An alternative approach for sustainable industrial DSM in South Africa

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It all starts here ™

Abstract

Title: An alternative approach for sustainable industrial DSM in South Africa

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Eskom generates 95% of the electricity consumed in South Africa. As a result of insufficient generation capacity, Eskom is struggling to meet the growing electricity demand. Load shedding had to be implemented during 2014 and 2015, which had damaging effects on the economy of South Africa. In addition to the electricity supply shortages being experienced, it recently also became public that Eskom has financial constraints.

Several generation capacity expansion projects have been implemented as a long-term solution to the electricity supply shortage. Due to the immediate nature of this problem, Eskom also had to implement short- to medium-term solutions in an attempt to avoid load shedding. The Department of Energy estimates that load shedding costs the economy of South Africa approximately R75 000 per MWh of unserved electricity.

Eskom uses gas turbine power stations to generate power as a short-term solution to avoid load shedding. These power stations are expensive to operate and are only used in times when demand threatens to exceed the available supply capacity. It was found that the net operating cost of using gas turbine power stations is approximately R1 941 per MWh. During 2014, Eskom spent R10 billion on diesel to operate the gas turbine power stations while they only had an approved budget of R3 billion.

The Demand Side Management (DSM) programme was another short- to medium-term solution implemented by Eskom. The operating cost of the DSM programme can be calculated by considering the funds spent, the savings achieved and the sustainability of the savings. With the existing performance of the DSM programme, this study found that the DSM programme is a more feasible approach than using gas turbine power stations.

Due to the immediate impact of using gas turbine power stations, their use is still required when demand threatens to exceed the available supply capacity. However, by implementing more DSM projects and improving the impact of the DSM programme, the required use of gas turbine power stations and load shedding can be reduced. This will result in cost savings for Eskom and it will also have a positive impact on the economy.

Although the DSM programme is a more feasible approach than load shedding and using gas turbine power stations, this study revealed that it is not performing to its full potential. A case study consisting of 37 industrial DSM projects revealed that 41% of industrial DSM projects did not achieve their initial project targets during the performance assessment period. It was also found that the savings of industrial DSM projects deteriorated an average of 17% per annum.

Previous studies focused on separate aspects of industrial DSM projects such as the measurement and verification (M&V) and maintenance of projects. Since it has been found that industrial DSM projects do not perform optimally, the need for an alternative industrial DSM Energy Services Company (ESCO) model was identified. By improving the performance of industrial DSM projects using an alternative approach, the impact of the DSM programme can be improved.

A novel, alternative approach to the industrial DSM ESCO model was developed. The alternative approach specifically focused on resolving challenges during different project phases to improve the overall performance of industrial DSM projects. The project phases included were the investigation, procurement, implementation, M&V and project maintenance phases. It was found that by implementing the alternative approach, the performance of industrial DSM projects could be improved.

By improving the initial impact and the sustainable savings with 6% and 9% respectively, the expected required use of gas turbine power stations from 2016 to 2018 can be reduced by 381 GWh. This will result in a net cost savings of R740 million for Eskom. The expected required load shedding can be reduced by 10% from 2016 to 2018, which can have an estimated positive impact of R51 billion on the economy of South Africa.

Keywords: Demand-side management (DSM), load shedding, gas turbine power station, ESCO.

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Nomenclature

List of units		
Symbol	**Description**	**Unit of measure**
h	Measure of time	Hour
s	Measure of time	Second
k	Denotes 1×10^3	Kilo
M	Denotes 1×10^6	Mega
G	Denotes 1×10^9	Giga
ℓ	Measure of volume	Litre
m	Measure of distance	Metre
mm	Measure of distance ($1\ m \times 10^{-3}$)	Millimetre
W	Measure of power	Watt
A	Measure of electric current	Ampere
%	A fraction or ratio	Percentage
R	Measure of currency (South Africa)	Rand
Wh	Unit of energy	Watt-hour
J	Unit of energy	Joule

List of symbols		
Symbol	**Description**	**Unit of measure**
P_{in}	Input power required	MW
P_{out}	Power output	MW
ƞ	Gas turbine efficiency	-
E_{in}	Energy input required	MWh
t	Time	s
R^2	Coefficient of determination	-

Abbreviations and acronyms

Symbol	Description
CCGT	Combined Cycle Gas Turbine
CEM	Contract Energy Management
CIC	Capital Investment Committee
DSM	Demand-side Management
EAF	Energy Availability Factor
EEDSM	Energy Efficiency Demand-Side Management
ESCO	Energy Services Company
ESKOM	Electricity Supply Commission
FBE	Free Basic Policy
IPMVP	International Performance Measurement and Verification Protocol
IRP	Integrated Resource Plan
M&V	Measurement and Verification
MAD	Measurement Acceptance Date
Nersa	National Energy Regulator of South Africa
OCGT	Open Cycle Gas Turbine
PA	Performance Assessment
PEC	Project Evaluation Committee
PUC	Public Utility Commission
SD&L	Skills Development and Localisation
TOU	Time of Use
UK	United Kingdom
Unisa	University of South Africa
USA	United States of America
VSD	Variable Speed Drive

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Chapter 1: Introduction and background

[1]

This chapter will focus on the identification and formulation of an original research problem. The need for an original solution will be formulated and the novel contributions of this study will be explained.

[1] (*Figures and other information that do not contribute to the academic value of this dissertation will not be referenced in the bibliography. Footnotes will be used instead.)*

EMG Consultants, "Energy Efficiency Training programme summary," (2013). [Online]. Available: http://www.emg-csr.com/blog/energy-efficiency-awareness-training/. [Accessed: 02 February 2015]

1.1 South African electricity constraint

Eskom is the leading utility company in South Africa, producing 95% of the country's electricity. Eskom was established in 1923 by the government of that time and was known as the Electricity Supply Commission (ESCOM). The Afrikaans name was "Elektrisiteits Voorsienings Kommissie" (EVKOM). In 1986, the two acronyms were combined to form the name Eskom [1].

Eskom, previously a non-profitable statutory body, was converted into a public company in 2002 and is now known as Eskom Holdings Limited. The South African government is the sole shareholder of Eskom Holdings Limited, but a board of directors was appointed in 2002 to manage the company. Although the company can make a profit from generating and selling electricity, the profit should be reinvested in the company to ensure a sustainable electricity generation supply [1].

After the South African political restructuring in 1994, Eskom had a reserve electricity generation margin[2] of 31%. Due to the ample spare capacity available at that time, government decided that existing plans to expand the electricity generation capacity had to be suspended. Instead, an effort to supply electricity to the undeveloped rural areas commenced. This effort was called the Rapid Electrification Programme and caused the electricity demand of the country to rise significantly [2].

In 2001, the Free Basic Policy was implemented by Eskom, which stated that the first 50 kWh consumed by a client would be subsidised. This allowed poor households consuming less than 50 kWh per month to have access to electricity free of charge. It is estimated that the number of these households has increased with 85% since 1995 [1]. This caused a large amount of electricity being consumed without clients having to pay for it [2].

As a result of the lack of investment in building new power stations during the late 1990s and the growing electricity demand, the reserve margin shrank to 7% in 2004. Planned and unforeseen maintenance on power stations resulted in the total installed capacity not always being available. Because of demand exceeding the available capacity, load shedding has been regularly implemented since 2008 to avoid a total blackout. Figure 1 shows the historical Eskom generation capacity and the annual peak electricity demand of South Africa since 1950.

[2] The reserve margin can be explained as the amount of spare electricity generation capacity available at a point of time.

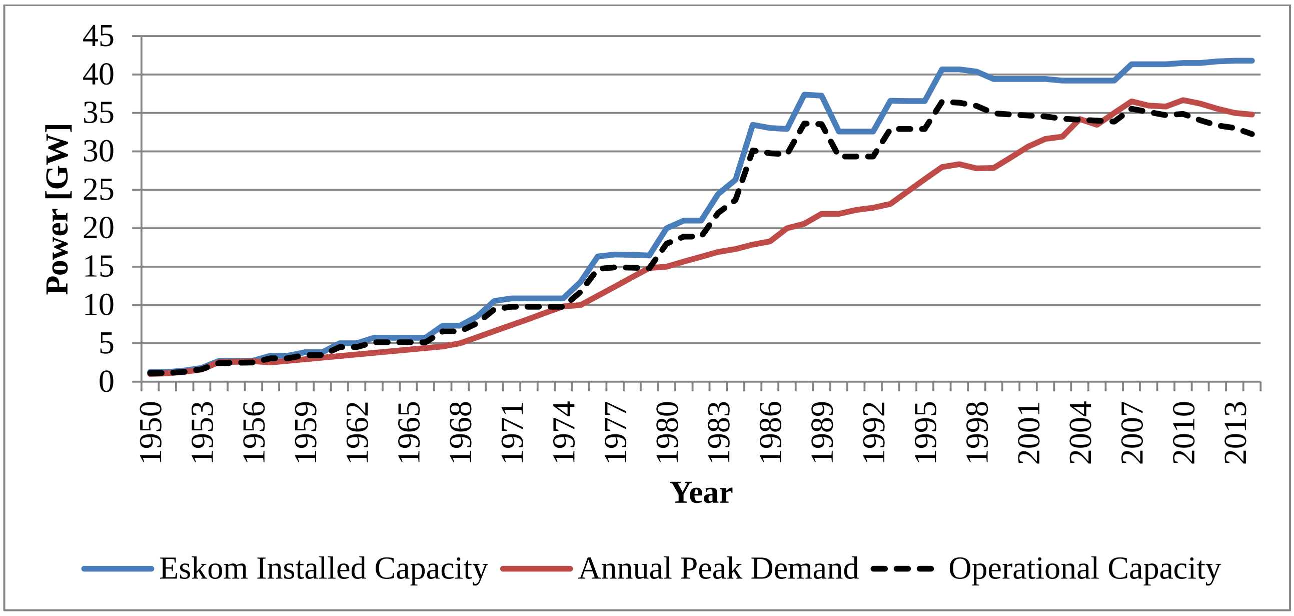


Figure 1: Historical maximum demand and generation capacity[3]

The Economics Department of the University of South Africa (Unisa) conducted a study in 2009 to determine the correlation between electricity consumption and economic growth in the country. It was found that a bidirectional correlation between electricity consumption and economic growth exists. It was recommended that electricity generation capacity expansion programmes be intensified to avoid future load shedding [3].

The updated South African Integrated Resource Plan (IRP) for electricity quantified the effect of load shedding in terms of cost per unit of unserved energy. The plan defines the cost of unserved energy as the opportunity cost to electricity consumers and the economy from electricity supply interruptions. It is estimated that the cost of unserved energy is R75 000 per MWh [4].

1.2 Solutions implemented

Eskom realised that an action plan had to be put in place to increase its electricity generation capacity. This action plan included building new coal power stations, recommissioning old coal power stations and building new wind and solar energy facilities. Some of these strategies were

[3] Eskom Holdings Limited, (2015) "Eskom generation medium term adequacy report," [Online]. Available: http://www.eskom.co.za/Whatweredoing/SupplyStatus/Media/Adequacy%20%20Report%202013w33.swf. [Accessed: 14 May 2015].

implemented prior to 2008, but not in time to avoid the electricity demand from exceeding the available capacity.

Except for the Majuba power station being commissioned in 1996, no new coal power stations were commissioned after the political restructuring in 1994. In the period from 2010 to 2013, the coal power stations Camden, Komati and Grootvlei were recommissioned, which added 3 800 MW to the generation capacity. Figure 2 displays a timeline of the majority of Eskom's power plants, indicating their commissioning and decommissioning dates from 1923 to 2015.

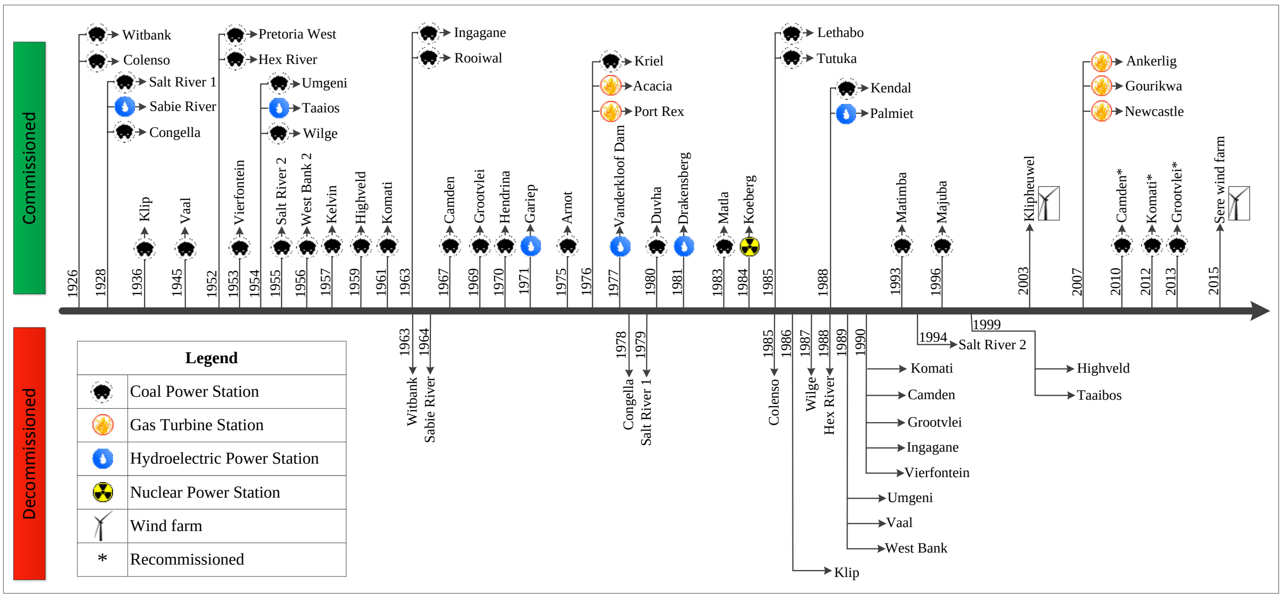


Figure 2: Eskom power plant timeline (1926–2015)[4]

As part of the renewable energy action plan, Eskom constructed a wind farm near Klipheuwel on the West Coast in 2003. This wind farm consists of three wind turbines with a combined generation capacity of 3 MW. Another wind farm was commissioned in 2015 near Vredendal in the Western Cape. This wind farm, named Sere wind farm, consists of 46 wind turbines, each with an installed capacity of 2.3 MW.

The Kusile and Medupi dry-cooled, coal-fired power stations are new power stations to be built as part of Eskom's long-term action plan to expand its generation capacity. The construction of the

[4] Adapted from "Eskom power stations from 1926 to 2015". [Online]. Available: http://mybroadband.co.za/news/energy/122478-eskom-power-stations-from-1926-to-2015.html. [Accessed 12 May 2015]

Medupi power station started in 2007, with Kusile following shortly thereafter in 2008. Final commissioning dates for both these coal-fired power stations were meant to be in 2018, with the first unit of the Medupi power station commissioned in March 2015 [5]. Difficulties being experienced with the construction of these power stations, however, are delaying the commissioning dates[5].

The Medupi and Kusile coal power stations are long-term solutions and the immediate nature of the electricity constraint forced Eskom to implement short-term solutions as well. After necessary internal investigations by Eskom, the installation of open cycle gas turbine (OCGT) power stations was selected as an appropriate short-term solution[6].

In 2007, the Ankerlig and Gourikwa Eskom-funded gas turbine power stations were commissioned, adding 2 067 MW of generation capacity to the electrical system. The reasons provided by Eskom to install these OCGT power stations as part of their short-term solutions to the electricity constraint included [6]:

- The technology is widely used around the world.
- An OCGT power station can be implemented in 2–3 years.
- OCGT technology has a proven track record.
- There are various OCGT suppliers.

An OCGT can operate with either gas (kerosene) or liquid (diesel) fuel as energy source. The hot gas used to turn the OCGT is released into the atmosphere. The privately owned Newcastle gas power station, however, is a combined cycle gas turbine (CCGT) power station. With CCGT technology, the hot exhaust gas is used to heat water to produce steam, which in turn is used to power a secondary turbine [7].

With both OCGT and CCGT gas turbine power generators, air is sucked in from the atmosphere and passes through a number of compressor stages that compress the air. The compressed air is

[5] Adapted from “Kusile and Medupi coal-fired power stations under construction”. [Online]. Available: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/Kusile_and_Medupi.pdf. [Accessed: 01 July 2015]
[6] Adapted from “Eskom fact sheet”. [Online]. Available: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/GS_0002AnkerligGourikwaGasTurbineRev10.pdf. [Accessed: 30 June 2015]

redirected to a combustion chamber where the fuel is injected. The fuel/compressed air mixture is ignited in the combustion chamber. This causes high velocity hot gas which is forced to pass over the turbine blades. The turbine blades turn the shaft, which is connected to a generator [8].

The Ankerlig gas turbine power station consists of two phases. The first phase has four OCGTs, each with an electricity generation capacity of 148 MW. The second phase has five OCGTs with a total generation capacity of 735 MW. The combined generation capacity of the Ankerlig gas turbine power station is therefore 1 327 MW [6].

The Gourikwa gas turbine power station consists of five OCGTs, each with a generation capacity of 148 MW. The combined generation capacity of the Gourikwa gas turbine power station is 740 MW. Figure 3 displays a computer-aided design (CAD) image of an OCGT used in the Ankerlig and Gourikwa gas turbine power stations [6].

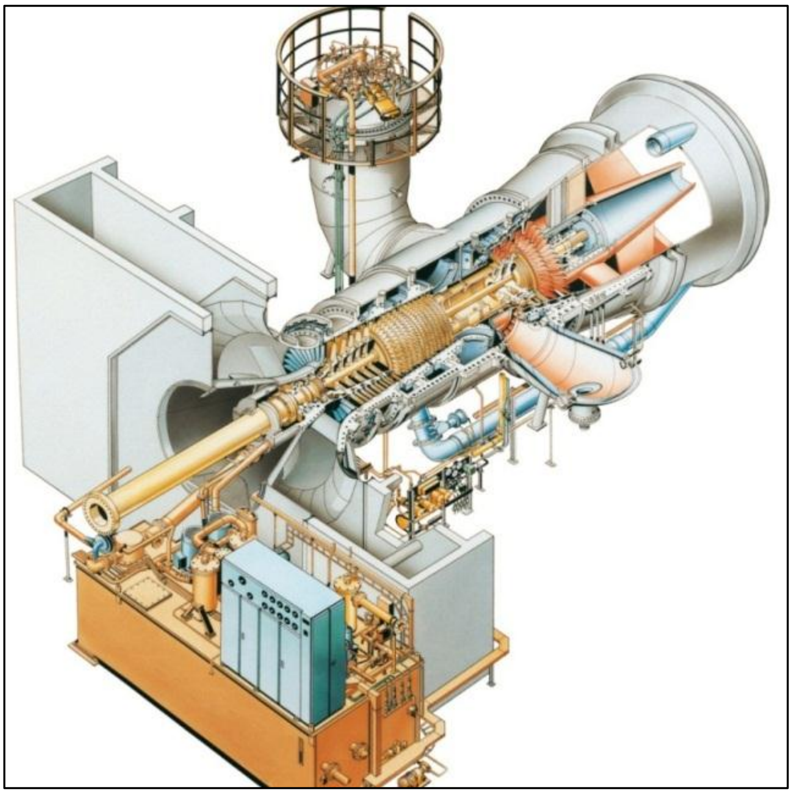


Figure 3: An SGT5-2000E Siemens OCGT[7]

[7] Adapted from "Siemens Gas Turbine". [Online]. Available: http://www.siemens.com/press/en/presspicture/?press=/en/presspicture/2009/fossil_power_generation/efpg20050701-01.htm&sheet=1. [Accessed: 01 July 2015]

The Newcastle gas turbine power station, which is a privately owned power station, was also commissioned in 2007. The Newcastle gas turbine power station has two CCGTs and two Aalborg steam boilers. This power station has a generation capacity of 18 MW and supplies electricity and steam to three industrial companies in the immediate vicinity.

Technical information about the Siemens SGT5-2000E OCGT, which is used in the Ankerlig and Gourikwa power stations, is supplied in Appendix A. The Ankerlig and Gourikwa power stations were commissioned to assist Eskom with generating electricity during peak demand periods. The peak demand periods are usually during weekdays between 07:00 and 10:00 in the mornings and 18:00 and 20:00 in the evenings. Considering that the evening peak demand period is two hours, parameters involved with operating the gas turbine power stations for two hours are summarised in Table 1. The calculations are presented in Appendix B.

Table 1: The Ankerlig and Gourikwa power stations – general operational parameters

Description	**Unit**	**Ankerlig**	**Gourikwa**
Installed generation capacity	[MW]	1 327	740
Electricity generated in two hours	[MWh]	2 654	1 480
Diesel required for two hours	[ℓ]	725 747	404 712
Diesel flow rate required	[ℓ/s]	100.8	56.21
Diesel cost per unit	[R/ℓ]	9.4	9.4
Total diesel cost for two hours	[R million]	6.8	3.8
Cost per energy unit	[R/MWh]	2 570	2 570

The gas turbine power stations were only intended to be operated in the case of demand surges and temporary supply shortfalls. This usually occurred only during the two hours of the evening peak period. However, these turbines are being operated for longer periods in an attempt to avoid load shedding. During the 2014 financial year, Eskom spent R10 billion on diesel to operate these power stations. The approved diesel budget for 2014 was only R3 billion. Recently, Eskom investigated the possibility to operate the gas turbines on alternative, less expensive fuel to release some of its financial pressure.

In addition to its lack of sufficient generation capacity, Eskom also recently made it public that financial constraints are being experienced. Despite an annual electricity increase of 12.6% approved by the National Energy Regulator of South Africa (Nersa) for 2015/2016, Eskom applied for an additional 9.5% increase in June 2015. Eskom indicated that the funds raised with the increase would be used to fund the diesel used to operate the gas turbine power stations. Nersa denied Eskom’s application for an additional increase in the 2015/ 2016 electricity tariffs.

There is a need to evaluate the feasibility of the short-term solutions to the immediate generation capacity problem before addition capital is invested. The shortage of electricity generation capacity and the financial constraints being experienced by Eskom support this statement. Available funds should first be allocated to the most feasible short-term solutions. Section 3.2.3 will be used to develop a feasibility model that can be used to determine the feasibility of each short-term solution.

DSM is a short- to medium-term solution to the electricity supply constraint problem. In comparison with using gas turbines, DSM initiatives might be a more feasible approach to match electricity supply with demand. A detailed study needs to be done to compare the feasibility of DSM initiatives with the feasibility of operating the gas turbine power stations. The next section will focus on DSM as a solution to the electricity constraint.

