations should be implemented in this sector. However, the large number of individual consumers in this sector makes it extremely difficult to monitor and substantially decrease the amount of energy usage during peak hours. DSM initiatives such as the 49-million initiative have been launched to motivate South Africans to save electricity [28].

This sector, however, does include some large consumers such as water supply schemes. Water supply schemes are ideal DSM candidates because they use large energy intensive transfer pumps and large storage dams which are an important component of these systems [29].

1.3.3 Need for more DSM projects

The Eskom DSM program has been operating for a number of years and has played an important role in improving the electrical supply reserve margin. As a result Eskom has intensified their efforts to increase the number of DSM initiatives and has set out to achieve an average power saving of 1.37 GW by 2015 [30].

The News24 website stated on 20th of February 2009 that South Africa's water demand is reaching a point where it will surpass the supply [31]. To solve this problem, the Department of Water Affairs (DWA) has introduced various water distribution schemes. These schemes, in particular the Usutu-Vaal water scheme, have the primary goal of distributing water from areas with excess water to areas with shortages [32].

Due to these factors the need for more DSM projects are growing at a substantial rate. A DSM study has been completed on the Vaal Gamagara water scheme which yielded positive results [33]. This study will focus on the possibility of reducing electricity usage in the Usutu-Vaal water scheme.

Pumps with large installed capacities are required to pump water from one area to another at the Usutu-Vaal water scheme. Reservoirs and dams of this scheme are situated at elevated levels above the pump stations. High flow rates are required to ensure that the dams remain at correct capacities. This makes the Usutu-Vaal water scheme a prime candidate for a DSM initiative.

1.4 Objectives

The objective of this dissertation is to determine the possibility of a DSM intervention on a national water pumping scheme and to implement an appropriate control strategy. In particular, the following will form part of this research:

- Evaluate the complete pumping system of the client and the amount of water supplied to other consumers in order to determine the feasibility of a load shifting project.
- Determine the infrastructure improvements and new equipment necessary to realise the project savings.
- Design and implement a DSM project on a national water pumping scheme in order to control and automate existing equipment and upgraded infrastructure.

- Determine, simulate and implement optimised pumping control schedules and parameters to increase savings and adhere to the water pumping scheme delivery constraints.
- Optimise the control system in order to achieve maximum cost savings by shifting load out of peak demand periods to off-peak periods.

The following benefits could be achieved by implementing an effective control strategy:

- Reduction in the electricity supply during peak demand times, resulting in increased electricity supply reserve margins.
- Reducing the electrical energy costs of the national water scheme.
- Ensuring enough water to all consumers by introducing effective pumping strategies.
- Financial benefits for the client.

1.5 Overview of this document

DSM initiatives have significantly reduced the demand on the national grid [34]. However, a need for more projects exists, not only to meet the national demand, but also to comply with the 2015 target set by Eskom. This will reduce the risk of further compulsory load shedding schedules in South Africa.

Water distribution schemes have been identified as prime candidates for a DSM initiative due to the large amount of electricity used to transfer water from one point to another. A study on introducing an intervention method that may be applied on a national water pumping system will be the main focus of this dissertation.

In Chapter two the potential for load shifting in water pumping systems will be investigated. The reader will be introduced to the Usutu-Vaal water distributing scheme which supplies water to different users such as SASOL II & III and the Matla Power station. Firstly, an initial investigation will be done to determine if there is potential for a DSM project. Subsequently a detailed project investigation will be done to determine the feasibility of the project.

The third chapter will focus on the implementation of a Real time Energy Management System (REMS) on a national water pumping system. The system constraints and control parameters associated with the Usutu-Vaal water scheme will be investigated. A simulation model will then be developed and optimised for implementation on the Usutu-Vaal water scheme. Implementation and problems encountered with the system will be discussed.

Results of the DSM intervention will be discussed in chapter four. This will include performance and financial results of the system. A comparison between actual results and simulated results will also be included. The potential for applications to other water schemes will be discussed.

Chapter five will be the conclusion to the dissertation. Benefits resulting from a project of this nature will be provided, as well as recommendations for future investigations and research.