1.3 DSM as short-term solution

More than 80% of the electricity generated in the United States of America (USA) is produced by privately owned utility companies. The main objective of these privately owned companies is to make a profit by selling the electricity that they produce. Feasibility in terms of profit made while producing and selling electricity is constantly being considered by these companies [9].

Up to the 1970s, electricity utilities in the USA experienced a period of positive financial health. Technologies for electricity generation improved rapidly and utilities expanded their generation capacities on a regular basis. As a result, Public Utility Commissions (PUCs) decreased the cost of electricity. In response, the utilities promoted the use of electricity to increase their profits. A mutual understanding existed between the utilities, the PUCs and the electricity consumers [9].

This situation changed drastically in the 1970s. Between 1971 and 1976, the US government approved a series of laws to regulate air emissions [10]. These laws enforced air emission regulating technologies to be implemented on newly built power stations, which increased the implementation cost. The energy crisis of the 1970s also caused a drastic increase in world oil and gas prices, which effected utilities that relied on these energy sources to generate electricity [11].

The Three Mile Island nuclear reactor accident in 1979 created public awareness of the effect that nuclear electricity generation could have on the environment. Utilities found it difficult to obtain suitable sites to build new nuclear power plants, which made it more difficult for the utilities to meet the growing electricity demand. Utilities needed a drastic increase in electricity cost to fund new power plants, but with the PUCs regulating the cost of electricity, utilities were only allowed to increase the cost to a certain extent [12].

The cost to operate existing power plants and to expand the generation capacity kept on rising throughout the 1970s. It became more feasible to the privately owned utility companies to change the electricity consumption pattern to match electricity supply with demand, than to build new power plants. This is seen as the origin of demand-side management (DSM) [13]. A recent study defined DSM as “modifications on the demand side of the electricity grid to change the power consumption pattern, in order to ensure that electricity supply and demand is effectively matched” [14].

Electricity demand of a typical electricity system varies on a daily and a seasonal basis. Considering the negative effect an unplanned electricity supply interruption can have on a country’s economy, the electricity generation capacity should always be able to meet the maximum demand. Ideally, electricity systems should be designed to have a generation capacity of 20% more than the maximum electricity demand [15].

In the USA, PUCs, privately owned utility companies and government institutions play a role to ensure that the electricity demand never exceeds the generation capacity. The PUCs are responsible for ensuring that electricity prices are reasonable for the clients and feasible for the privately owned utility companies to expand their generation capacity. DSM becomes feasible to utilities when it is more cost effective to change the electricity demand pattern than it is to build new power stations.

The situation is different in South Africa. Eskom is the main utility, producing 95% of the country’s electricity. Eskom is a public company owned by the government. Due to various reasons already discussed, Eskom cannot supply sufficient electricity to meet the demand. DSM, therefore, became a necessary short- to medium-term solution to match the electricity demand with the supply. In May 2004, Nersa approved the Eskom energy efficiency DSM programme in an attempt to reduce the electricity demand of the country [16].

Although the South African DSM framework was only finalised in 2004, various DSM strategies have already been implemented prior to 2004. These strategies included the time of use (TOU) tariff structure and the efficient lighting initiative. Figure 4 illustrates the South African DSM programme and the early DSM strategies implemented by Eskom.

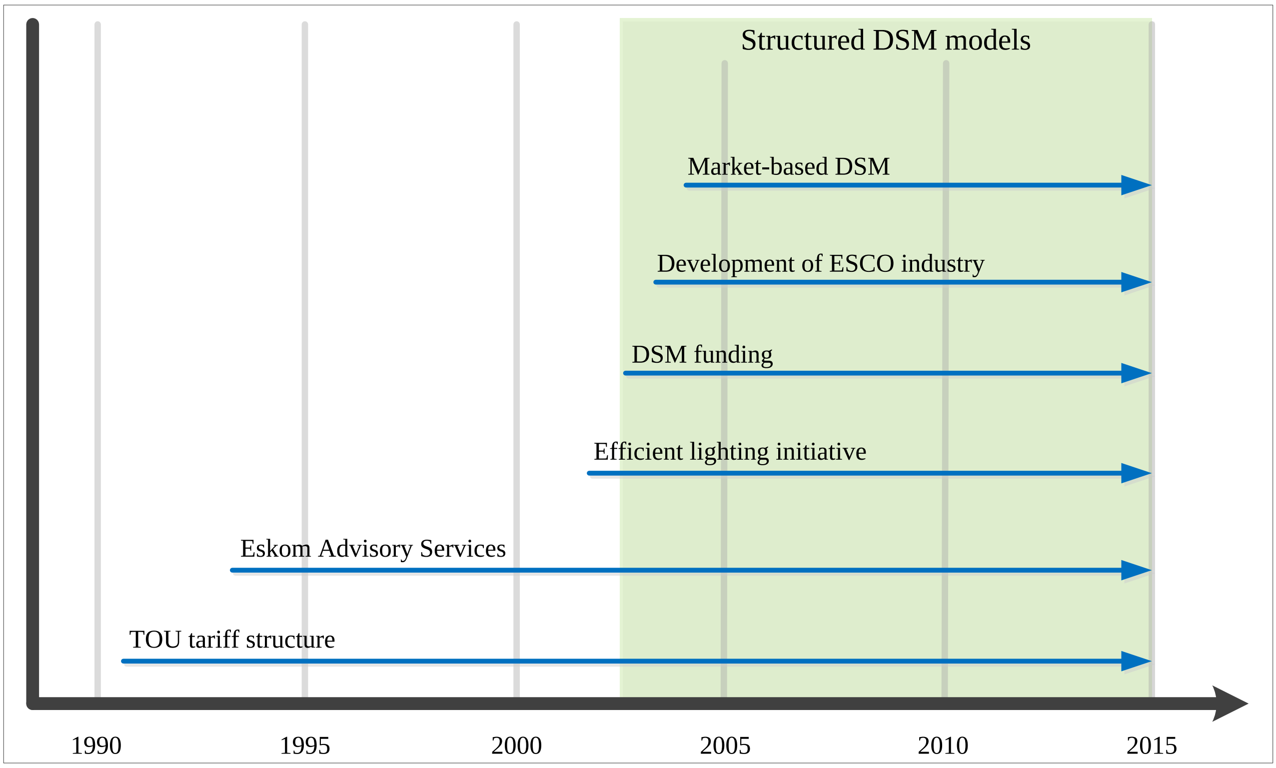


Figure 4: Development of the South African DSM programme[8]

As indicated in Figure 4, various measures are implemented as part of the DSM programme. These measures either improve the efficiency or change the consumption pattern of an electricity intensive system. Although energy efficiency is also important, the recent focus has been on changing the consumption pattern of the country due to the nature of the South African electricity constraint.

[8] Adapted from: T. Nortje, "South Africa's demand side management programme," Vector, vol. 2006, no. January, pp. 1818–2119, 2006.

Eskom is struggling to generate enough electricity during the high demand hours, especially during the winter months. During 2014, Eskom had an installed generation capacity of 42 090 MW with an average availability factor of approximately 75%. With the unexpected breakdowns of the Eskom power plants that keep on rising, the utilisation factor is expected to deteriorate rapidly in the near future. Figure 5 shows the winter and summer load profiles and the operational generation capacity [17].

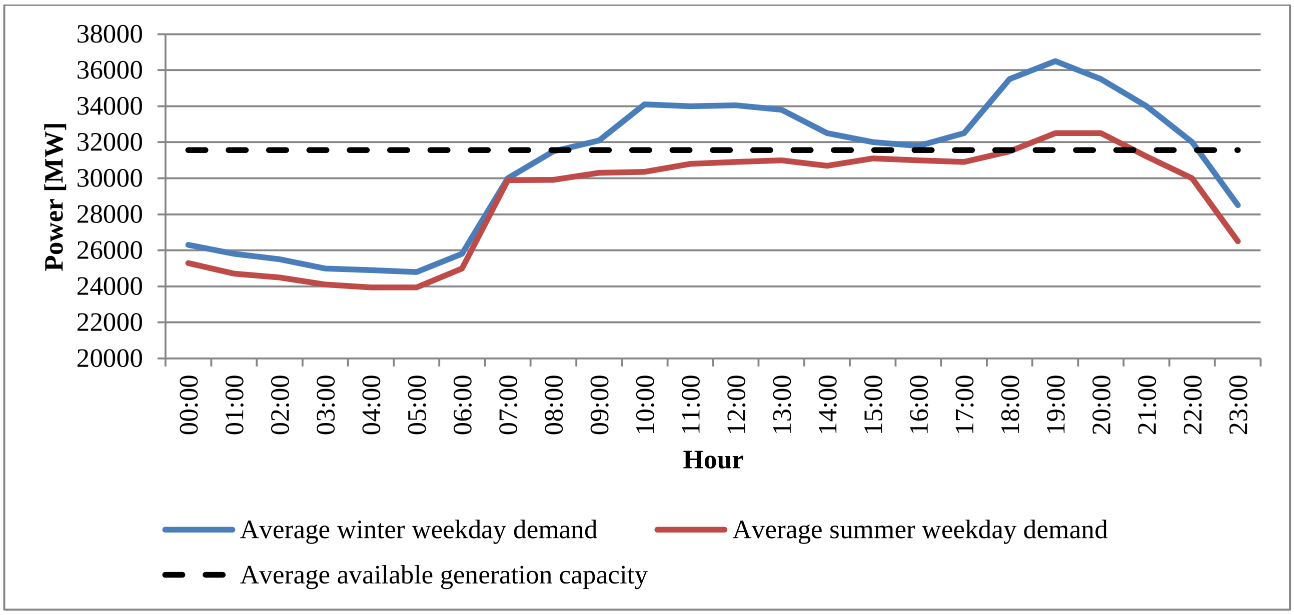


Figure 5: Average 2014 summer and winter demand profiles

From the graph in Figure 5, it is evident that there is a morning and an evening consumption peak during the winter months. During summer months, the demand during the day is relatively constant with a peak during the evening. Various DSM measures have been implemented to reduce the consumption during the peak hours. Some of the measures that have been implemented are:

- TOU tariff structure,
- load-shifting measures, and
- peak-clipping measures.

The TOU tariff structure introduces different costs for electricity depending on the season, weekday and time of consumption. This measure was implemented to motivate industrial electricity consumers to reduce their electricity consumption during high demand hours. Load shifting and peak-clipping measures became feasible to clients because of the TOU tariff structure.

A load-shifting measure reduces the load consumed by clients during the Eskom peak hours, but reintroduces the load during non-peak periods. A peak-clipping measure only reduces the load during peak hours. Both measures reduce the electricity cost of the client during peak hours.

The graph in Figure 6 shows an average weekday power profile for a cement plant. It is evident from the power profile that an evening load-shifting project has been implemented at this plant. Note the reduction in power demand between 18:00 and 20:00 in the evening.

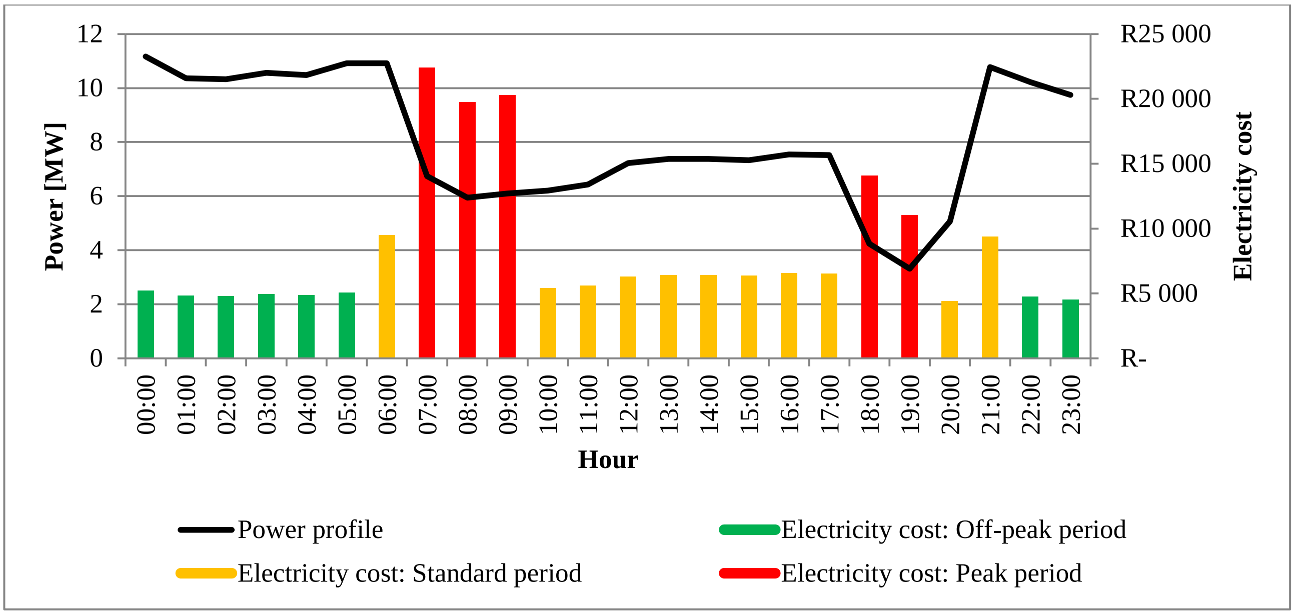


Figure 6: TOU electricity cost for a typical daily power profile

As part of the load-shifting project implemented at the cement plant, load has been moved from the expensive Eskom evening peak period to the less expensive standard and off-peak periods. Despite the load reduction of 3.7 MW during the evening peak period, the electricity cost during this period is still high when compared with the other TOU periods.

During winter, electricity cost during the peak period can be up to seven times more expensive than during the off-peak periods [18]. This encourages clients to reduce their demand during peak periods by implementing load-shifting or peak-clipping projects. To support this argument, the 2015/2016 Eskom Megaflex tariffs are presented in Appendix C.

Energy efficiency projects focus on improving the efficiency of a system. This is done by reducing the electricity consumption of a system without affecting production activities. Depending on the system constraints, the electricity consumption is either reduced throughout the day or only reduced during certain periods of the day. Although energy efficiency projects could also contribute to load reduction during Eskom peak periods, load-shifting and peak-clipping projects are more effective in reducing the peak demand.

If energy efficiency savings are achieved, less electrical energy is used to produce the same amount of product. This has a positive impact on the environment due to the reduction in CO_2 emissions. A load-shifting project only shifts the electrical energy used to another period of the day but the total energy used to produce the product stays the same. Energy efficiency projects are, therefore, preferable from an environmental point of view. Table 2 lists typical load-shifting, peak-clipping and energy efficiency projects found in industry.

Table 2: Industrial DSM projects

Load-shifting projects	Peak-clipping projects	Energy efficiency projects
• Pump scheduling. • Mill scheduling. • Winder scheduling. • Industrial refrigeration plant load management. • Industrial ventilation system load management.	• Compressor off-loading. • Pump stopping. • Mill stopping. • Industrial furnace stopping.	• Variable speed drive control on industrial equipment. • Efficient lighting equipment. • Water demand control. • Compressed air demand control.

With the DSM framework finalised in 2004, one of the main objectives was to save a cumulative total of 4 225 MW of power over a period of 20 years [16]. This is equivalent to the installed capacity of a six-unit coal-fired power station. The cumulative verified peak demand DSM savings from 2005 to 2014 are displayed in Figure 7.

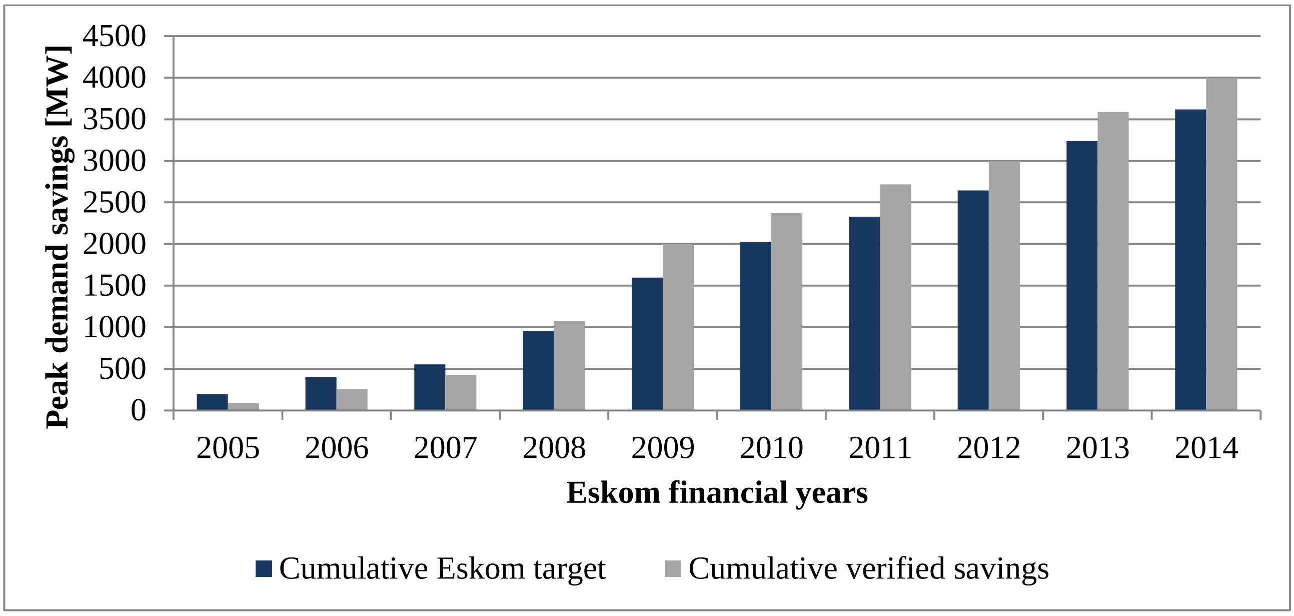


Figure 7: Cumulative target and actual peak demand DSM savings (2005–2014)[9]

From Figure 7 it should be noted that the cumulative DSM savings target of 4 225 MW set in 2004 has already been met, almost 10 years before the expected due date. During the 2013/2014 financial year, Eskom spent R1.36 billion on DSM initiatives, which indicates that Eskom is still interested in driving the DSM programme. Despite reducing electricity demand during peak hours, the DSM programme savings also have various benefits on a social, economic and environmental level [19].

The South African DSM programme focuses on the residential, commercial as well as the industrial sectors. Nersa specifies that the measurement and verification (M&V) of savings achieved by DSM initiatives should be according to the International Performance Measurement and Verification Protocol (IPMVP)[10]. Independent M&V teams, accredited according to the Energy Efficiency and Demand-Side Management (EEDSM) rules, should be appointed to measure and verify the savings achieved through DSM initiatives [20].

[9] Adapted from "Eskom Holdings SOC Limited: 2014 Integrated Report". [Online]. Available: http://integratedreport.eskom.co.za/pdf/full-integrated.pdf. [Accessed: 04 July 2015]

[10] Adapted from "NERSA Consultation Paper: Revision of Regulatory Rules for Energy Efficiency and Demand Side Management (EEDSM) including Standard Offer Programme (SOP)". [Online]. Available: http://www.nersa.org.za/. [Accessed: 04 July 2015]

Despite the IPMVP guidelines, appointed M&V teams encounter various challenges during the M&V process. These challenges affect the accuracy with which the M&V teams determine the savings achieved. Some challenges identified by Eskom are[11]:

- Insufficient and incorrect baseline information from Energy Services Companies (ESCOs).
- Inaccurate savings calculation with seasonal performance projects.
- M&V teams relying on ESCOs to obtain performance-tracking data.

A case study consisting of 37 industrial DSM projects that were out of their contract period was evaluated. It was found that the initial project targets of these projects and the savings achieved after commissioning differed significantly. From the ESCOs' calculated savings, it was also found that the project savings deteriorated after the project performance assessment (PA) period. These results are displayed in Table 3.

Table 3: Industrial DSM projects – average project performance

Description	Total initial target [MW]	Average deviation from initial target [%]	Average annual savings deterioration [%]
Load shifting	74	29	10.6
Peak clipping	55	46	22.4
Total/average	129	36	17

The case study also revealed that 41% of the projects did not reach their initial targets. These projects underperformed by an average of 26%. The following aspects of the industrial DSM ESCO model should be re-evaluated to determine the causes for the industrial DSM projects underperforming, and why the savings tended to deteriorate:

- The procedure used to measure and verify the savings of DSM initiatives implemented in industry.
- The industrial DSM ESCO model used to implement DSM initiatives in industry.

[11] Adapted from "Eskom: M&V Guideline, Processes and Expectations". [Online]. Available: http://www.eskom.co.za/IDM/MeasurementVerification/Documents/MV_GuideforDSM.pdf. [Accessed: 04 July 2015]

1.4 Problem statement and research objective

Inefficient electricity generation capacity is a reality Eskom has to face. Eskom implemented various strategies to solve the electricity generation shortage. Some strategies are long-term solutions such as building the new Medupi and Kusile coal power stations. In addition to the long-term solutions, various medium-term generation capacity expansion strategies have already been implemented:

- the recommissioning of coal power stations,
- the implementation of gas turbine power stations, and
- the commissioning of wind farms.

Short- to medium-term solutions, which focus on changing the demand pattern to match the electricity supply and demand, have also been implemented. These solutions are the DSM programme, the TOU tariff structure and demand-market participation. These strategies are not always sufficient. Load shedding is often implemented to protect the electricity network from a total blackout. Load shedding has damaging effects on the South African economy, affecting industries such as gold and platinum mining [21].

Besides the shortage in electricity generation capacity, Eskom also has financial problems. Nersa approved a series of increases over the next few years to help Eskom finance the strategies implemented to resolve the shortage. These approved electricity cost increases are, however, not sufficient to save Eskom from its financial dilemma. During 2015, Eskom applied for additional electricity price increases but the application was denied by Nersa.

Due to Eskom's financial situation, available funds should be allocated to short-term strategies that offer the most feasible solution to the immediate problem. Operating gas turbine power stations offers an immediate solution when the demand exceeds the available supply capacity. Operating these power stations is, however, expensive and does not offer a sustainable solution. DSM is a short- to medium-term solution that offers a more sustainable solution, but is not as effective when immediate action is required.

Eskom needs a model to determine which strategies are the most feasible to resolve the electricity supply constraint. This model should consider factors such as: the effect of load shedding as short-term solution; return on investment in terms of capital investment versus expected savings; and the environmental impact of each strategy.

The total power contribution of using the gas turbine power stations can easily be measured. When the Ankerlig and the Gourikwa power stations are operated, an additional 2 067 MW is added to the generation capacity. On the contrary, establishing the effect of DSM initiatives on the electricity demand pattern is more difficult. Although guidelines are supplied on how the M&V of DSM initiatives should be approached, various challenges affect the accuracy of the verified savings.

Although a study could show that DSM is a more feasible approach, the actual impact of DSM in South Africa should also be investigated. For DSM to be successful, the following conditions should be met:

1. DSM projects should be investigated and implemented correctly to achieve optimal savings.
2. The M&V process should be done correctly to ensure that savings are reported accurately.
3. The DSM initiatives should be maintained properly to ensure sustainable results.

If the above-mentioned conditions are not met, DSM could be a strategy that consumes money without delivering the required results. This will affect the feasibility of DSM negatively and it should be considered. A case study revealed significant discrepancies between the savings verified by M&V teams and the savings calculated by an ESCO company. The results also showed that the performance of industrial DSM initiatives tended to deteriorate after implementation. These results prompted the need to re-evaluate the South African industrial DSM ESCO model and the effect DSM has in the South African context.

The South African industrial DSM ESCO model will be compared with other models implemented in countries with similar electricity constraints. The findings will be used to help determine the effectiveness of the South African industrial DSM ESCO model. Results of existing DSM initiatives will also be analysed to determine if the existing model is being applied correctly. Necessary changes will be proposed, to the model itself or to the methods used when applying the model. The result will be a new alternative approach to the South African industrial DSM ESCO model to ensure sustainable results.

1.5 Novel contributions of this study

Novel contribution 1: *A unique approach to the South African industrial DSM ESCO model to ensure an improved DSM programme impact.*

From previous studies and by evaluating the performance of existing projects it was determined that industrial DSM projects do not always perform optimally. Research identified various problems with the existing industrial DSM ESCO model that could influence the performance of projects negatively. Some problems identified include:

- An inconsistency in the drive towards the DSM programme during the past decade restricted the ESCO market growth in South Africa.
- Inaccurate project investigations, unrealistic project savings targets and system changes during the Eskom project approval phase are just a few challenges that influence the initial project performance.
- Eskom assigns M&V teams to measure and verify the savings achieved by DSM projects. The M&V team develops the measuring technique used to quantify the project performance. However, this measuring technique is not updated on a regular basis to account for system changes. This can result in inaccurate savings being reported.
- Insufficient knowledge regarding the system on which the DSM project is implemented restricts M&V teams from updating their savings measuring techniques properly if system changes occur.
- Reporting on the savings achieved after the PA period does not always occur on a regular basis.
- A lack of active and continuous maintenance on existing industrial DSM projects results in project performance deteriorating.

An alternative approach to the industrial DSM ESCO model will be developed. The alternative approach will address the challenges mentioned above to improve the performance of industrial DSM projects. The main aim of the alternative approach will be to improve the initial impact and the sustainable savings of industrial DSM projects.

Novel contribution 2: *Proposing a new funding strategy for industrial DSM project maintenance to ensure an improvement in the sustainability of project performance.*

From existing studies and research, the following problems with the existing method of maintaining industrial DSM projects were identified:

- Eskom spends large amount of funds to implement industrial DSM projects but is not involved in maintaining the projects. If the client does not maintain the DSM initiative, savings deteriorate and the return on the investment made by Eskom is reduced.
- Old DSM contracts indicate that the client should maintain the project savings after the PA period. Although the client is liable to pay penalties if project savings are not maintained, penalties cannot always be enforced by Eskom due to various reasons mentioned in this study (Section 2.6).
- As part of the new DSM model recently introduced by Eskom, future industrial DSM projects must be maintained by the ESCO for three years after the project has been implemented. This should improve the sustainability of projects. Project savings are, however, expected to deteriorate after three years if no active maintenance is done. Savings of existing projects, which still needs to be maintained by the clients, are also deteriorating due to a lack of active maintenance.
- Clients usually do not want to spend additional funds to maintain the DSM initiatives implemented on their sites. Their argument is that operators and client personnel responsible for the project should maintain the initiatives.
- Training programmes are given to client personnel to operate equipment related to the DSM project. Interest in the initiative soon fades after training and despite the training programmes, the required knowledge to maintain the initiative properly is quickly lost.

A new maintenance funding approach for existing industrial DSM initiatives will be developed. The new maintenance funding approach will ensure that active maintenance is done to sustain project savings. This study will prove that an improved sustainability of industrial DSM projects will have a cost benefit to Eskom.

Novel contribution 3: *A new measurement and verification model to ensure accurate and continuous performance monitoring of industrial DSM projects.*

Various studies have been done to ensure accurate M&V of industrial DSM projects. Challenges such as data accuracy, the selection of a suitable baseline model and the effect of system changes on the project performance were addressed [22]. The correct interpretation of M&V results by the parties involved was also emphasised [23]. Despite the good work done by previous studies, the following existing challenges regarding the M&V of industrial DSM projects have been identified:

- Inaccurate baseline information from the ESCOs.
- Late and incomplete allocation of M&V teams by Eskom.
- Negligence of M&V teams to continuously report on the performance of existing projects.
- Inaccurate data being used to measure and verify the project performance.

Although previous studies have been done to ensure accurate M&V, the above-mentioned challenges still affect the accuracy of M&V reporting. It is believed that the problem is, therefore, not with the processes developed to ensure accurate M&V, but rather with the model used to ensure that the correct processes are used.

A new approach to the M&V model being used to measure the performance of industrial DSM projects will be developed. The new approach will ensure that all the accurate M&V processes developed by previous studies are used effectively to eliminate the above-mentioned challenges. The effect of accurate and continuous M&V reporting on the performance of industrial DSM projects will also be investigated as part of this study.

1.6 Overview of this study

In **Chapter 1** of this thesis, the history and objective of DSM measures were explained. The build-up to the South African electricity constraint was provided. The DSM programme implemented in South Africa to assist with the electricity constraint was discussed. The need to evaluate the feasibility of the DSM programme measured against other short-term solutions was highlighted. The need to develop an alternative approach to the existing ESCO DSM model to improve the sustainability of future industrial DSM project was discussed.

Chapter 2 evaluates existing international DSM models implemented in countries with similar electricity constraints as South Africa. These models are compared with the South African model to help identify possible changes to improve the existing model. Previous studies are also considered to evaluate the South African industrial DSM ESCO model further. Challenges during the project investigation and implementation phases, which affect the performance of DSM initiatives, are investigated.

The procedure prescribed in the existing industrial DSM ESCO model, which is used to measure and verify the performance of DSM initiatives, is investigated. Differences between the prescribed procedure and the actual procedure followed by appointed M&V companies are evaluated. Existing maintenance programmes that ensure project sustainability are investigated. Previous studies are considered to help evaluate the sustainability of existing DSM initiatives and to justify the need to improve project sustainability.

In **Chapter 3**, a model is developed to measure the feasibility of DSM by using the operating conditions and the cost of using gas turbines as benchmarks. The following changes to the existing ESCO DSM model are made:

- An alternative DSM project investigation and implementation approach is developed to ensure optimal project performance.
- Measures to ensure an accurate and reliable project M&V of the impact of DSM initiatives are proposed.
- A solution to improve the sustainability of existing DSM initiatives is proposed.

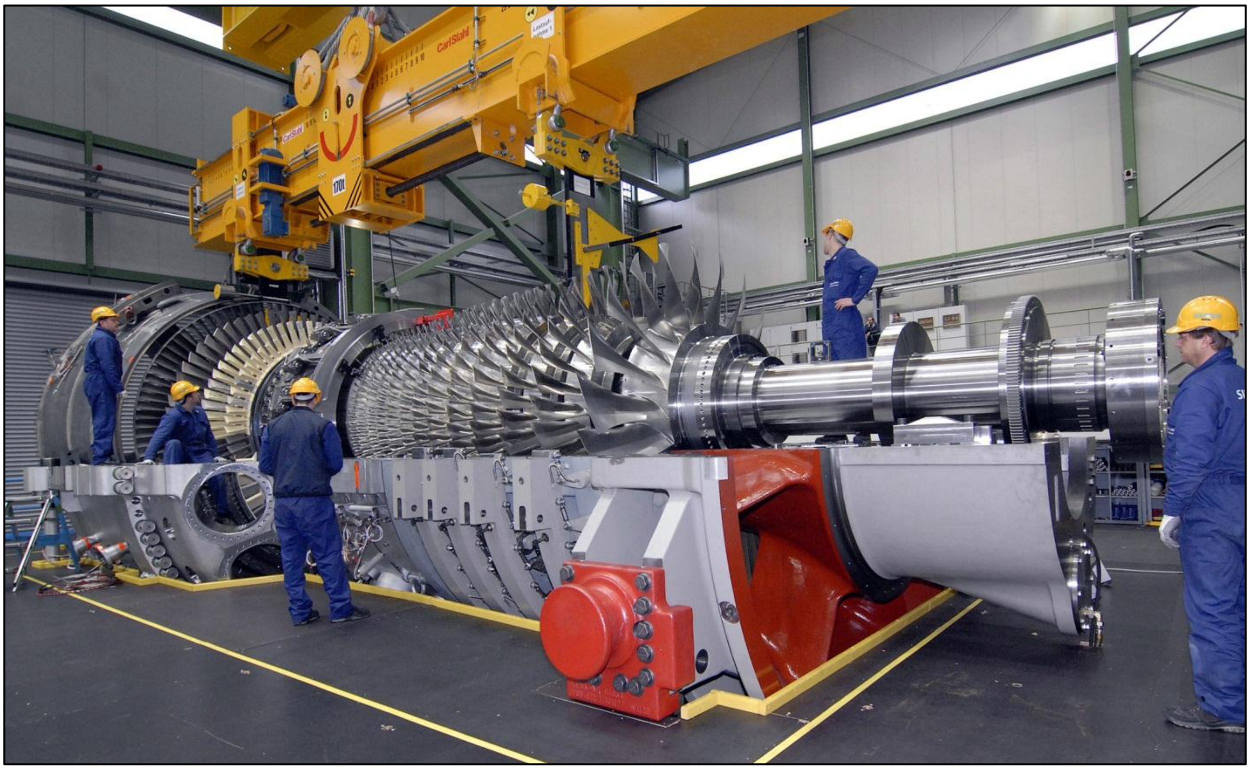
The above-mentioned solutions are integrated into the existing industrial DSM ESCO model. An alternative approach to the existing model is developed in order to ensure optimal and sustainable results.

In **Chapter 4**, the circumstances and results of various historical DSM initiatives are evaluated. This is achieved by dividing the initiatives into different project phases. The implementation method and results achieved during each project phase are then evaluated for each DSM initiative. These results are compared with the theoretical results of the improved, alternative industrial DSM ESCO model for verification.

The applicable project phases of historical DSM initiatives are combined to formulate one theoretical DSM initiative. This theoretical DSM initiative simulates a DSM initiative implemented through the improved, alternative industrial DSM ESCO model. The improvement in DSM performance and sustainability will be discussed. These results will be used within the newly developed feasibility model to determine the financial feasibility of DSM as a solution to the South African electricity constraint.

Chapter 5 contains the conclusion of this study and recommendations for future work.

Chapter 2: Literature review



[12]

This chapter will consist of a critical, relevant and comprehensive literature survey indicating the originality of the novel contributions.

[12] Diesel and gas turbines worldwide (2013). [Online]. Available: http://ww.live-diesel.com/2013/06/turbines-to-bangladesh-plants/. [Accessed: 03 June 2015]

2.1 Introduction

In Chapter 1, the origin and main objectives of DSM were investigated. It was found that DSM can be implemented when it becomes financially more feasible to change the demand pattern than to expand generation capacity. If the electricity network cannot generate enough electricity to meet the growing demand, DSM can serve as a short-term solution to match supply and demand. It was found that this situation is applicable in South Africa.

DSM has already been implemented in South Africa to assist with the current electricity constraint. It has been found that in addition to this constraint, Eskom is also experiencing financial problems. This led to the conclusion that Eskom needs to evaluate the financial feasibility of initiatives before they are implemented.

The performance of existing industrial DSM initiatives, measured by appointed M&V companies, was briefly evaluated in Chapter 1. The findings prompted the need to investigate the industrial DSM ESCO model and compared it with other short-term solutions such as operating gas turbine power stations. The need to develop an alternative approach to the industrial DSM ESCO model to improve the sustainability of future DSM initiatives implemented in industry was identified.

This chapter is a literature survey to obtain the required information needed to develop a detailed, practicable and relevant alternative approach to the industrial DSM ESCO model. Relevant existing studies will be evaluated, shortcomings will be identified and new ideas will be formulated. The focus will be on the following areas:

- similar international DSM ESCO models,
- the South African DSM approach,
- challenges regarding the investigation and implementation of industrial DSM initiatives,
- M&V procedures, and
- the sustainability of existing projects.

2.2 International DSM models

2.2.1 Introduction

An ESCO is a company that contributes to DSM by offering energy improvement initiatives to clients [24]. This chapter will evaluate international DSM models involving ESCOs. Differences between DSM models in first-world (developed) countries and DSM models in third-world (developing) countries will be investigated first.

Factors that make it necessary for DSM models to be applied differently in developed and developing countries will be identified. These international DSM models will be evaluated and compared with the South African industrial DSM ESCO model. Possible changes to the South African model to improve the feasibility and sustainability of industrial DSM projects in South Africa will be investigated.

2.2.2 DSM in developed countries

ESCOs can implement energy improvement initiatives on the premises of a client using performance-based contracts or nonperformance-based contracts. With performance-based contracting, the ESCO is responsible for delivering the energy and/or cost saving, and the ESCO's compensation is based on the performance of the initiative. Nonperformance-based contracts only focus on the delivery of a service without linking the ESCO's compensation to the performance of the initiative [25].

In the USA, approximately 68% of the initiatives implemented by ESCOs uses performance-based contracting [26]. In the United Kingdom (UK), ESCOs mostly use performance-based contracting, which is also known as Contract Energy Management (CEM). CEM is synonymous with performance-based contracting. CEM also stipulates that some degree of risk lies with the ESCO to make sure that the energy savings initiative performs [27]. Energy companies in the UK that do not use performance-based contracting are referred to as energy service provider companies [28].

Performance-based contracting is preferred in most developed countries over nonperformance-based contracting. Performance-based contracting links the financial compensation of the ESCO with the performance of the initiative. This risk motivates the ESCO to investigate, engineer and install an initiative accurately to ensure optimal performance [29].

Energy improvement initiatives implemented by using the performance-based contracting method can be financed through two models. These models are the shared-savings and guaranteed-savings models. In both models, the risk of the initiative to perform lies with the ESCO but the connection between the parties involved differs. The connection between the different parties involved with each model is shown in Figure 8 [30], [31], [32].

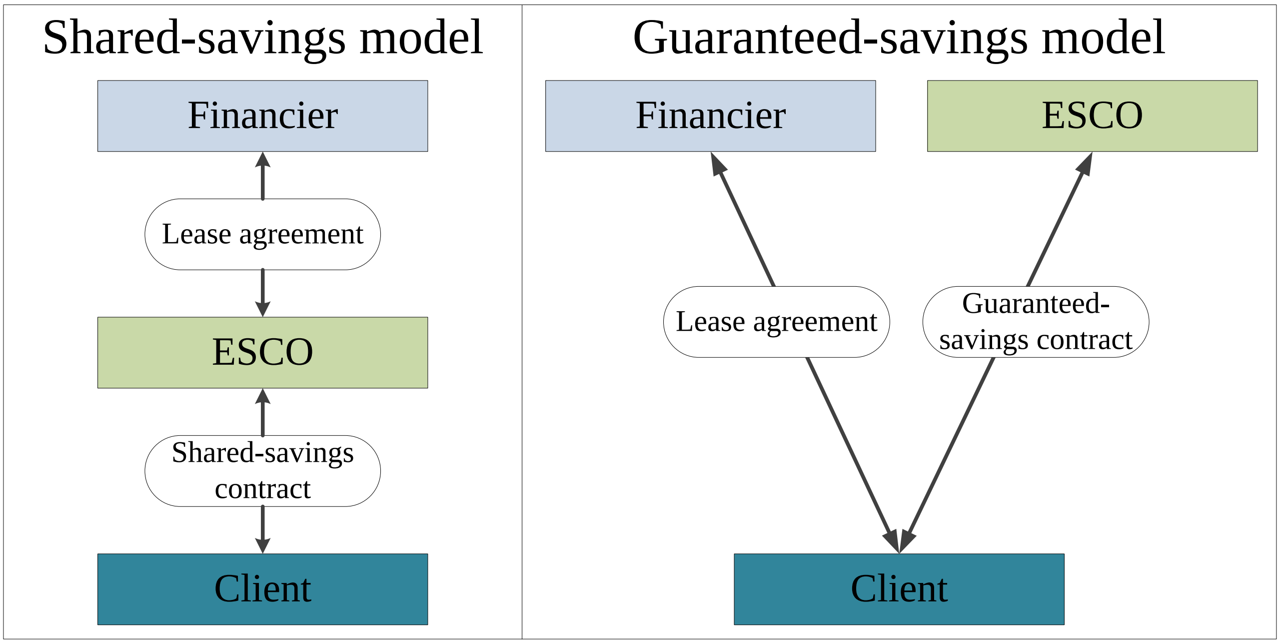


Figure 8: Shared and guaranteed-savings contracting models

With the shared-savings model, it is the responsibility of the ESCO to arrange financing for the initiative to be implemented on the premises of the client. Finance can either be arranged internally (self-financed by the ESCO) or from a third-party lender. A contractual agreement between the ESCO and the third-party lender is signed, with the ESCO assuming credit liability. The client then pays the ESCO its share of the savings as specified in the shared-savings agreement between the ESCO and the client. The ESCO then repays the third-party lender [26].

If the savings shared by the ESCO according to the shared-savings contract are less than the payment to the third-party lender, the ESCO records a loss. If the savings shared are more than the payment to the third-party lender, a profit is recorded. There is no agreement between the client and the third-party lender and the full responsibility lies with the ESCO to repay the loan. The shared-savings model was regularly used in the USA during the 1980s and early 1990s, but has become less popular in recent years [24]. Literature showed that this model is more popular in countries with an upcoming ESCO market and a developing economy than it is in developed countries [33].

With the guaranteed-savings model, however, the client takes responsibility to finance the initiative. Although the ESCO may assist the client in obtaining financing, the contractual agreement will be between the client and the third-party lender. The ESCO is usually paid upfront to install and commission the initiative. Regular interval payments are also made to the ESCO for ongoing services such as maintenance and M&V. The guaranteed-savings contract between the ESCO and the client specifies the savings that must be achieved by the ESCO after implementing the initiative [26].

If the actual savings achieved are less than the guaranteed savings, the ESCO has to reimburse the client. If the actual savings are more than the guaranteed savings, the client benefits from the excess savings. With both contracting models, the ESCO carries the performance risk. The guaranteed-savings model has been used more frequently in developed countries during recent years. Literature indicated that this contracting model is used especially in countries that have developed ESCO markets, stable economies and established banking structures. Some countries that use the guaranteed-savings model are the USA, the UK, Germany, Austria and Hungary [24], [34].

In developed countries, there are many established ESCOs with expertise in different fields [28]. Although these ESCOs have departments investigating new possible energy savings initiatives, clients also actively identify energy savings initiatives. ESCOs are usually approached by a client to implement an identified energy savings initiative. As part of a formal tender procedure, the ESCOs are allowed to investigate the energy savings initiative properly. The client assists the ESCO during the investigation of the initiative [35], [36].

The client submits a request for proposal document, which the ESCOs can use as a basis for their investigations. Based on the proposals received from the ESCOs, the client selects the most appropriate ESCO to implement the energy savings initiative. Typical measures that are used to select a suitable ESCO are: samples of previous work; interviews with previous clients; and the experience of the key ESCO personnel [36].

As a result of the high number of established ESCOs and the formal tender procedure followed by a client when an ESCO is selected, ESCOs in developed countries have to be competitive in order to survive. After a client selects a suitable ESCO to implement an energy savings initiative, the next step is usually to conduct a feasibility audit. A contract is signed between the client and the ESCO to conduct this audit. Terms and conditions of this contract are: scope and schedule; the ESCO's fee; and the format and content of the deliverables [36].

This audit is done by the selected ESCO to [36]:

- Verify information gathered during the initial investigation.
- Determine the significance of the possible energy savings.
- Compile the scope of work for the initiative.
- Calculate the feasibility of the initiative.

Various issues are addressed in the performance-based contract between the client and the ESCO. Some of these issues include the performance of the project, financing of the project and the ESCO's compensation. This ensures that the project is successfully implemented and executed without any disputes between the parties involved. A detailed M&V plan is also compiled that stipulates how the performance of the project will be verified.

It was found that performance-based contracts between ESCOs and clients tend to be long-term contracts. Contracts can typically be between 10–25 years, depending on the return on investment of the energy savings initiative. Long-term contracts are more reasonable for both parties in a healthy, first-world economy, which is typically found in developed countries. Long-term contracts can be signed with a reasonable amount of certainty that the client will keep on doing business in the long run [37], [38], [39].

In the USA, the ESCO market primarily focuses on energy efficiency improvements in the public market, local government and state facilities. Most clients include schools, universities and hospitals. Although ESCOs have also implemented initiatives in the commercial and industrial sector, limited success has been achieved in these markets. ESCOs can participate in federal energy efficiency programmes to obtain funding to implement energy efficiency initiatives [40].

In Europe, the majority of initiatives implemented by ESCOs have been implemented in the public sector [33]. It was found that initiatives implemented by ESCOs in the industrial sectors of developed countries declined over the past decade. It is believed that the reason for this occurrence is that industrial processes in developed countries are already mostly energy efficient, leaving small room of improvement [24].

Although it has been found that ESCOs are mainly privately owned companies in developed countries, studies showed different recent trends in the UK. ESCOs are still mainly privately owned, but recent studies proposed that local authorities should get more involved with the UK ESCO model. The main reasons for this argument were [39]:

- Privately owned ESCOs tend to prioritise energy savings initiatives according to financial returns, rather than to common good benefits such as environmental impact.
- Privately owned ESCOs tend to take a significant amount of the total project revenue, which is then reinvested outside the local areas.

Although ESCO models in developed countries tend to vary significantly, various similar concepts were identified. In almost each of the developed countries investigated, the awareness and understanding of the ESCO market grew as the importance of cost efficient energy consumption increased. This was mainly due to growing energy cost and environmental awareness.

The procurement process was identified as one of the main barriers of implementing ESCO energy savings initiatives. Several European countries tend to remove public procurement rules that unnecessary delay ESCO initiatives. New procedures that have been implemented, which are more receptive to ESCO energy savings initiatives, include [28]:

- A new procurement law adopted by Spain in 2007 limits long-term service contracts to only 20 years.
- The new Public Private Partnership law in Greece (3389/2005) allows public institutions to appoint privately owned ESCOs to manage building energy services.
- The Energy Efficiency Agreements of 2008–2016 in Finland are aimed at encouraging municipalities to use ESCOs to implement energy efficiency initiatives.

Literature indicated that utilities tend to fund DSM programmes when long-term shortages in electricity generation are being experienced. DSM is then considered as a better solution than building new power plants. These DSM programmes entail providing technical information to clients on how they can improve their electricity consumption; installing energy efficiency technology; and reducing peak demand [41].

In most developed countries, provisions have been made to expand the electricity generation capacity in time to meet the growing demand. Utilities are, therefore, not pressured to implement

DSM as part of a solution to match electricity supply with demand. In fact, studies indicated that when utilities contribute to energy efficiency DSM initiatives, electricity sales tend to decrease [41]. Figure 9 summaries the characteristics of a typical ESCO DSM model in a developed country.

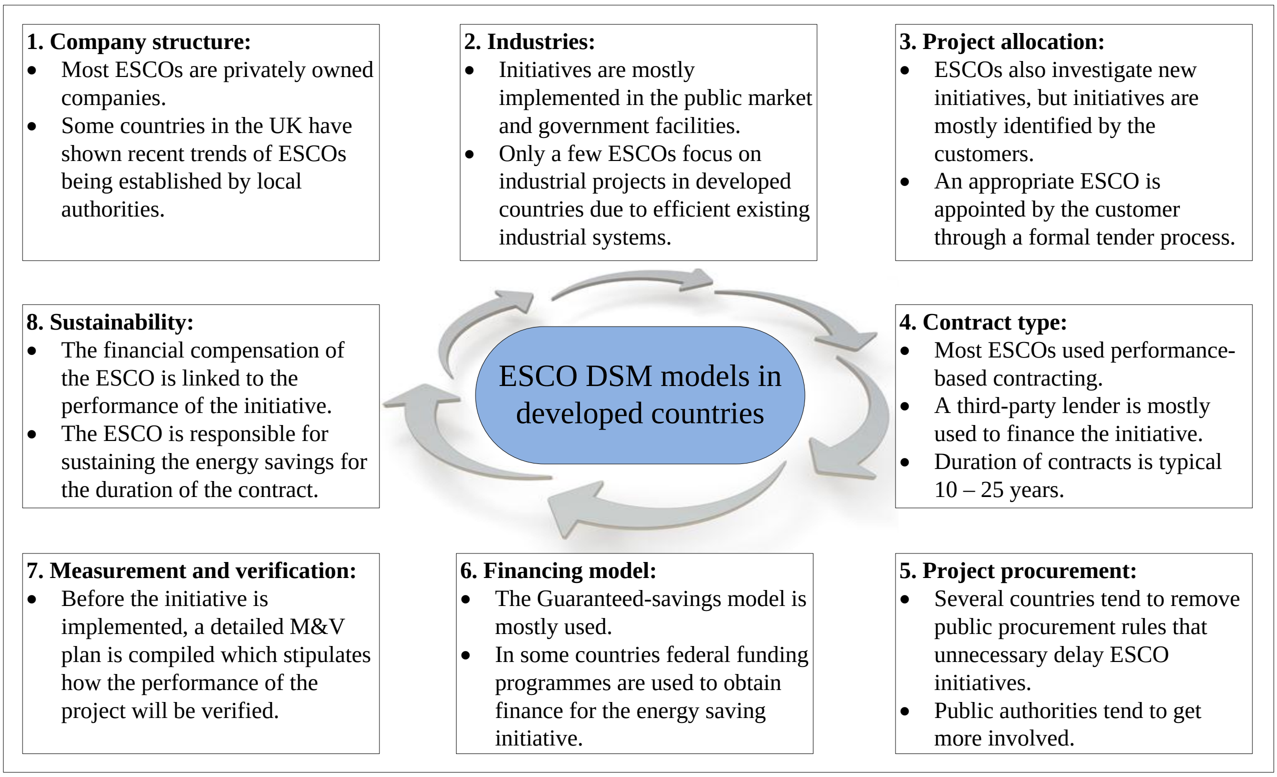


Figure 9: Summary of ESCO DSM models in developed countries

The use of renewable power (such as wind and solar power) is expanding rapidly in developed countries. Some studies claim that renewable energy is the fastest growing electricity source, with traditional coal-fired and nuclear power stations languishing behind. This also changes the purpose of DSM. It is estimated that clients will have to adapt their electricity consumption according to the availability of renewable generation power in the future. DSM will then be used to manage clients' consumption in order to maintain the stability of the electricity supply grid.

2.2.3 DSM in developing countries

From literature, it has been found that ESCOs in developing countries mostly use the shared-savings model to finance energy savings initiatives. This is mainly because the client has no financial risk with this financing model. Borrowing money in developing economies also tends to be more expensive than in developed economies. This supports the fact that clients in developing countries would rather select the shared-savings financing model [31].

Unfortunately, the shared-savings model does not promote long-term ESCO market growth. Due to a limited credit history, newly established ESCOs are struggling to obtain financing for new energy savings initiatives. This makes it difficult for new ESCOs to enter the market and limits healthy competition between ESCOs [42]. Clients in developing countries are also hesitant to invest in energy savings initiatives. If an energy savings initiative is approached, the client mostly pursues short-term benefits [43].

Similar to the ESCO market in developed countries, ESCOs in developing countries also tend to implement energy savings initiatives based on the performance-contracting method. ESCOs are usually synonymous with performance-based energy savings initiatives and are responsible for designing, developing and installing these initiatives. They are also responsible for the M&V of the savings achieved, and the maintenance involved during the project contract period [44], [45].

Through literature, it has been found that there is tremendous potential for implementing energy savings initiatives in developing countries [46]. As a result of already established ESCO markets in developed countries, the potential for energy savings in developing countries tends to be higher. The need for a healthy growing ESCO market in developing countries is therefore curtailed.

An assessment financed by the Central European University on ESCOs worldwide, identified various barriers preventing the growth of ESCO markets in developing countries. It was found that although experience and lessons learned from various countries can be shared, barriers preventing ESCO market growth is mostly country-specific. The need for local experts in energy savings initiatives was highlighted [47].

Vine also did a study to determine the barriers influencing the growth of the ESCO market in most developing countries. From 1 500 case studies, the following most common barriers were identified [45]:

- Lack of knowledge regarding energy savings initiatives and energy efficiency opportunities.
- Difficulty to obtain finance for energy savings initiatives because financial institutions are not familiar with energy efficiency and performance contracting.

- Procurement processes making it difficult for clients to use an ESCO to implement energy savings initiatives.
- New technology not being used due to the client being unfamiliar with the technology.

Although all of the above-mentioned barriers are obstacles in developing countries, studies showed that financing challenges is the biggest obstacle. ESCOs are in most cases responsible for the financing of the initiatives (shared-savings financing model). To minimise risks, ESCOs tend to focus on initiatives with relatively small payback periods. Performance-based contracts in developing countries tend to have contract periods of 5–10 years [45].

Unlike developed countries, various developing countries are facing electricity generation shortage constraints. Some developing countries that are struggling to expand their electricity generation capacities to meet growing electricity demands are Brazil, China, Pakistan, Nepal, Bangladesh and India [48], [49], [50]. Some African countries that recently had to implement load shedding because of electricity generation shortages are Ghana, Botswana and Zimbabwe[13].

The energy consumption of India is considered the fourth-highest energy consumption of all the countries worldwide[14]. Their annual economic growth is 8–9%, with the electricity demand also increasing year-on-year. Due to the increasing demand for electricity, their power industry is facing supply shortages. Other challenges include transmission losses, distribution losses and power theft. It is estimated that the total power lost due to these challenges amounts to 50% of the generated power[15].

India expanded their electricity generation capacity from 30 GW in 1981 to over 229 GW in 2013. Despite the expansion of their generation capacity, India is still struggling to meet the growing electricity demand. Although India is currently experiencing shortages in overall electricity generation, generation shortages during peak hours are their biggest concern. Hence, efficient load management strategies are being prioritised over energy efficiency strategies [51], [52].

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[13] Load shedding around the world (2014). [Online]. Available: http://mybroadband.co.za/news/general/115213-load-shedding-around-the-world.html. [Accessed: 24 June 2015]
[14] US Energy Information Administration: Report on India. (2013). [Online]. Available: http://www.eia.gov/countries/analysisbriefs/India/india.pdf. [Accessed: 06 July 2015]
[15] CEA: Power scenario at a glance (2012). [Online]. Available: www.cea.nic.in/reports/planning/power_scenario.pdf. [Accessed: 06 July 2015]

India’s economy is primarily based on agriculture – with this sector consuming more than 30% of the total power being generated. Other major electricity consumers include residential, commercial and industrial consumers. Electricity supply-side solutions are considered a more reliable approach than demand-side solutions to meet the growing electricity demand. Inadequate revenue collection by utilities and a lack of access to capital, however, force utilities to consider demand-side solutions [53], [54].

In India, DSM is considered as a utility-driven programme involving end-use efficiency and load management. Although DSM is primarily driven by utility programmes, government policies and client participation also promote DSM. DSM initiatives involve TOU tariff structures, incentives for energy efficiency and load management initiatives, and information programmes informing clients of different DSM initiatives and financing options [51].

Although DSM initiatives have been implemented as a short- to medium-term solution to the electricity generation shortage, commercial and industrial clients have to face load shedding occasionally. Barriers that prevent the successful implementation of DSM initiatives in India include [54], [55]:

- the lack of technical abilities,
- poor financial situation of state-owned utilities,
- lack of industry awareness,
- inappropriate policies influencing the procurement of DSM initiatives, and
- the availability of sufficient financing for DSM initiatives.

Although a multi-objective DSM solution to reduce peak demand in India has been developed [55], a different study identified the need for a larger scale DSM programme to be implemented [54]. This study developed an action plan that utilities could use to implement DSM programmes. This action plan is shown in Table 4.

Table 4: Action plan for implementing a DSM programme in India

Step	Description	Responsible party
1	Assess current electricity market	Not specified
2	Forecast end-use demand/load	Utility

Step	Description	Responsible party
3	Perform load/market research	Utility
4	Define load shape objectives	Utility
5	Identify sources of financing	Regulatory
6	Select/design programme	Utility
7	Analyse cost benefit	Not specified
8	Identify economic and environmental impact	Regulatory
9	Plan programme implementation	Utility
10	Monitor and evaluate	Not specified

The electricity constraint in India is mostly similar to the electricity constraint in South Africa. Although the action plan shown in Table 4 is not comprehensive regarding the responsible party for each step, this action plan could be useful when evaluating the South African DSM approach.

As a result of the uncertainty regarding future economic growth in developing countries, clients are scared to commit to initiatives with long-term payback periods. Although utilities and government institutions tend to fund DSM initiatives in developing countries, clients tend to contribute only when the payback period is relatively small. Figure 10 summarises the characteristics of ESCO DSM models in developing countries.

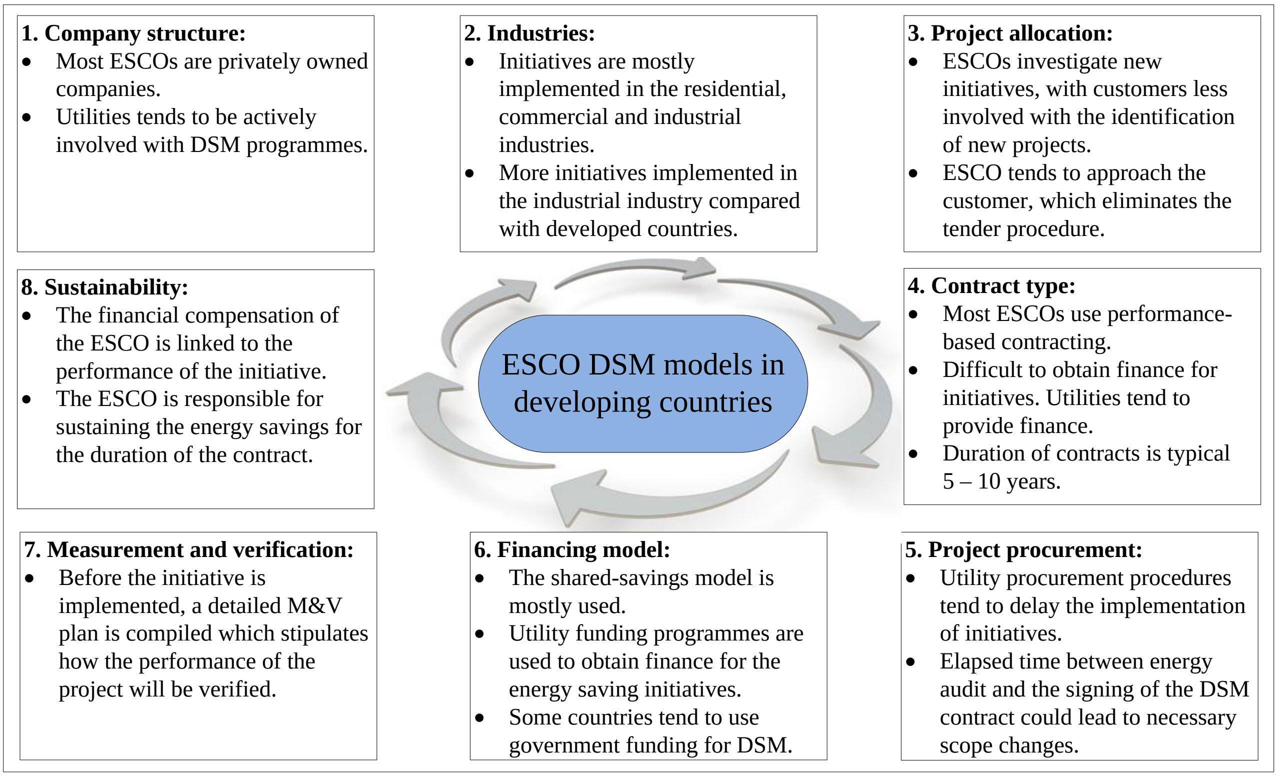

Figure 10: Summary of ESCO DSM models in developing countries

ESCO markets in developing countries are small compared with ESCO markets in developed countries. It is difficult for new ESCOs to enter the market in developing countries because of uncertain long-term economic growth, which makes it difficult for new ESCOs to obtain finance to implement DSM initiatives. This results in fewer ESCOs being established in developing countries, thus limiting healthy competition between ESCOs.

The next section will focus on the DSM programmes implemented in South Africa. The different South African DSM models will be investigated whereafter the ESCO DSM model will be discussed in more detail. The South African ESCO DSM approach will be compared with the characteristics of ESCO DSM models in developed and developing countries.

2.3 Evaluating the South African DSM approach

2.3.1 Existing DSM models

As a result of the South African electricity system being under constant strain, DSM is being actively driven by Eskom. Due to various challenges being faced by Eskom with the building of the Medupi and Kusile coal power plants, the commissioning dates are being delayed. This puts the electricity network under even more strain with the demand for electricity that keeps on growing. This leaves Eskom with DSM, the running of gas turbines and load shedding as short-term solutions to solve the immediate problem.

Eskom also implemented the demand response programme to assist with the electricity supply shortage. As part of the Eskom demand response programme, Eskom asks large electricity-consuming clients to reduce their consumption in times when the electricity demand threatens to exceed the available supply capacity. The demand response programme is, therefore, seen as controlled load shedding [56], [57].

As part of the South African DSM programme, Eskom developed six funding models to drive different DSM initiatives actively. These models are [58]:

- the rebate model,
- the standard product model,
- the standard offer model,
- the performance-contracting model,
- the client model, and
- the ESCO funding model.

For the purpose of this study, electricity consumers will be referred to as clients.

The rebate model is structured to pay the client an incentive for improving the efficiency of inefficient systems/technologies. However, the client has to be registered for this funding model – applying for funds can be a time-consuming process. Typical programmes registered for this funding model are solar water heating and residential heat pump programmes.

The standard product and standard offer funding models were developed for clients with a potential load saving of between 1–100 kW and 100 kW–5 MW respectively. These models ensure a fast project approval and payment process. Projects approved by Eskom for these funding models include projects that replace inefficient technologies with standard, efficient, off-the-shelf components. A typical standard product model project is replacing lighting equipment. A typical standard offer model project is improving a plant’s load factor.

The performance-contracting model aims to contract project developers to achieve verified energy savings across multiple sites and technologies. The minimum project size is a saving of 30 GWh over a period of three years. The focus of this model is to achieve energy efficiency savings between 06:00 and 22:00 during weekdays. With projects funded through this model, administration requirements, project lead times and contractual complexity are reduced.

With the performance-contracting model, Eskom issues energy savings blocks available for performance-contracting projects. The project developer has the opportunity to tender for a savings block. The tender should include delivery time frames, project proposals, savings possible and the complexity of the M&V. If the tender is awarded to the project developer, it is their responsibility to finance the implementation. Eskom pays the project developer at fixed intervals for verified savings achieved.

The client model is designed for clients who want to implement energy reduction initiatives on their own. In order for the client to qualify for funding, the client needs to register with Eskom as an ESCO. A contract is then signed between Eskom and the client. Eskom also has an advisory team with offices across the country to provide advice regarding effective and efficient electricity use to clients.

The ESCO funding model is designed for companies specialising in energy efficiency and load management. An ESCO who is accredited by Eskom can submit any project with a load saving potential of 100 kW or more. The ESCO identifies energy savings projects at client premises and submit these projects to Eskom. A three-way partnership between the ESCO, Eskom and the client is established. The ESCO uses their knowledge of DSM and the latest technologies to implement the energy savings project.

For the purpose of this study, ESCOs submitting projects for the ESCO funding model are going to be divided into two groups:

1. ESCOs who submit projects related to residential areas and large buildings.
2. ESCOs who submit projects related to industrial sites.

In this study, the sole focus is on the industrial DSM ESCO model that finances projects related to industrial sites. These projects are mainly implemented in the gold and platinum mining sectors, cement industry and water distribution networks. Figure 11 provides a summary of the different Eskom DSM funding models available for different types of DSM initiative.

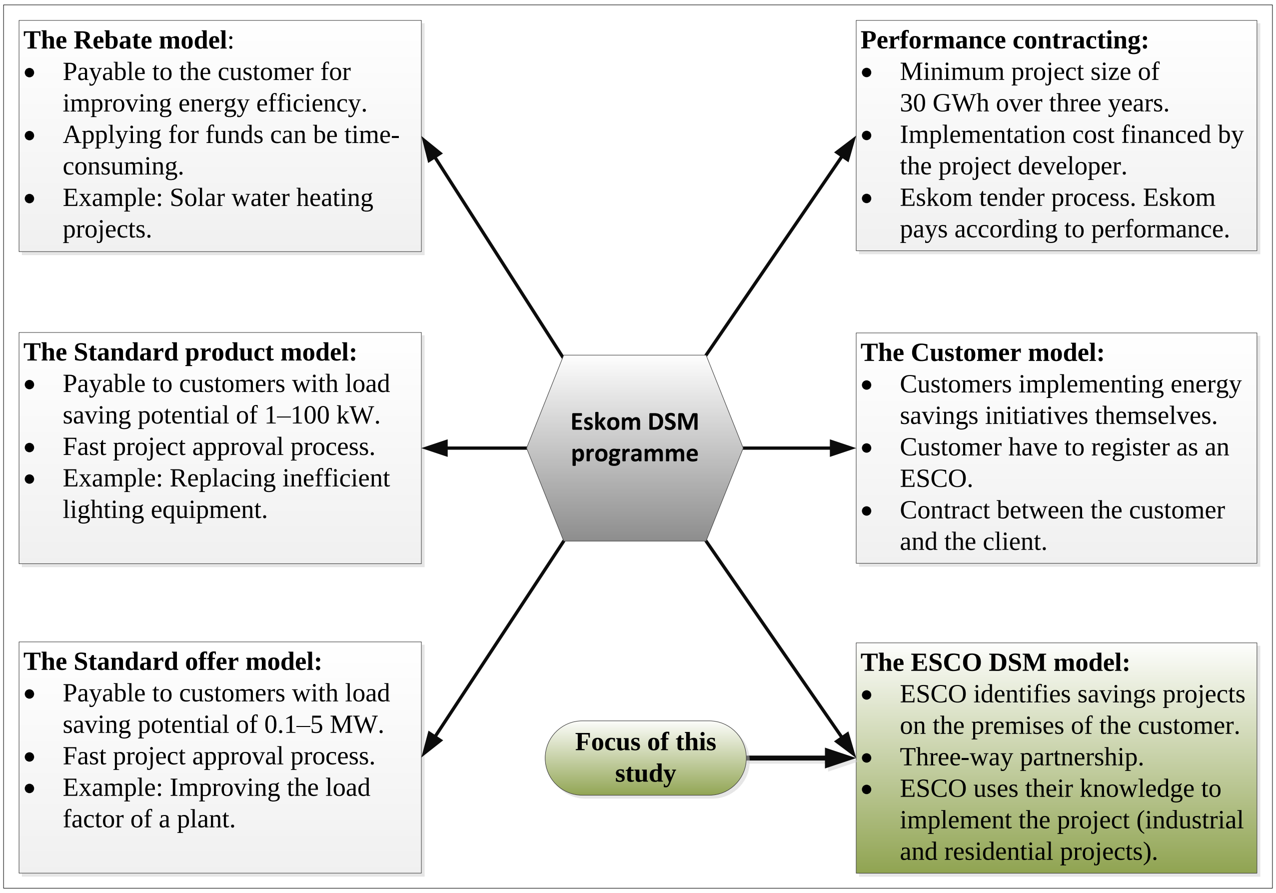

Figure 11: Eskom DSM funding model summary

The following section will provide more detail regarding the use of the ESCO DSM model to implement projects in the industrial sector.

2.3.2 ESCO DSM model

In order to explain the DSM ESCO model in detail, the model will be divided into five phases:

1. project investigation,
2. proposal approval,
3. project implementation,
4. project assessment, and
5. maintenance.

Project investigation phase

Before an ESCO can proceed with an in-depth investigation, certain documentation needs to be in place between the ESCO and the client. This documentation usually consists of a confidentiality agreement between the ESCO and the client, thereby giving the ESCO permission to obtain information regarding a certain sub-section of the client's operation.

During the project investigation, the ESCO identifies possible energy savings initiatives on the premises of the client. The ESCO determines the project type, infrastructure required, possible savings, project sustainability and the impact of the project on the environment. This information is verified with the client and the feasibility of the project is determined.

Some projects are not completely financed by Eskom. In these situations, the client also needs to contribute a certain percentage to the total project cost. The ESCO will take the client contribution and the expected cost savings of the project into account when calculating a payback period. The client approves the project in terms of the payback period, project scope, implementation period and project feasibility.

The ESCO needs to finance the project investigation since Eskom funds only become available after the utility approval phase. Some costs related to the project investigation phase are:

- labour cost of the engineers doing the investigations,
- travel expenses and
- accommodation cost.

Proposal approval phase

After the necessary design reviews have been done to re-evaluate the findings during the project investigation, the client preliminary approves the project. The ESCO prepares the standard Eskom proposal document. Information such as project type, expected savings, load profiles, project scope, infrastructure cost and project risks need to be included in the proposal document. The completed proposal document is submitted to the Eskom Project Evaluation Committee (PEC) for approval.

The PEC evaluates the technical aspects of the project. After the PEC approves the project, the ESCO and the client sign the proposal document. The PEC submits the approved proposal document to the Eskom Capital Investment Committee (CIC) for financial approval. The CIC evaluates the project in terms of financial feasibility.

After the CIC has found the project to be financially feasible, the project needs to go through the Eskom procurement process. During the procurement process, the ESCO negotiates the terms and conditions of the DSM contract with Eskom. Terms such as project management cost, ESCO technology cost, implementation period and payment conditions are agreed.

If the client contributes to the project funding, the terms and conditions of a DSM contract between Eskom and the client should also be discussed. Terms such as the client contribution, payment conditions and penalties (if the savings are not maintained) should be agreed. The signing of a DSM contract between Eskom and the ESCO (and between Eskom and the client if necessary) is the end of the procurement process.

Eskom appoints an independent M&V company to verify the savings achieved by the ESCO after project implementation. The M&V company develops a baseline that will be used to measure the performance of the project after implementation. Depending on the type of the project, a scaling model is developed to scale the baseline if necessary. This information is signed off by the ESCO and the client in the form of a report (also known as the baseline report).

Project implementation phase

It is the responsibility of the ESCO to implement the project according to the agreed project scope. The first step in the project implementation process is for the ESCO to appoint a sub-contractor who will implement the project. The ESCO should follow the normal tender process to select an appropriate sub-contractor:

1. Compile a detailed request for quotation document.
2. Arrange a site visit with at least three sub-contractors.
3. Evaluate the quotations received.
4. Appoint the most appropriate sub-contractor.

When an appropriate sub-contractor is selected, various factors such as cost, skills, localisation development and transformation should be considered. When a sub-contractor has been chosen, contract terms and conditions between the ESCO and the sub-contractor should be negotiated.

When the terms and conditions are agreed, a contract is signed between the ESCO and the sub-contractor.

The ESCO is still responsible for managing the sub-contractor to ensure that the project deadlines are met and that the client is satisfied with the installations. After the project has been implemented, the client signs a completion certificate indicating that the project has been implemented according to standard. The completion certificate is sent to the M&V company. It serves as proof that the project has been completed. The PA period can commence.

PA phase

It is the responsibility of the ESCO to prove that the projects meet the proposed savings as stipulated in the Eskom proposal document and the DSM contract. This is done for three consecutive months after project commissioning. The savings are verified by the M&V company based on the terms stipulated in the signed baseline report.

The M&V company compiles a PA report after each month, reporting on the project performance during that month. After the PA period, the M&V compiles a performance certificate that indicates the verified project performance during the PA period. The ESCO uses the values of the performance certificate to compile a Measure Acceptance Date (MAD) document, which is signed off by the client. If the savings target was not achieved during the three months of PA, the ESCO is liable to pay penalties.

Maintenance phase

After the PA period, the project is handed over to the client. The client becomes responsible for maintaining the project savings. Depending on the DSM contract, the client can be responsible to maintain the savings for up to five years after the PA period. The client's savings target is usually the lowest value between the MAD value and the original project target (as stipulated in the DSM contract).

After the PA period, the M&V company keeps track of the project performance on a monthly basis. Should the client fail to maintain the project savings target, Eskom could hold them liable for penalties as stipulated in the DSM contract. The client can sign a contract with the ESCO to maintain the project after the PA period, but this is an agreement between the client and the ESCO. It does not form part of the ESCO DSM model.

Recent changes to the DSM ESCO model have been made by Eskom. These changes should be considered when the alternative approach to the industrial DSM ESCO model is developed. Figure 12 provides a summary of the DSM ESCO model and the proposed time frames for each model phase, considering the latest changes made by Eskom.

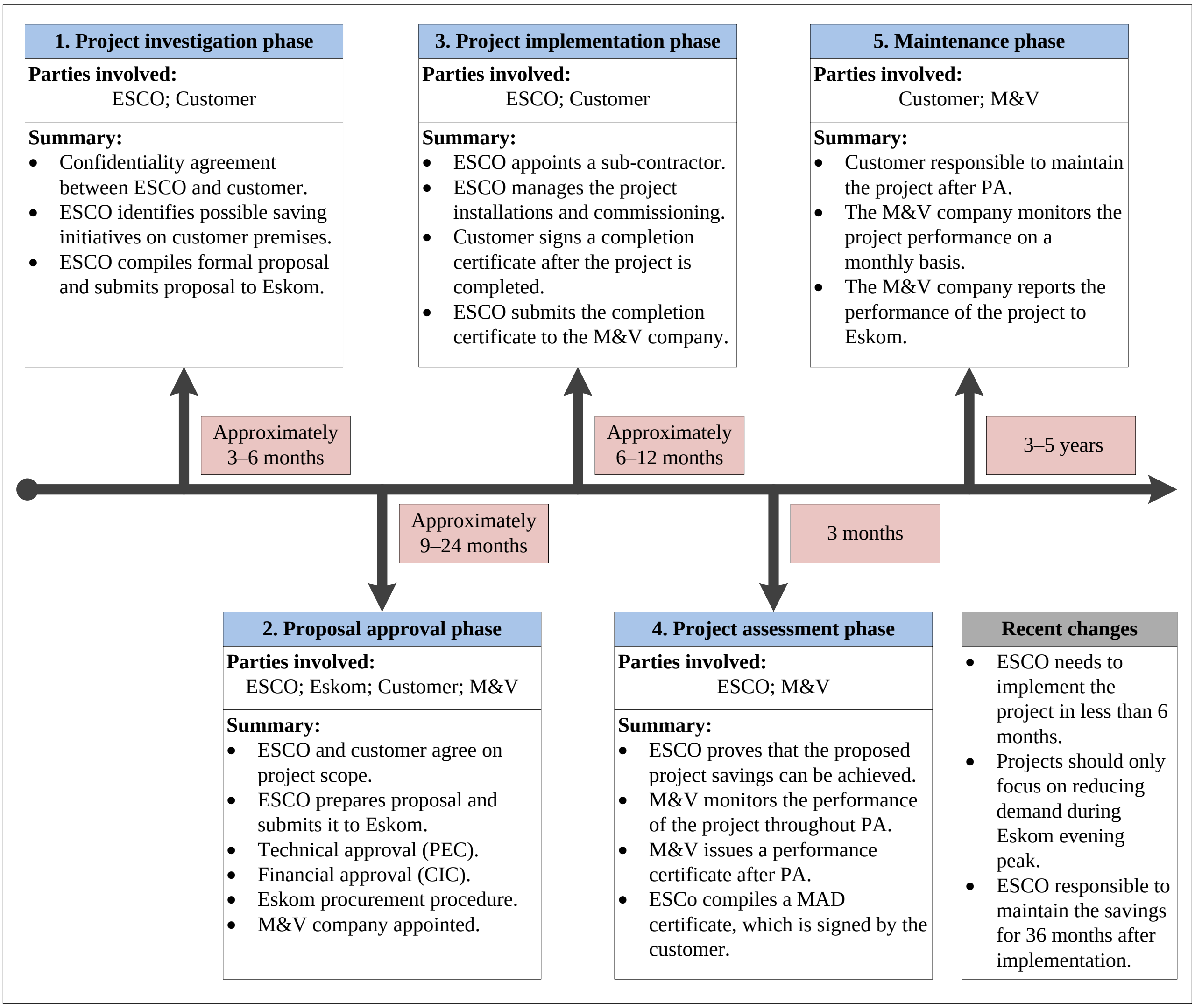

Figure 12: DSM ESCO model summary

In April 2015, Eskom announced that ESCOs could submit new proposals for DSM projects until 30 June 2015. Changes to the existing DSM ESCO model were also implemented. Only projects with a maximum implementation period of six months would be considered. These projects had to obtain electricity savings equal or greater than 500 kW. The ESCO had to sustain the savings over a period of 36 months[16].

The payment structure has also been changed to ensure sustainable project savings during the Eskom evening peak period. Eskom will pay the ESCO 30% of the payment after three months of verified savings. The remaining 70% of the payment will be made in equal payments every quarter, subjected to the verified savings achieved. A retention amount of 10% per invoice is payable if the skills development and localisation (SD&L) obligations are met.

Research has been done on ESCO DSM models in developed countries, developing countries and in South Africa. Following the research, the South African ESCO DSM model can be compared with similar models found in developed and developing countries. This information can be used to develop an alternative approach to the South African ESCO DSM model to ensure sustainable savings. Table 5 compares the different ESCO DSM models.

Table 5: Comparison between different ESCO DSM models

Developed countries	**Developing countries**	**South Africa**
Established ESCO market.	Relative small ESCO market.	Relative small ESCO market, especially in the industrial sector.
Uses performance-based contracting.	Uses performance-based contracting.	ESCOs are only responsible for sustaining the project savings for three months after PA.
Uses the guaranteed-savings financing model.	Uses the shared-savings financing model. Utilities tend to finance DSM initiatives.	Eskom funds are mostly used to finance industrial DSM projects.
Contract duration 10–25 years.	Contract duration 5–10 years.	Contract duration 3–5 years.
Projects are mostly implemented in the public market and government facilities.	Compared with developed countries, more opportunities exist in the industrial sector.	Projects are mostly implemented in residential, commercial and industrial industries.

[16] Adapted from “ESCO model: Invitation to submit energy efficiency project”. [Online]. Available: http://www.eskom.co.za/sites/idm/pages/whattsupaccordion.aspx?tabid=pnl_33. [Accessed: 09 July 2015]

Developed countries	Developing countries	South Africa
Clients allocate projects to ESCOs through a formal tender process.	ESCOs tend to approach clients.	ESCO investigates projects and approaches the client with a project proposal.
Client funds the project investigation. Client provides full cooperation during the investigation.	ESCO is usually responsible for funding the project investigation.	ESCO funds the project investigation. Sometimes clients do not cooperate during the investigation.

2.4 Challenges of DSM project investigation and implementation

In section 2.3.2, the ESCO DSM model was divided into five phases. The first three phases of the ESCO DSM model are divided into more detailed steps to identify the challenges relating to each model phase accurately. Each step will be investigated during this section. The detailed steps of each model phase are shown in Table 6.

Table 6: DSM ESCO model – detailed project investigation and implementation steps

Model phases	Detailed steps
1. Project investigation	1.1. Confidentiality agreement
	1.2. Energy audit
	1.3. Client preliminary approval
	1.4. Develop DSM proposal
2. Proposal approval	2.1. Eskom PEC and CIC approval
	2.2. Eskom procurement process
	2.3. Appoint M&V team; baseline report
3. Project implementation	3.1. ESCO appoints and manages sub-contractor
	3.2. Implementation and commissioning
	3.3. Project completion confirmation

During the previous section, the importance of an established ESCO market was highlighted. It was found that most developed countries have large established ESCO markets. Most developing countries have relatively small ESCO markets when compared with developed countries. South Africa is no different to other developing countries with its relatively small ESCO market, especially in the industrial sector [45], [47].

Most studies indicated that obtaining finance for DSM projects is the main obstacle for establishing a large ESCO market in developing countries [59], [60], [61]. Eskom supplied ample financing support during the past decade through its DSM programme, but not with the same consistency each year. This challenge and its effect on the ESCO market will be discussed in detail.

A study conducted by the Centre for Research and Continuing Engineering Development (CRCED) further found that the reason for the small South African industrial ESCO market is the unique challenges facing industrial DSM projects [62].

Challenges during the project investigation phase

It was found that ESCOs in developed countries are usually contracted by clients to do energy audits on systems as part of the investigation phase. The first major challenge facing ESCOs that implement DSM projects in the industrial sector of South Africa is that the project investigation has to be financed by the ESCO. The risk, therefore, exists that ESCO time and money will be spent on an investigation without the project being approved and implemented [62].

During the energy audit step, the biggest challenge for an ESCO is to do a proper investigation with the funds that are available. Due to the uncertainty of whether a project will be feasible and will be approved by Eskom, ESCOs tend to do quick and inexpensive investigations. These investigations can be inaccurate and can result in target savings not being achieved. An example is running statuses of equipment being used to establish baselines instead of buying expensive electric power loggers to log power data at key locations.

Considering that an ESCO obtains sensitive information (such as layouts, power and production data), a confidentiality agreement between the ESCO and client has to be signed. Compiling a confidentiality agreement between an ESCO and client can be a time-consuming event. The terms and conditions have to be agreed upon by both parties and a lack of commitment from the client can sometimes delay the process even further.

In addition to inaccurate investigations, ESCOs tend to propose unrealistic savings targets. The complexity of DSM projects is sometimes misjudged and safety margins are not built into the proposed savings targets. The inability of ESCOs to predict unforeseen events that could affect the savings target also contributes to unrealistic targets being proposed. This could result in Eskom financing a DSM project that will not achieve the proposed project target.

The effect seasonal changes can have on an industrial DSM project is sometimes overlooked during the project investigation phase. It is often found that an ESCO proposes an annual savings target without considering that the system might consume less electrical power during other periods of the year. An example of such a system is a refrigeration system on a deep level mine. During summer months, the refrigeration system is used to generate cold water, which is used to cool down the underground working environment. The use of this refrigeration machinery is reduced as the winter approaches and less cooling is required [63].

Another challenge is the cooperation of the client during the energy audit step. It is often found that management personnel welcome the energy audit, but technical personnel are not comfortable with an external company evaluating their system. Important technical information that can influence the outcome of the investigation is often withheld due to the following reasons:

- Technical personnel do not have sufficient time to assist the ESCO properly when they analyse the system.
- Technical personnel are scared that automating a system could affect their job viability.
- Technical personnel do not welcome system changes due to a resistance to change.

Various industrial DSM projects have been financed through the Eskom DSM programme over the past decade. Obtaining funding for industrial DSM projects in South Africa was, therefore, not such a serious problem when compared with other developing countries. Although ample funding for industrial DSM projects was available at times, the Eskom drive towards the DSM programme had been inconsistent during the past decade.

As a result of the inconsistent DSM drive, ESCOs could not enter the industrial ESCO market with certainty that Eskom would allocate funding for future DSM projects. This made it difficult to establish a large competitive ESCO market. Because of this uncertainty, established ESCOs tend to submit proposals without doing proper investigations during times when the Eskom drive behind the DSM programme is not high. This is mainly to minimise investigation cost while submitting new projects, which can be approved when DSM funding become available.

Challenges during the proposal approval phase

After an ESCO submits a project proposal to Eskom, the project has to be approved technically. As discussed in section 2.3.2, this process is known as the PEC process which can take up to four months. Thereafter, approval for the financing of the project has to be obtained by submitting the proposal to the CIC. Securing financing for a project can be troublesome and time-consuming as the CIC approval process can also take up to five months [62].

Literature showed that the procurement process discussed in section 2.3.2 can take 11 to 15 months. This means that the total project proposal approval process can take up to 24 months. This could result in cash flow challenges for the ESCOs who are submitting projects. Another challenge is system changes that take place during the project proposal approval period, which follows the project investigation period. These system changes can affect either the achievable project savings or the project scope or both.

Another challenge is political transformation policies enforced by Eskom when an M&V company is appointed to measure and verify savings. Political transformation is important, but it is often found that M&V companies without the necessary experience are appointed to develop a baseline and scaling model. ESCOs tend to take advantage of such M&V companies in order to establish inaccurate baselines and scaling models, which can benefit the ESCO during the PA of the project.

Challenges during the project implementation phase

Due to the dynamic nature of industrial systems, major differences could occur in the power consumption profile of a system between project investigation and implementation. The difference in power consumption could be due to various reasons such as production and system changes. Figure 13 displays the power profiles of a dewatering system on a deep level gold mine during the project investigation phase and after the Eskom project approval phase.

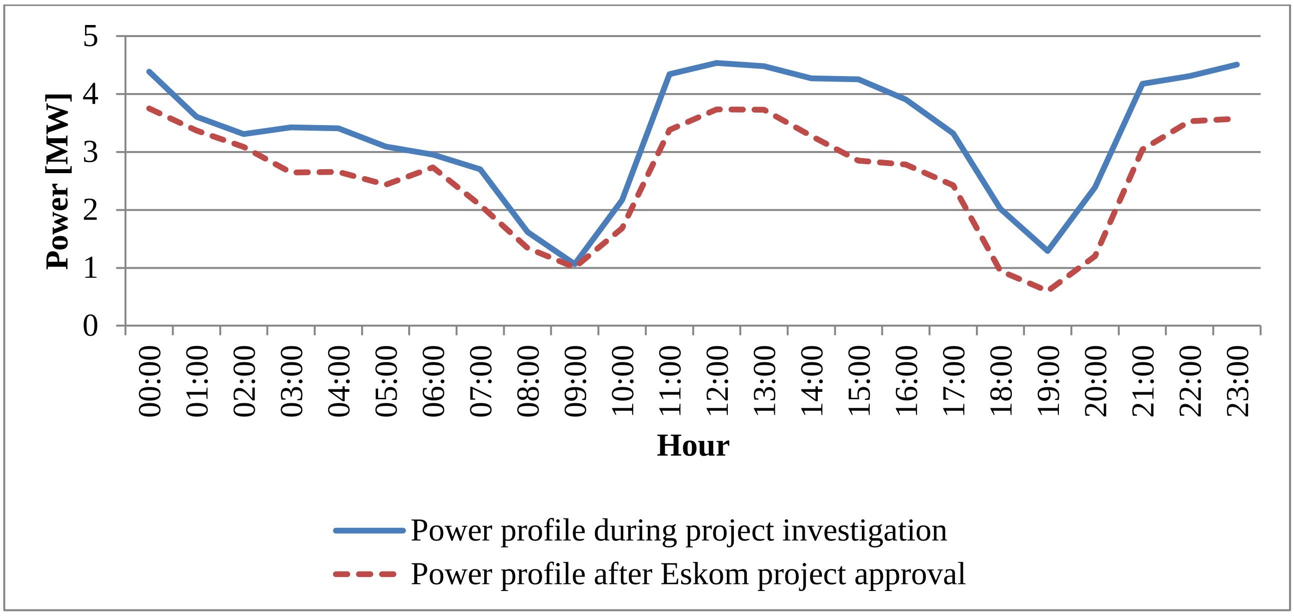

Figure 13: System changes affecting the power consumption profile

The power profile in Figure 13, measured during the project investigation, showed a power reduction potential of 1.6 MW during the evening peak period (18:00–20:00). The Eskom project approval phase took 18 months. During the Eskom project approval phase, the mine experienced a decrease in production. The mine also implemented a more effective load management strategy on its own. These changes reduced the possible power reduction during the evening peak period to 0.8 MW.

An ESCO, therefore, needs to re-evaluate a system after the Eskom project approval phase to confirm that the information obtained during the project investigation is still valid. This re-evaluation procedure could delay the implementation of a project even further. It could also result in additional costs for the ESCO. Another challenge is the cost escalation of equipment that has to be installed as part of the project scope.

Due to the length of the time period between the initial investigation and the project implementation, disputes between an ESCO and client regarding the project scope could arise. Literature advises ESCOs to draw up a detailed project scope directly after the project investigation phase in order to avoid disputes [62].

Industrial DSM projects usually require the installation of specialised equipment such as variable speed drives (VSDs), programmable logic controllers (PLCs) and control valves. Sub-contractors specialising in the installation and commissioning of this equipment are usually contracted by ESCOs to install the equipment. Managing sub-contractors is one of the most important responsibilities of ESCOs [64].

Challenges regarding the management of sub-contractors include [62]:

- Ineffective communication between the parties involved.
- Scope changes by the sub-contractor without the necessary approval.
- Sub-contractors failing to comply with the rules and regulations of the client.
- Insufficient access to the working areas.
- Sub-contractors not taking responsibility to achieve the project deadlines.

Political transformation and SD&L regulations enforced by Eskom on ESCOs also pose various challenges. The biggest challenge ESCOs face in this regard is finding reliable sub-contractors who have the required experience and who comply with the political transformation and SD&L regulations of Eskom.

Other challenges that could occur during the project implementation phase include:

- Delays in the procurement of equipment.
- Insufficient cooperation of the client.
- Machinery that cannot be stopped to install and commission certain equipment.

Summary of DSM ESCO model challenges

Table 7 summarises the challenges identified regarding the project investigation, proposal approval and project implementation phases. Chapter 3 will evaluate these challenges together with the existing DSM ESCO model. A new model or an alternative approach to the existing model should be developed to eliminate the negative effects of the challenges. The effects of the challenges identified are summarised in Table 7.

Table 7: Project investigation and implementation challenges summary

No.	Challenge identified	Effect
1.	Inconsistent DSM drive by Eskom	Small, not competitive ESCO market; inaccurate proposals
2.	Investigation financed by ESCO	Inaccurate investigations

No.	Challenge identified	Effect
3.	Unrealistic savings proposed by ESCO	Eskom funding spent without achieving expected results
4.	The effect of seasonal changes	Annual savings target not being achieved
5.	Insufficient cooperation of the client	Insufficient information; ineffective spending of funds
6.	Time-consuming project approval	System changes; cost inflation; baseline changes
7.	Political transformation and SD&L policies	ESCOs taking advantage of inexperienced M&V companies
		Few sub-contractors with sufficient experience
8.	Sub-contractor management	Project deadlines not achieved; implementation not on standard

2.5 Investigate existing project M&V procedures

Industrial DSM projects benefit both clients and Eskom. Clients benefit in terms of lower electricity costs because of more efficient systems, or more effective management of their electricity usage. The lower electricity demand, especially during the evening peak periods, benefits Eskom.

The performance of a DSM project is used by Eskom and the client to quantify the benefits of the project. It is, therefore, important that savings achieved by DSM projects are measured accurately and continuously. Inaccurate M&V of the performance of DSM projects could mislead the stakeholders, resulting in ineffective spending of funding of future DSM projects.

The amount of Eskom funding allocated to a project mostly depends on the expected electricity savings for a project. The value (return on investment) received for the funds spent by Eskom depends on the actual performance of that project and how well the savings are maintained. Eskom also uses the performance of historical DSM projects to justify the need to implement future DSM projects.

In some cases, clients also provide funding to implement industrial DSM projects on their systems. The actual performance of those projects are important to the clients to determine their actual return on investment. Depending on the DSM contract, clients could pay penalties to Eskom if projects do not perform. It is, therefore, important that the performance of industrial DSM projects is accurately measured and verified on a continuous basis.

As mentioned in section 2.3.2, Eskom appoints an independent M&V team to measure and verify the savings achieved by an industrial DSM project. The independence of the M&V team increases the confidence in the reported results. The appointed M&V team is responsible to determine the project savings and the social, economic and environmental impact of the project. These results are calculated on a monthly basis and are published in a formal report [65].

As stipulated by the EEDSM policy, Eskom can only appoint Nersa-accredited M&V teams to measure and verify savings achieved by DSM projects. Figure 14 summarises the process Nersa uses to accredit interested applicants [66].

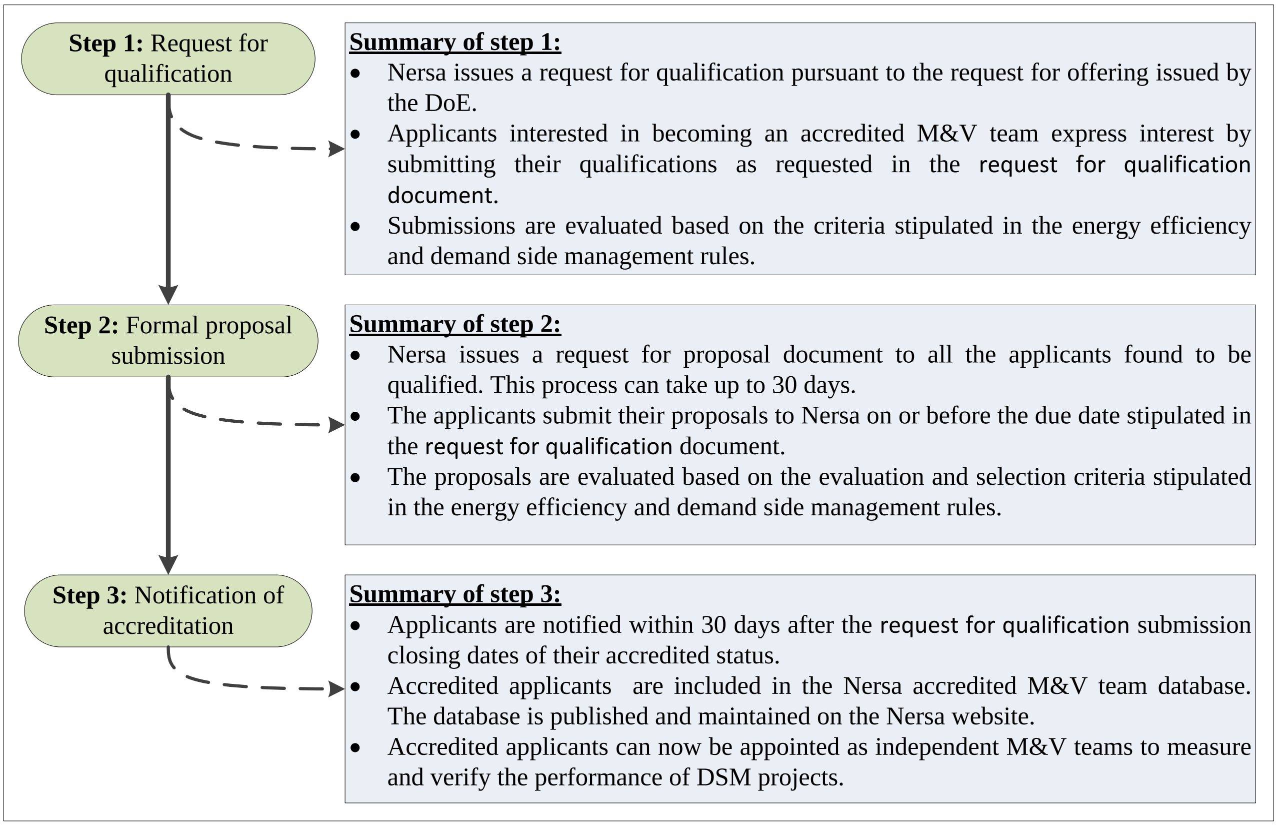

Figure 14: Nersa M&V team accreditation procedure

The M&V process, which accredited M&V teams should use to measure and verify the savings of DSM projects, was adapted from the following guidelines [66], [67]:

- The IPMVP, and
- The Federal Energy Management Programme (FEMP) M&V guidelines.

The ESCO DSM model was discussed in detail in section 2.3.2. A summary of the different phases for a typical industrial DSM project implementation is displayed in Figure 12. Figure 15 illustrates the M&V process in parallel with the different DSM project phases [68].

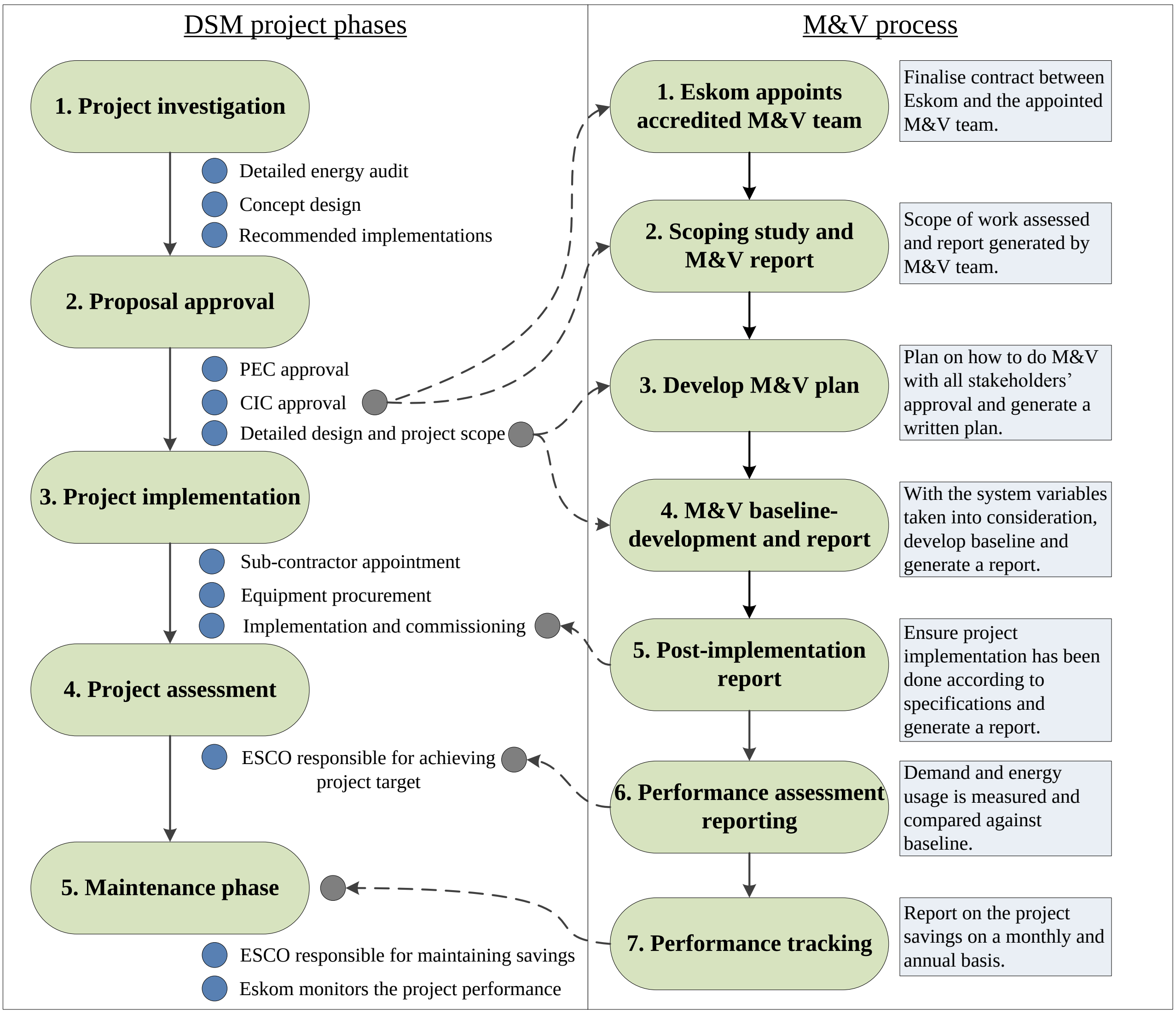

Figure 15: The M&V procedure in parallel with DSM project phases

Various challenges affect the accuracy of the measured and verified savings of an industrial DSM project. The long-term evaluation of existing projects is also affected by challenges such as[17]:

- Inaccurate baseline information from the ESCOs.
- Late and incomplete allocation of M&V teams by Eskom.

[17] M&V Guideline, Processes and Expectations (2012). [Online]. Available: http://www.eskom.co.za/IDM/MeasurementVerification/Documents/MV_GuideforDSM.pdf. [Accessed: 25 July 2015]

- Negligence of the M&V team to report continuously on the performance of existing DSM projects.
- Inaccurate data used to measure and verify the project performance.

Various studies have been done to ensure more accurate M&V processes. Booysen dedicated his PhD study to analysing the M&V of industrial DSM projects. During his study, the importance of accurate reporting regarding project performance was highlighted. Challenges such as data accuracy, selecting a suitable baseline model and the effect of system changes on the project performance were addressed [22].

Other studies highlighted the importance of the correct interpretation of M&V results. It was found that project results are often published without accurate interpretation. This could mislead the project stakeholders who rely on the results when calculating the benefit achieved from the project. A holistic approach to present DSM project results was developed to address this concern [23].

Existing studies addressed specific issues relating to the accuracy with which the impact of a DSM project is measured and verified. Alternative approaches and different M&V procedures were proposed to address these issues. Despite the good work done by previous studies, the challenges mentioned still affect the accuracy of the savings reported.

Figure 16 shows the average actual weekday power profile of a dewatering pumping system during PA as calculated by the ESCO and the M&V team. From the graph in Figure 16 it should be noticed that the average power consumption profiles calculated by the ESCO and the M&V company correlate. The only difference is that the two power consumption profiles are out of sequence with 30 minutes. This is because the ESCO used forward-filling when the average power profile was calculated, while the M&V team used backwards-filling.

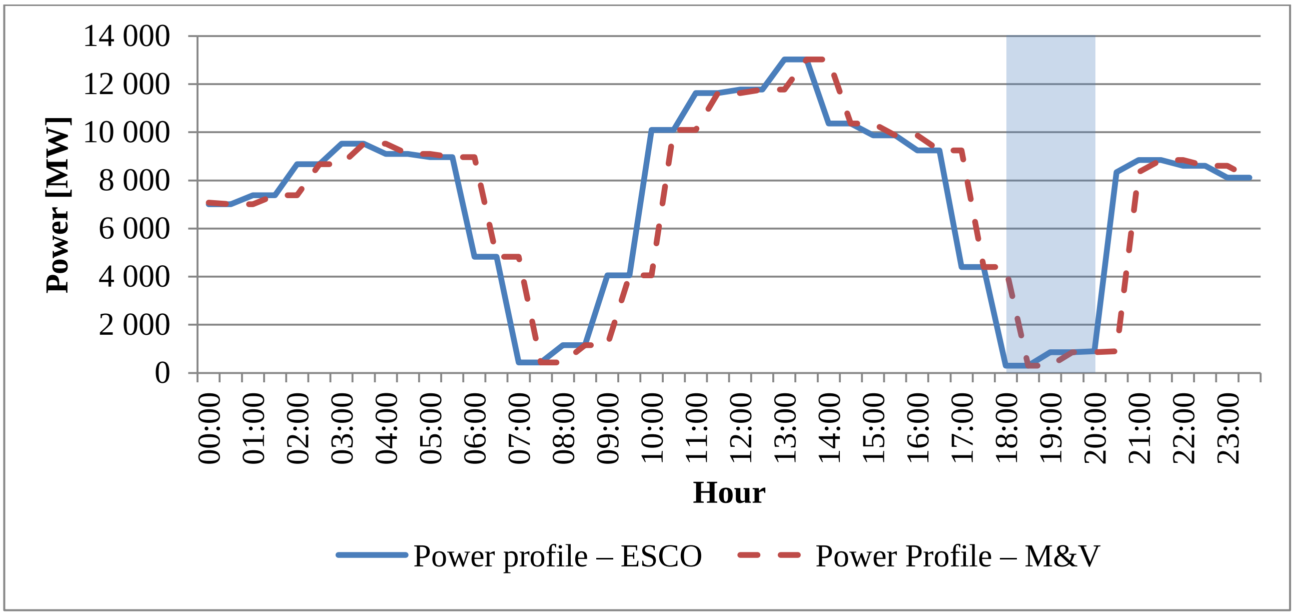

Figure 16: Accuracy of the actual power profile of a pumping system during PA

The baseline was also compiled using the forward-filling method, which means that the M&V company should have used forward-filling when the actual profile was calculated. As a result of this error, it seemed as if the pumping system operated for the first half hour of the evening peak period. This can be noticed by comparing the correct power profile (as calculated by the ESCO) with the incorrect power profile (as calculated by the M&V team) during the Eskom evening peak period (indicated by the blue transparent block).

This error was made by an M&V company appointed by Eskom to measure and verify the savings achieved by this industrial load-shifting DSM project. Although this error might look small, the load shifted out of the Eskom evening peak period was wrongly reported with 0.8 MW by the M&V team. This incident occurred in 2015 during the PA period of a load-shifting project implemented on the dewatering system of a gold mine in South Africa.

Previous studies investigated the existing M&V procedure in detail. The conclusion is made that ample information exists regarding an M&V procedure that will ensure accurate results. Due to an inaccuracy in some of the M&V reports that is still being experienced, the method Eskom uses to enforce the M&V procedure should be changed.

2.6 Sustainability of existing DSM initiatives

The cumulative evening peak demand reduction since 2005 due to the Eskom DSM programme was briefly discussed in section 1.3. This section will critically review the method Eskom uses to calculate the DSM programme saving. The need for a more realistic approach to determine the DSM programme saving, taking the sustainability of DSM initiatives into consideration, will be investigated.

Eskom's integrated and annual reports for 2005 to 2014 were evaluated. The verified DSM peak demand savings for each year were obtained. The verified yearly savings were cumulatively summed and compared with the cumulative DSM peak demand savings reported in the 2014 Eskom Integrated Report. A difference of 2% between the values was noticed. It is evident that Eskom continues to count the savings of DSM projects verified during previous years, even if the projects are out of their five-year contract periods.

Eskom can argue that they report on the total cumulative DSM savings achieved, irrespective of the current performance of historical projects. This, however, is not a true reflection of the current actual impact of the DSM programme. Due to insufficient continuous M&V, especially on DSM projects which are out of their contract period, it is difficult to quantify the exact actual impact of the DSM programme at the moment.

To be conservative, it is assumed that implemented DSM projects maintained their verified savings for the duration of the project contract. The majority of projects implemented since 2005 had a contract period of five years. Following this argument, the estimated cumulative impact of the DSM programme can be calculated without assuming that existing DSM projects will keep on performing. Figure 17 illustrates the estimated cumulative savings against the Eskom reported cumulative saving.

From the graph in Figure 17, it is evident that the actual impact of the DSM programme might be significantly less than the cumulative impact as reported by Eskom. In section 1.3, the need was identified to determine which short-term strategy would be the most feasible strategy to assist with the electricity supply constraint. The sustainability of DSM projects should be considered when this study is conducted.

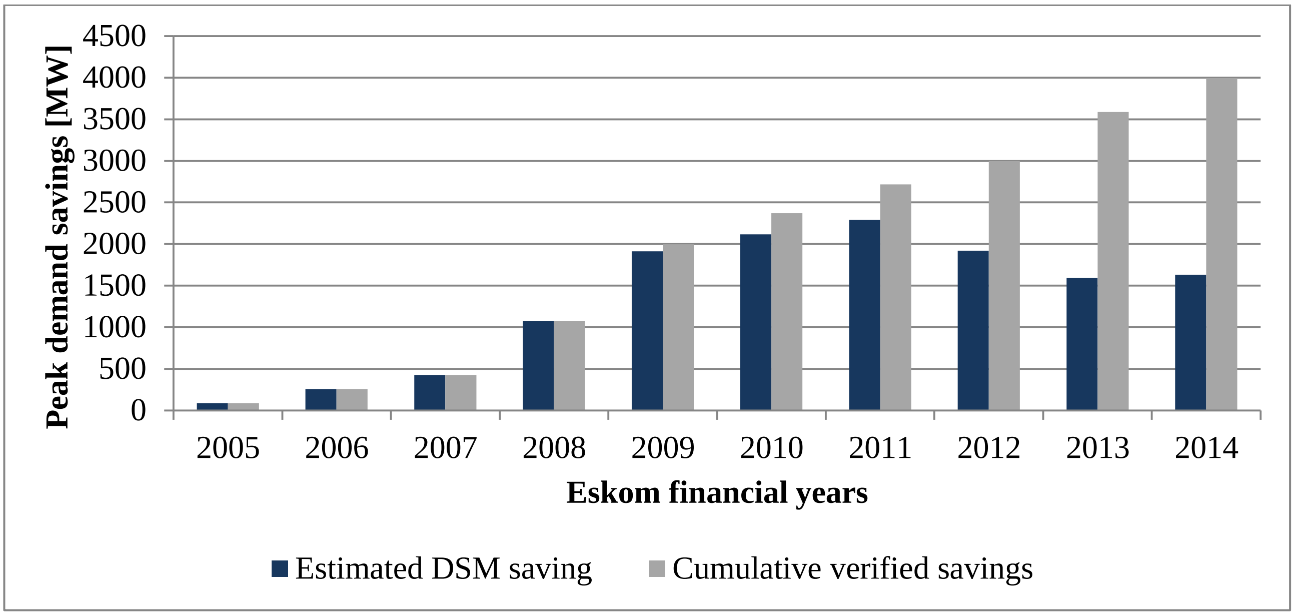

Figure 17: Estimated Eskom DSM programme impact

A previous study focused on developing a maintenance strategy to improve the sustainability of DSM projects. This study indicated that the performance of a load-shifting project could decrease to less than 20% of its original target within 20 months from project commissioning if the project is not maintained. A performance-centred maintenance strategy was proposed to improve the sustainability of industrial DSM projects. It is estimated that the performance of existing industrial DSM projects can be increased with up to 70% if this maintenance strategy is implemented [69].

It is important that the performance of a DSM project be maintained for as long as possible to maximise the return on investment. Since Eskom funds DSM projects, it is important for Eskom to ensure that existing projects keep on performing for as long as possible. But, Eskom could argue that clients should maintain the project according to the DSM contract.

Although Eskom could penalise clients if their project targets are not maintained, various situations could prevent Eskom from doing so:

- Most industrial clients assist Eskom by switching off large machinery at crucial times when Eskom cannot generate enough electricity to meet the demand. Eskom do not want to penalise clients for DSM projects not achieving their targets when clients assist Eskom with demand response.
- Some M&V teams do not report on the performance of DSM projects continuously and accurately, which means Eskom will not be able to enforce penalties.

- Some clients have various DSM projects implemented at different sites. Some projects overperform and some projects underperform. The overall performance of their DSM projects could be above target. This could prevent Eskom from penalising clients for projects which underperform due to the overperformance of other DSM projects.

A study needs to be done to determine the cost involved in maintaining an existing project and if it could be feasible for Eskom to become actively involved with the maintenance of DSM projects. As part of this study, the cost to fund a new DSM project should be compared with the cost of maintaining an existing project. Based on the results, a proposal should be made to Eskom on how to obtain maximum return on the capital invested in DSM projects.

2.7 Conclusion

In Chapter 1, Eskom's electricity supply and financial constraints were discussed. The importance of Eskom spending available funds on the most feasible short-term solution to address the electricity supply constraint was highlighted. The need to re-evaluate the ESCO DSM model to deliver more sustainable results was also pointed out. Chapter 2 evaluated literature available that could help to address these problems.

International DSM programmes were evaluated first. Countries where DSM programmes have been implemented were investigated and divided into developed and developing countries. Typical ESCO DSM models in each category were investigated. The differences between ESCO markets in developed and developing countries were identified. Since India has similar electricity constraints as South Africa, emphasis was placed on the methods they use to address the problem.

The different DSM models implemented by Eskom as part of the DSM programme were briefly discussed. Information such as the type of project qualifying for each model, the project approval process and the model structures were briefly discussed. Emphasis was placed on the South African ESCO DSM model. Each model phase was discussed in detail.

Challenges during the project investigation and implementation phases of the ESCO DSM model were investigated. The effect of each challenge was identified. Existing project M&V procedures used to evaluate existing industrial DSM projects were investigated. Challenges affecting the accuracy of the performance reporting of industrial DSM projects were discussed. Existing studies focusing on the improvement of the performance reporting accuracy were investigated.

The sustainability of the Eskom DSM programme was evaluated and the method Eskom uses to report on the evening demand impact of the DSM programme was reviewed critically. The importance of the current actual impact of the DSM programme was highlighted. The deterioration of the project performance of existing industrial DSM projects where no maintenance is done was investigated. Existing studies on maintaining industrial DSM projects were investigated.

The information gathered during this chapter will be used to formulate an alternative approach to the ESCO DSM model to ensure improved sustainability of future industrial DSM projects. A study will also be done to determine the feasibility of each short-term solution to address the South African electricity constraint.

Chapter 3: New integrated approach to the industrial DSM ESCO model

[18]

This chapter is dedicated to developing an alternative approach to the South African DSM ESCO model to ensure sustainable future industrial DSM projects. A short-term solution feasibility model will also be developed to quantify the expected impact of the alternative approach.

[18] Photo taken at a South African cement plant.

3.1 Introduction

Chapter 1 explained the nature of the South African electricity constraint. Long- and short-term solutions to address the problem were discussed. Long-term solutions mentioned were the building of the Kusile and Medupi coal power stations, and the recommissioning of old coal power stations. Short-term solutions entailed load shedding and operating gas turbine power stations. The implementation of the Eskom DSM programme, which is seen as a short- to medium-term solution, was discussed in detail.

Long-term solutions are implemented with the objective to expand the electricity generation capacity in the long run. As mentioned in section 1.2, the Kusile and Medupi coal power stations are scheduled for completion in 2018. With challenges such as labour disruptions and poor scope definition, the commissioning date can be delayed even further. Short-term solutions are, therefore, required to solve the generation capacity problem with immediate effect.

Load shedding is often implemented when demand threatens to exceed the available supply capacity. Load shedding then serves as a short-term solution to protect the electricity network from a total blackout. Literature showed that load shedding has a negative effect on the South African economy and should be avoided if possible.

Gas turbine power stations were installed in an attempt to avoid load shedding. However, gas turbine power stations are expensive to operate [70]. The 2014 Eskom Annual Report indicated that Eskom spent R10 billion on diesel to operate these power stations while they only had an approved budget of R3 billion [71]. Eskom also made it public during 2015 that the company has been experiencing financial constraints, which could affect the future operation of gas turbine power stations as a short-term solution.

DSM could be a more feasible short-term solution to avoid load shedding, than operating gas turbine power stations. However, DSM does not have such an immediate impact as the gas turbine power stations have. Case studies and literature also showed that industrial DSM projects did not always achieve sustainable results. Due to Eskom’s financial constraints, the need for Eskom to evaluate the feasibility of each short-term solution was identified.

An alternative approach to the DSM ESCO model will be developed. Focus will specifically be on the investigation and implementation phase, the M&V procedure and the project maintenance approach of the DSM ESCO model. The main objective with the new approach will be to improve the initial impact of future industrial DSM projects and to improve the sustainability of the savings achieved.

3.2 Short-term solution feasibility model

This section will be used to formulate a new feasibility model. The objective of the feasibility model is to determine the most feasible combination of short-term solutions to avoid a total blackout of the electricity network. Short-term solutions identified through literature are:

- load shedding,
- gas turbine power stations, and
- DSM.

Each short-term solution will be evaluated in terms of impact time, implementation and operating costs, and sustainability. The inputs of the feasibility model will be discussed, whereafter expected model outputs will be presented. The model will be verified with an actual case study. The most feasible combination of short-term solutions for South Africa will then be simulated with the newly developed feasibility model.

3.2.1 Short-term solution evaluation

Load shedding

Load shedding is implemented by Eskom as a last resort to avoid a total blackout of the electricity network. Load shedding was implemented during the 2008 electricity constraints. Thereafter, load shedding was avoided but has been reinstated from March 2014 onwards. This is due to excessive maintenance requirements of the coal power stations, which affect the available supply capacity of Eskom. It is estimated that load shedding could continue until 2018.

In section 1.1, it was mentioned that load shedding has a negative effect on the economy of a country. This is mainly because most industries rely on electricity to operate. The IRP for electricity, updated by the Department of Energy in 2013, indicated that load shedding costs the South African economy R75 000 per MWh of unserved electricity.

Since the IRP for electricity has last been updated in 2013, the effect of load shedding could be even more than R75 000 per MWh of unserved electricity. Recent news reports indicated that the effect of load shedding can now be up to R100 000 per MWh of unserved electricity[19]. Because the IRP for electricity is the last verified source to report on the effect of load shedding, the conservative value of R75 000 per MWh of unserved electricity is going to be used in this study.

The effect load shedding has on the South African economy is going to be categorised as a negative side effect of load shedding. This side effect is going to be evaluated separately and should not be misinterpreted as the Eskom operating cost for load shedding. The Eskom operating cost for load shedding is going to be taken as profit lost because of electricity that could not be sold.

Eskom supplies electricity to various sectors including agricultural, residential, industrial and municipal sectors. Each sector has different electricity tariff structures. The 2013/14 Eskom Integrated Report, however, indicated that the average revenue received by Eskom for selling electricity was 62.82c per kWh. The average operating cost for the 2013/14 financial year was 59.67c per kWh. Based on these values, the profit lost by Eskom as a result of load shedding is estimated to be R31.50 per MWh.

Load shedding has an immediate effect since the electricity supply of certain parts of the electricity network is disconnected when demand threatens to exceed the supply. Load shedding is seen as a temporary measure and is usually implemented for short periods only. The sustainability factor of load shedding can be ignored because load shedding has an immediate effect when implemented. Eskom can reduce the electricity demand of the country with up to 4 000 MW when stage 4 load shedding is implemented [72].

Gas turbine power stations

In section 1.2, it was mentioned that Eskom implemented two gas turbine power stations in 2007. The function of the gas turbine power stations is to generate electricity during high demand periods to avoid load shedding. The total gas turbine power station install capacity is 2 067 MW and the

[19] How much Eskom blackouts costs SA every month (2015). [Online]. Available: http://businesstech.co.za/news/general/79347/how-much-eskom-blackouts-costs-sa-every-month/. [Accessed: 05 August 2015]

operating cost is estimated at R2 570 per MWh (without including maintenance cost on the OCGTs).

The impact time of the gas turbine power stations is also considered immediate. As soon as the gas turbine power stations are started, additional electricity is supplied to the electricity network. The SGT5-2000E Siemens OCGTs, which are used in South African gas turbine power stations, have an availability factor of 95% if the correct maintenance procedures are followed. An SGT5-2000E Siemens OCGT has a life expectancy of 30 years.

If a new OCGT power station has to be built, the power station can be implemented within 2–3 years. The implementation cost of a new OCGT power station is estimated to be R8.32 million per MW of installed capacity. For the purpose of this study, it is going to be assumed that the electricity generated by the gas turbine power stations is also sold by Eskom for 62.82c per kWh.

DSM

DSM was defined in section 1.3 as modifications on the demand side of the electricity grid to ensure that electricity supply and demand are matched effectively. Although certain DSM initiatives have been implemented since 1990, the South African DSM programme was only finalised in 2004. Since 2004, Eskom has driven the DSM programme inconsistently, which made it difficult to establish a large ESCO market.

In section 1.3, 37 industrial DSM projects were evaluated. It was found that these industrial DSM projects underperformed with an average of 10.6% when compared with their initial project target. The savings of the projects during the PA period were compared with the savings after the PA period. It was found that the project savings achieved during the PA period deteriorated with an average of 17% annually.

Eskom reported in 2015 that R1.7 billion had been allocated to the DSM programme. A target of 975 MW savings during the evening peak period was set, of which 500 MW was expected from the mining and industrial sectors. This means that approximately 51% of DSM savings are expected from industrial DSM projects implemented through the DSM ESCO model [73].

It was mentioned in section 2.3.2 that Eskom recently made some changes to the existing DSM ESCO model. These changes included that:

- The ESCO needs to implement the project in less than six months.
- Projects should focus on reducing demand during the Eskom evening peak period only.
- ESCOs are responsible for maintaining the savings for 36 months after project implementation.

The new changes Eskom made to the DSM ESCO model might improve the sustainability of future industrial DSM projects. Otherwise, some changes might cause the initial impact of future DSM projects to be below the investigation target. These changes include:

- Data for a period of one month can now be used as a baseline.
- The client does not need to approve the baseline anymore.
- ESCOs only have a limited amount of time to implement the projects.

The effect that these changes could have on the initial impact and the sustainable savings of future projects will be discussed in more detail in the following sections. For the purpose of this study, it is going to be assumed that the savings of industrial DSM projects deteriorate with 17% per annum (which are the results of the 37 industrial DSM projects evaluated in section 1.3). The sustainability of industrial DSM projects is, therefore, quantified as 83% per annum.

The minimum periods identified in section 2.3.2 for the project investigation and project procurement phases were three and nine month respectively. Considering that the ESCO should implement the project within 6 months, the impact time of an industrial DSM project can be approximately 18 months. This is if the ESCO only commences with investigations after funding has been allocated to the DSM programme. Some ESCOs may complete some investigations prior to funding allocation, which could reduce the expected impact time.

With the R1.7 billion allocated to DSM and a power reduction target of 975 MW, the operating cost of the DSM programme can be quantified in terms of sustainable savings of the DSM programme. Should the sustainable savings of industrial DSM projects remain high, more MWh savings will be achieved over the project contract period. If the sustainable savings are lower, less MWh savings will be achieved, resulting in higher operating costs for DSM. This phenomenon is illustrated in Figure 18.

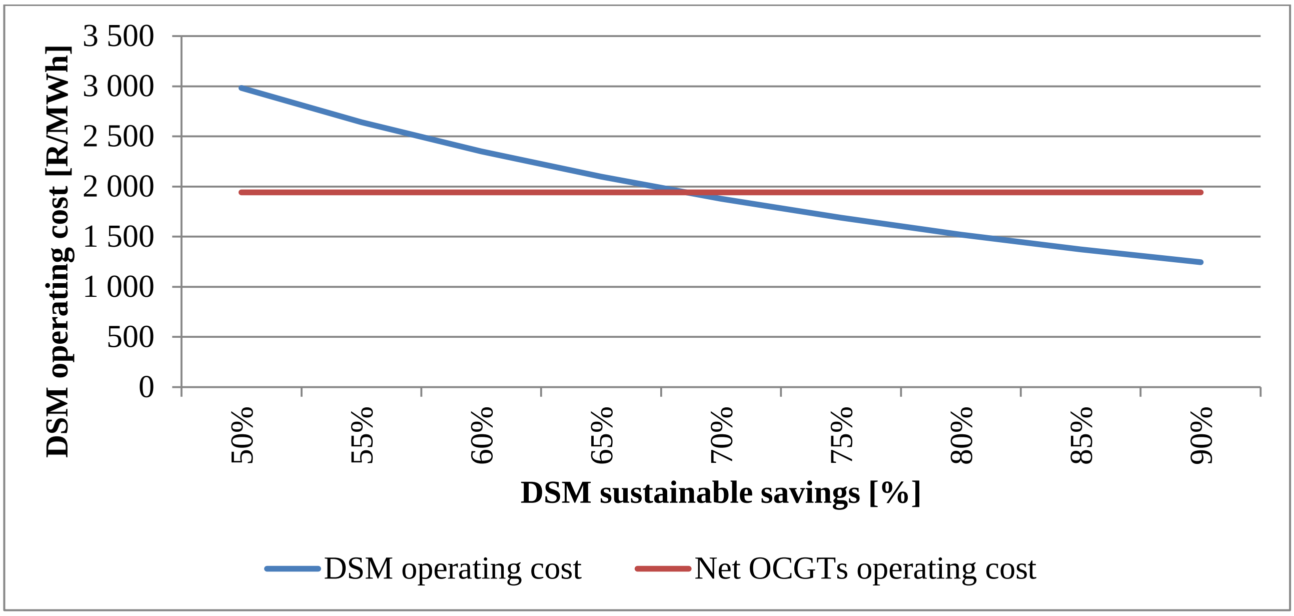

Figure 18: DSM operating cost

The red line in Figure 18 indicates the net operating cost to generate electricity using gas turbine power stations. The net operating cost is calculated by deducting the funds generated when the electricity is sold from the gas turbine power station operating cost. An average electricity selling price of 62.82c per kWh was assumed [1]. The gas turbine power station's net operating cost is R1 941 per MWh.

It was found that DSM projects should be at least more than 69% sustainable to achieve a lower operating cost than using gas turbine power stations. With a sustainability of 83%, the operating cost for industrial DSM projects will be R1 430 per MWh. This is R511 per MWh lower than generating electricity with the gas turbine power stations. By improving the sustainability of industrial DSM projects, the feasibility of DSM could be improved.

3.2.2 Model inputs

During the previous section, each short-term solution was evaluated in terms of impact time, implementation cost, operating cost and sustainability. The findings are summarised in Table 8.

Table 8: Short-term solution evaluation – results summary

Criteria	Unit	Load shedding	Gas turbine power stations	DSM	Cross reference to literature study
Impact time	[Months]	Immediate	Immediate	18	Page 48
Implementation cost	[R million/MW]	N/A	8.32	N/A	Page 63
Operating cost	[R/MWh]	31.5	2 489	1 430	Page 65
Sustainability	[%]	100	95	83	Page 64
Impact on economy	[R/MWh]	75 000	N/A	N/A	Page 3

It is assumed that only the gas turbine power stations have implementation costs, which is the cost to build and commission the gas turbine power stations. The cost Eskom spent on the DSM programme is categorised under operating cost. Depending on the sustainable savings of the DSM projects, the operating cost can vary. Only load shedding is considered to have an impact on the economy of the country.

The short-term solution feasibility model will be developed to predict the most feasible combination of short-term solutions for the next three years. The first step was to predict the available supply capacity of Eskom for the next three years. According to the 2014 Eskom Integrated Report, the installed capacity in 2014 was 43 495 MW. The energy availability factor (EAF) during 2014 was on average 74.95%.

By taking the existing Eskom installed capacity and the expected future installed capacity expansions into account, the total expected future installed capacity can be calculated. Not all of the Eskom installed capacity is, however, always available to generate electricity. This is due to maintenance requirements on the power stations and unforeseen breakdowns. The annual average Eskom EAF deteriorated with more than 10% from 2009 to 2014.

If the average annual rate the Eskom EAF deteriorated from 2009 to 2014 is considered, the Eskom EAF will deteriorate with a further 7% over the next three years. If Eskom's installed capacity and the annual Eskom EAF in 2014 are considered, only an average of 32 608 MW of the total installed capacity has been available during 2014.

The Eskom Generation Medium Term Adequacy report indicates the status of Eskom's New Power Station Building programme [74]. The expected commissioning dates of each power station unit along with its installed capacity, according to this Eskom report, are summarised in Table 9.

Table 9: Expected commissioning dates of new Eskom power stations

Power station	Unit commissioned	Year commissioned	Generation capacity added [MW]
Sere	50	2015	100
Medupi	1	2016	794
	2	2017	794
	3; 4; 5	2018	2 382
	5	2019	794
	6	2015	794
Ingula	1	2016	338
	2; 3; 4	2017	1 014
Kusile	1	2017	800
	2	2018	800
	3	2019	800
	4; 5	2020	1 600
	6	2021	800

The Eskom installed capacity is expected to expand with an additional 7 022 MW by the end of 2018. With the Eskom EAF expected to deteriorate with an additional 7% over the next three years, the available installed capacity in 2018 will be 32 595 MW. It can be argued that the additional installed capacity, therefore, just replaces the deterioration in Eskom EAF.

Figure 19 indicates the deterioration in Eskom EAF from 2009 to 2015, and the expected Eskom EAF from 2016 to 2018. Figure 19 also indicates Eskom's installed capacity from 2009 to 2015. Eskom's installed capacity is extended to 2018 by taking the expected installed capacity expansions indicated in Table 8 into consideration. Eskom's available capacity is also displayed in Figure 19.

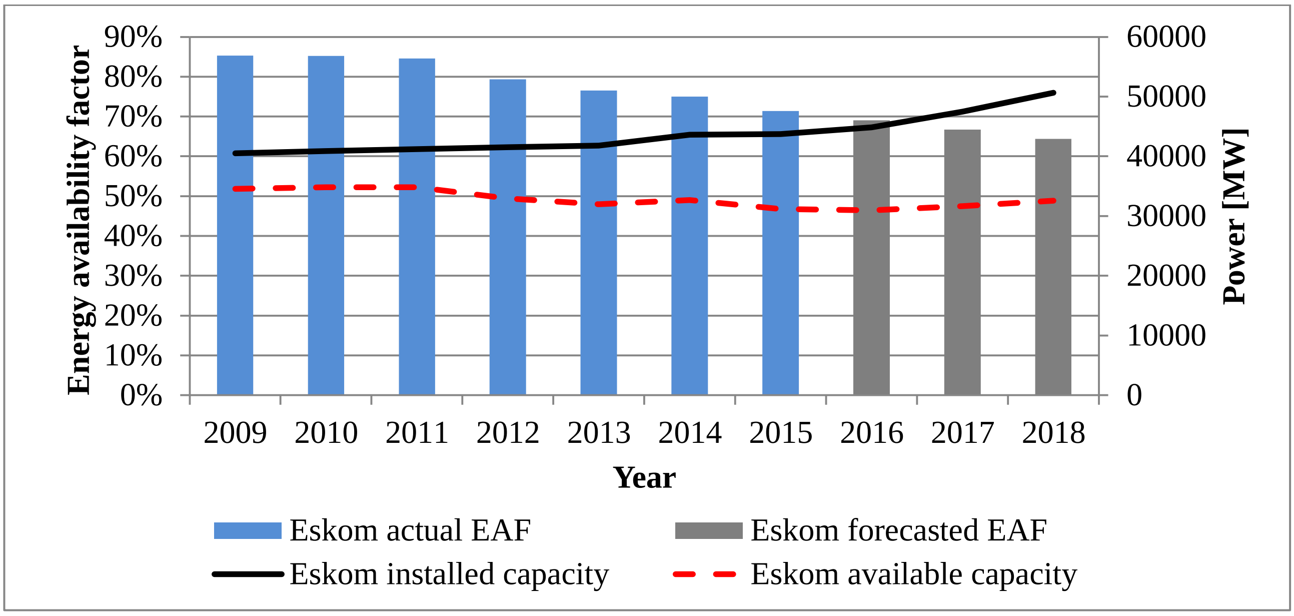

Figure 19: Eskom EAF and installed capacity

Eskom's available capacity is an important input of the short-term solution feasibility model. By considering the available capacity and the electricity demand, the shortage in electricity supply can be calculated. The next model input that will be discussed is the electricity demand for South Africa. Historical demand data together with the predicted increase in the future demand will be used to determine a realistic future electricity demand.

Figure 20 shows the week-on-week maximum demand of South Africa during 2014. These values, displayed as a line graph in Figure 20, can also be explained as the maximum demand for electricity during each week of 2014. It should be noted that the demand for electricity is on average higher during the winter months than during the summer months. June, July and August are seen as winter months (Week 22 to Week 35 in Figure 20).

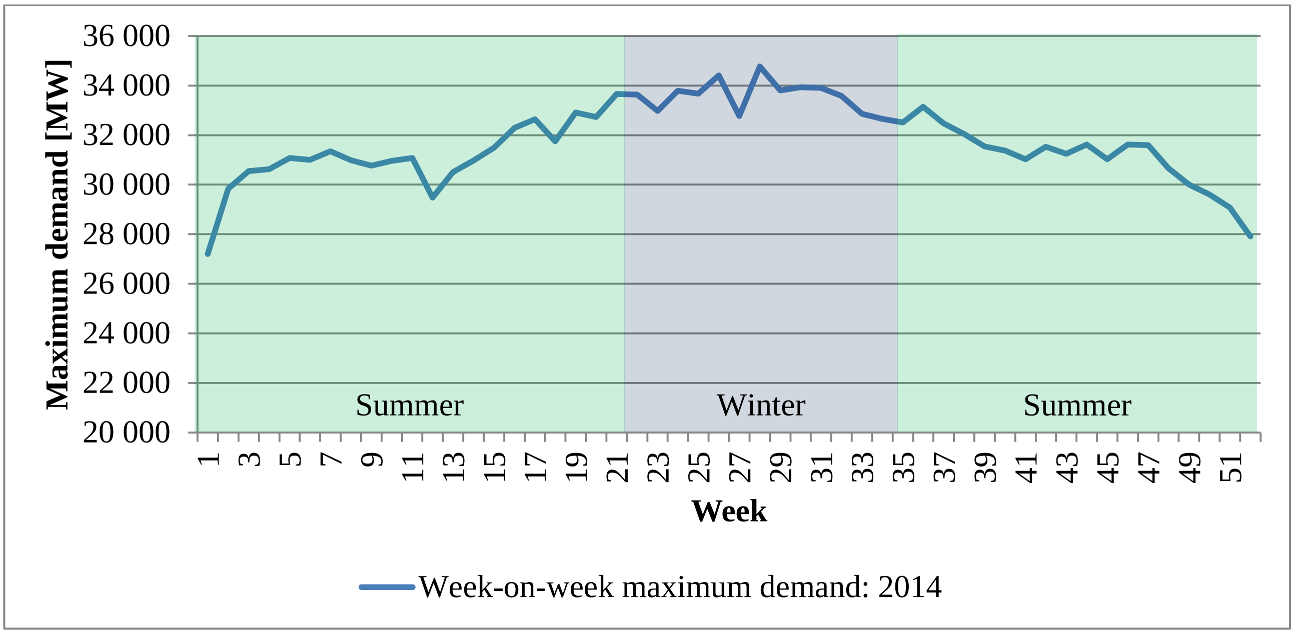

Figure 20: Week-on-week maximum demand during 2014

In addition to the maximum demand, which is much higher during the winter months, the average weekday electricity demand profile also differs from winter to summer. The difference in the daily electricity demand profiles is mainly due to behavioural changes of people. During winter months, people tend to consume more electricity to counteract the cold weather conditions. Equipment such as heaters and geysers are used to a greater extent, especially during the early morning and early evening hours.

The residential sector, therefore, contributes significantly to the prominent morning and evening peak periods experienced during winter months. These peak hours are visible in Figure 21 between 07:00–10:00 and 18:00–20:00 respectively. During the summer months, electric equipment such as heaters and geysers are used less frequently. The electricity consumption during the morning peak periods is more similar to the consumption during the standard period. However, the demand for electricity is still at its highest in the summer months between 18:00 and 20:00.

An explanation of the Eskom peak, standard and off-peak periods are provided in Appendix C. The flat demand profile from 07:00 in the morning to 18:00 in the afternoon in summer months is known as the “table mountain” effect. This effect is visible in Figure 21.

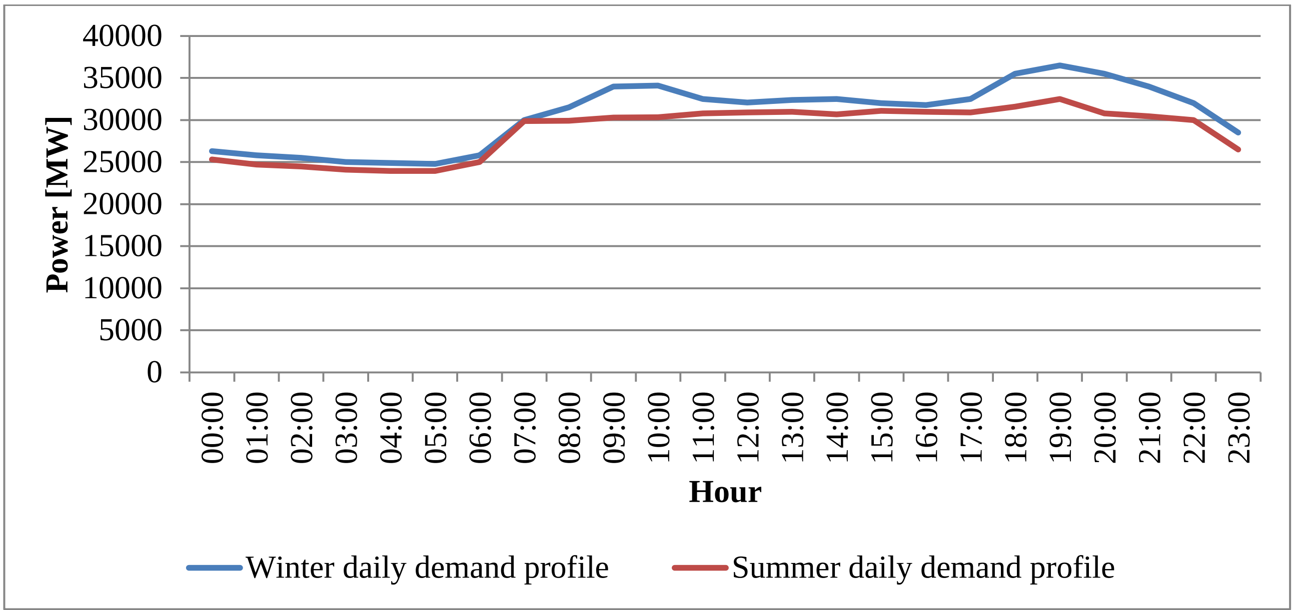

Figure 21: Winter and summer average daily demand profiles

Due to the fact that Eskom already implements load shedding, the actual electricity demand during times of load shedding is hard to predict. Although Eskom has implemented load shedding during 2014, the effect is assumed small enough to not affect the 2014 week-on-week electricity demand. For the purpose of this study, the actual week-on-week electricity demand during 2014 is used as a starting point to predict the electricity demand for the years to come.

The expected increase in the country's annual average electricity demand according to the Eskom Generation Medium Term Adequacy Report is displayed in Table 10 [74].

Table 10: Expected annual electricity demand increase

Year	Expected electricity demand increase
2015	2.1%
2016	4.5%
2017	2.5%
2018	3.0%

In order to predict the daily electricity demand of the country until the end of 2018, the following methodology is followed:

1. The 2014 week-on-week electricity demand profile displayed in Figure 20 is increased by the expected annual electricity demand increase for each year.
2. A scaling factor is calculated to scale the average daily profile to the maximum demand of a week, for each day in the week. The scaling factor is calculated with Equation 1.

Equation 1: Daily demand profile – scaling factor

$$Scaling\ factor = \frac{A}{B}$$

$Where$:

$A = $ *Maximum demand for the applicable season's average daily profile.*

$B = $ *Week-on-week maximum demand for a particular week.*

By using the last mentioned methodology, a daily electricity demand prediction is simulated until the end of 2018. Due to the fact that the average daily electricity demand profile is scaled to the expected weekly maximum demand, the worst-case scenario is simulated. This reasoning is used to ensure that the worst-case scenario is considered when the short-term solutions are evaluated.

At this stage of the model development, the expected available installed capacity until the end of 2018 and the simulated daily electricity demand are available. By realising the quantity by which the simulated daily electricity demand exceeds the available installed capacity, the energy supply shortage can be calculated.

In order to obtain an overall view of the expected electricity supply shortage within the next three years, a month-on-month analysis was done. The month-on-month maximum demand, as predicted by the model, was compared with the expected available supply capacity. These results are shown in Figure 22.

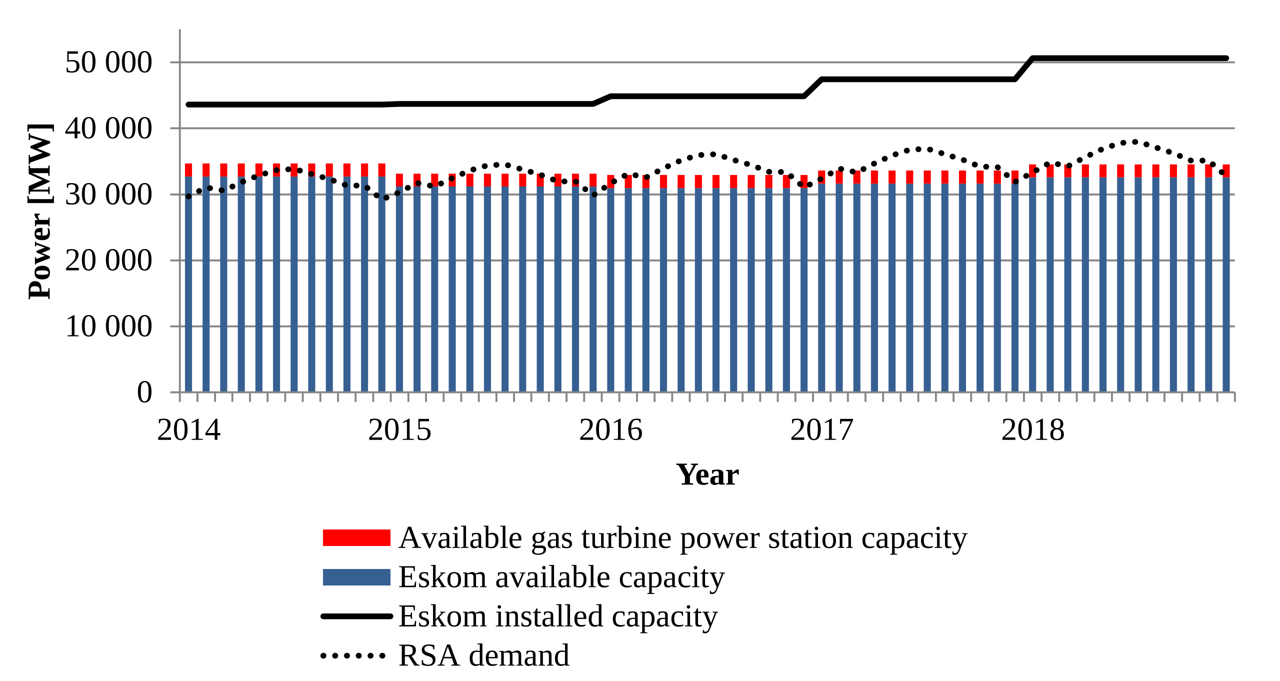

Figure 22: Month-on-month maximum demand and available supply

It should be noted that actual data from 2014 are used as inputs to the feasibility model in order to simulate the expected electricity supply shortage from 2015 until the end of 2018. This is due to the fact that load shedding was less frequently implemented during 2014 compared to 2015. The 2014 week-on-week maximum demand should therefore be a more accurate reflection of the actual maximum demand.

3.2.3 Model outputs

From Figure 22 it should be noted that according to the model, the electricity demand exceeds the available electricity installed capacity during each year from 2015 onwards. At first, the electricity supply shortage is only prominent during the winter months, as can be noticed during 2015. From 2016 onwards, the results indicate that the problem intensifies during the winter months. More summer months also show electricity supply shortages.

The results shown in Figure 22, however, only indicate the expected power supply shortages on a month-on-month basis for the next three years. In order to understand the nature of the expected supply shortage, the energy supply shortage needs to be evaluated in terms of:

- hourly energy supply shortage during winter months, and
- hourly energy supply shortage during summer months.

It is important to note that operating the gas turbine power stations is categorised as a short-term solution to the power supply shortage. The energy supply shortage evaluated is, therefore, before the available gas turbine power station capacity is considered.

The expected available installed capacity (without the available installed capacity of the gas turbine power stations) and the simulated hourly electricity demand until the end of 2018 are considered. This data is used to calculate the energy supply shortage during each hour of the day. This calculation is done separately for winter and summer months. Figure 23 shows the total expected energy supply shortage during the different hours of the day for the winter months, from 2015 to 2018.

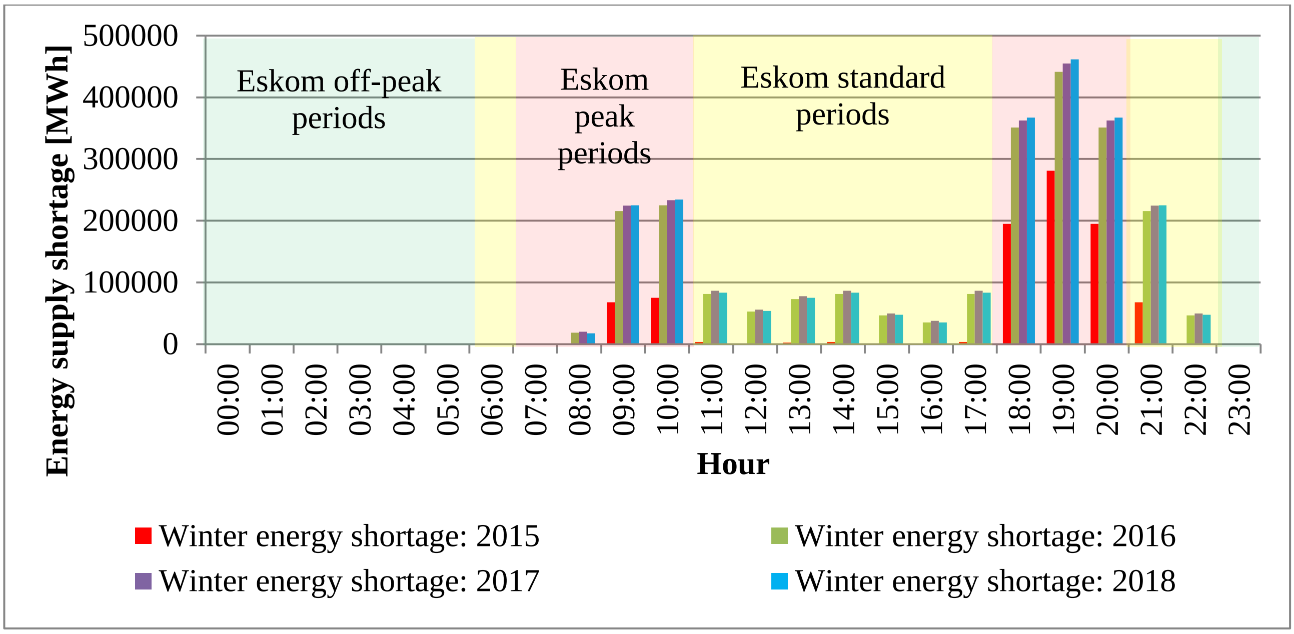

Figure 23: Expected energy supply shortage during winter months

It should be noted that the energy supply shortage is prominent during the morning and evening peak periods for the 2015 winter months. During the winter months from 2016 to 2018, the energy supply shortage intensifies during the peak hours and also becomes prominent during the standard hours. This phenomenon is due to:

- the expected increase in the country’s electricity demand, and
- the expected decrease in Eskom’s installed capacity EAF.

Figure 24 shows the total expected energy supply shortage during the different hours of the day for the summer months from 2015 to 2018. It should be noticed that the energy supply shortage for the summer months is much higher than the shortage for the winter months. This is because winter is only three months compared with summer being nine months.

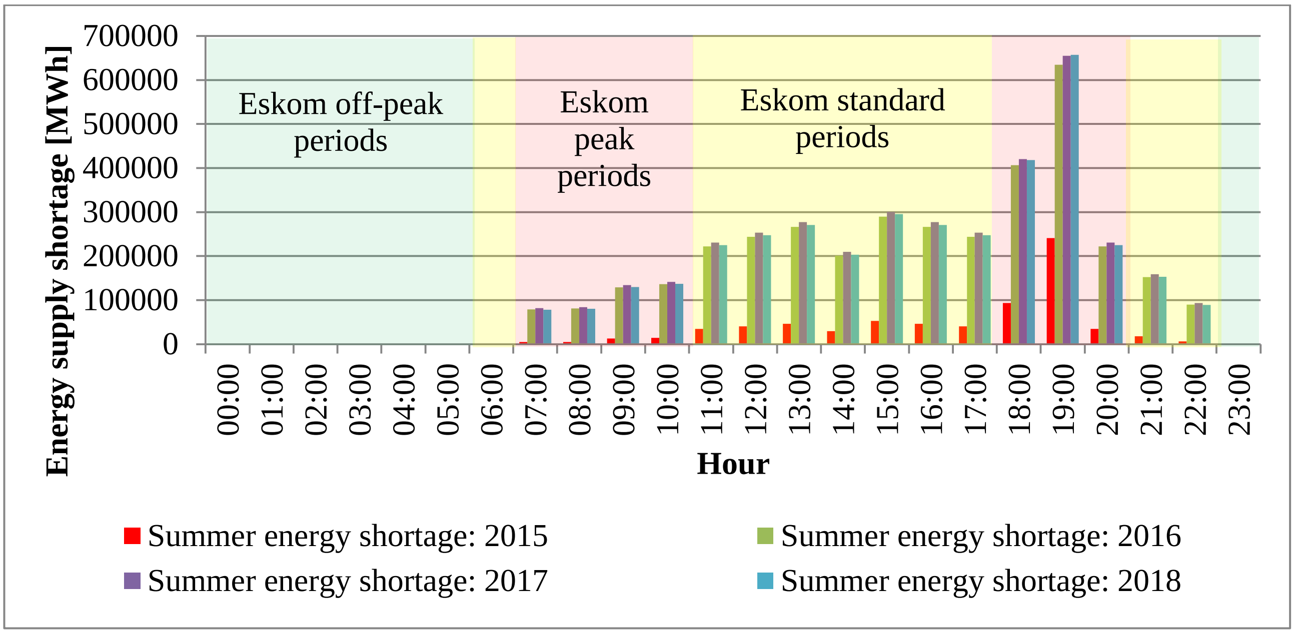

Figure 24: Energy supply shortage during summer months

It should be noted from Figure 24 that the energy supply shortage during the summer months is more prominent during the evening peak periods. The energy supply shortage is more uniform during the morning peak period and the standard periods. The energy supply shortage intensifies from 2015 onwards due to the increase in electricity demand and the decrease in Eskom’s installed capacity EAF.

The gas turbine power stations can supply enough electricity to meet the 2015 supply shortage for the winter standard periods, the summer morning peak period and the summer standard periods. During the 2015 winter evening peak periods, however, the gas turbine power stations are not sufficient to meet the energy supply shortage. The impacts of the Eskom DSM programme and load shedding are used as solutions to meet the additional energy supply shortage. Although 2015 has past already, these results will be compared to the actual results during section 4.1.1 in order to verify the accuracy of the model.

The simulated energy supply shortage for the 2016, 2017 and 2018 summer months indicates a different scenario. Due to the energy supply shortage increase already discussed, load shedding is expected to become a necessity even in the standard periods. This scenario can be seen by comparing the short-term solution distribution of 2015 in Figure 25 with the short-term solution distribution in Figure 26.

Figure 25 displays the energy shortage supply and the short-term solution distribution for the 2015 summer months. It is assumed that the gas turbine power stations will be used first, followed by the DSM programme impact, with load shedding being implemented as a last option.

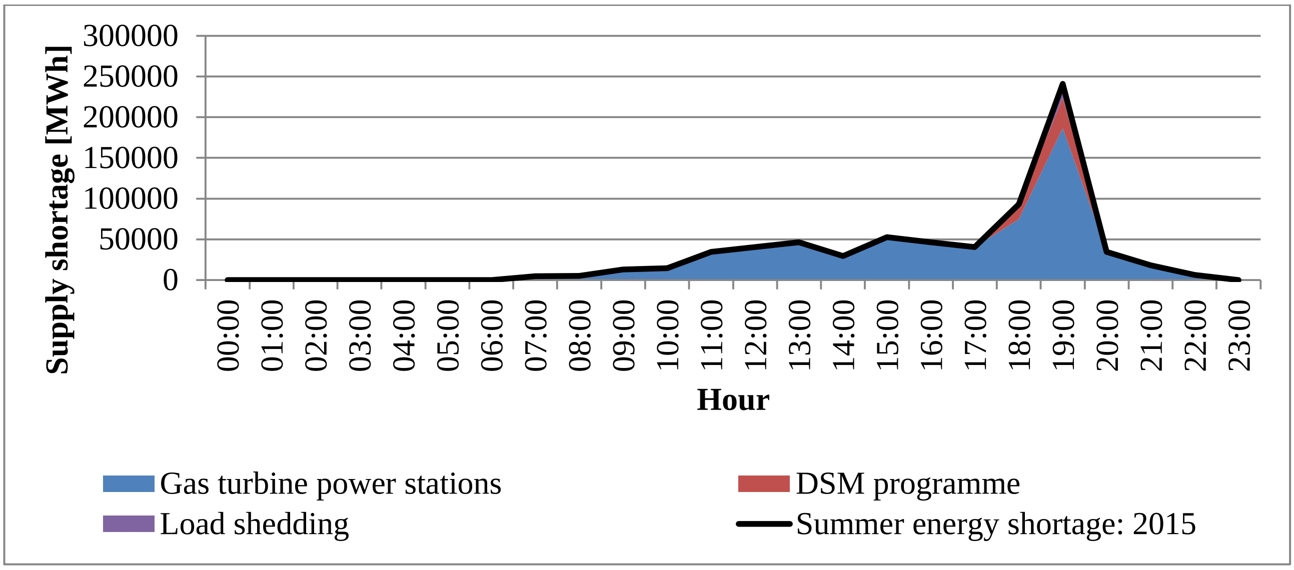

Figure 25: Short-term solution distribution – 2015

Figure 26 displays the energy shortage supply and the short-term solution distribution for the 2017 summer months.

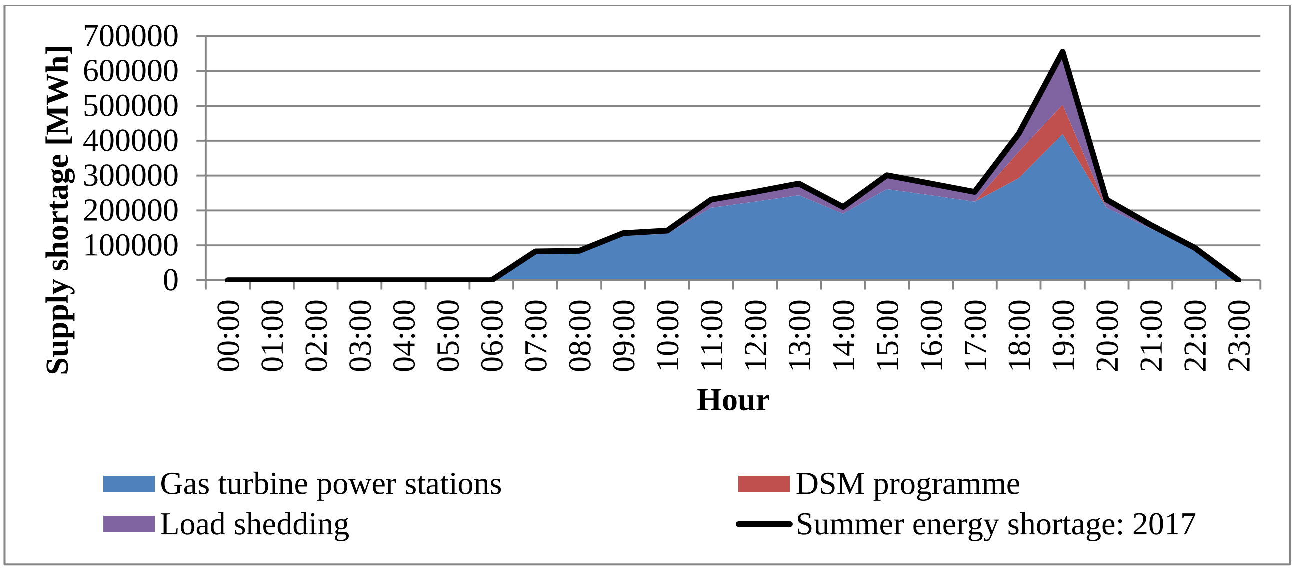

Figure 26: Short-term solution distribution – 2017

It should be noted that the DSM programme only shows an impact during the evening peak period (between 18:00 and 20:00). Although Eskom has implemented energy efficiency projects in the past, the recent focus of the DSM programme shifted to reduce evening peak hour demand only. The expected load shedding during the standard periods and evening peak period for 2017 indicates that the focus point of the DSM programme has to change.

3.2.4 Conclusion

The energy supply shortage was simulated from 2014 to 2018. The short-term solution distribution for this period was also simulated. The results showed an increase in energy supply shortage after 2015 due to the expected electricity demand increase. Although the electricity demand is expected to increase from 2016 to 2018, the electricity installed capacity expansions are expected to keep the supply shortage constant during this period. These results are displayed in Figure 27.

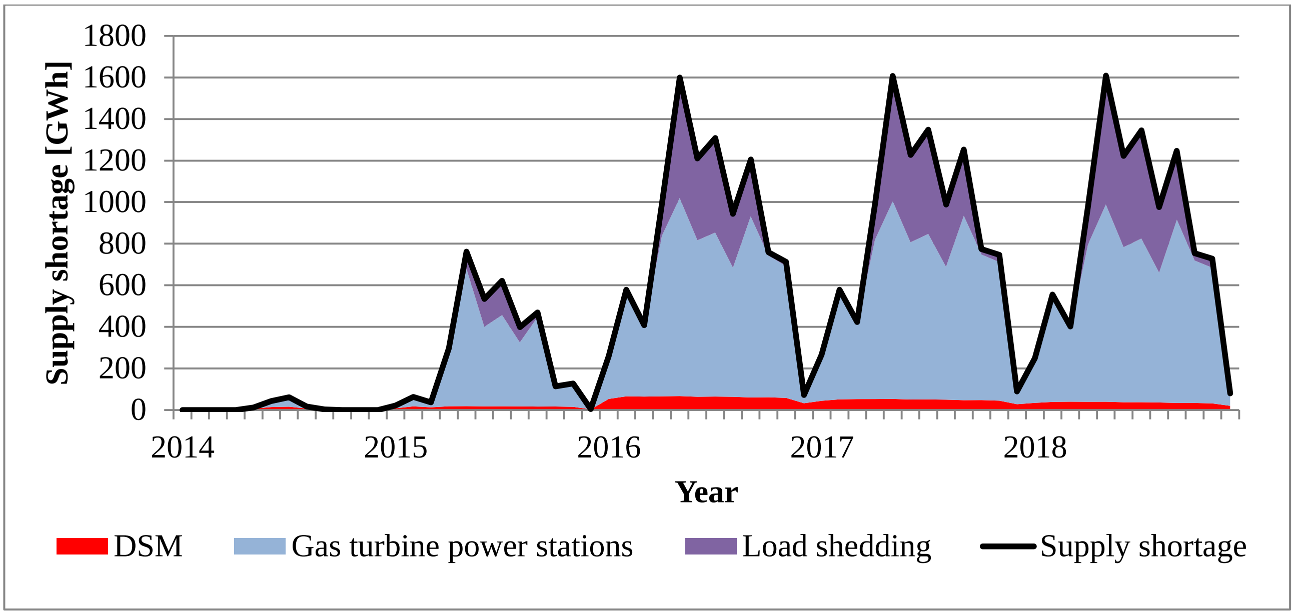

Figure 27: Year-on-year supply shortage and short-term solution distribution

From Figure 27 it should be noticed that the effect of the DSM programme is small relative to the gas turbine power stations. This is because the DSM programme is structured to have an impact only during the evening peak period, while the gas turbine power stations are available to supply electricity when needed. The next step in the methodology is to propose an alternative approach to the ESCO DSM model in order to:

- Improve the initial impact of industrial DSM projects.
- Improve the sustainability of the initial savings achieved.

The results will be used as inputs to the short-term feasibility model in order to determine the effect on the short-term solution distribution. The difference in the required load shedding will also be discussed along with the expected effect on the economy. The effect on the operating cost of the DSM programme will also be evaluated. Figure 28 summarises the methodology used to achieve this objective.

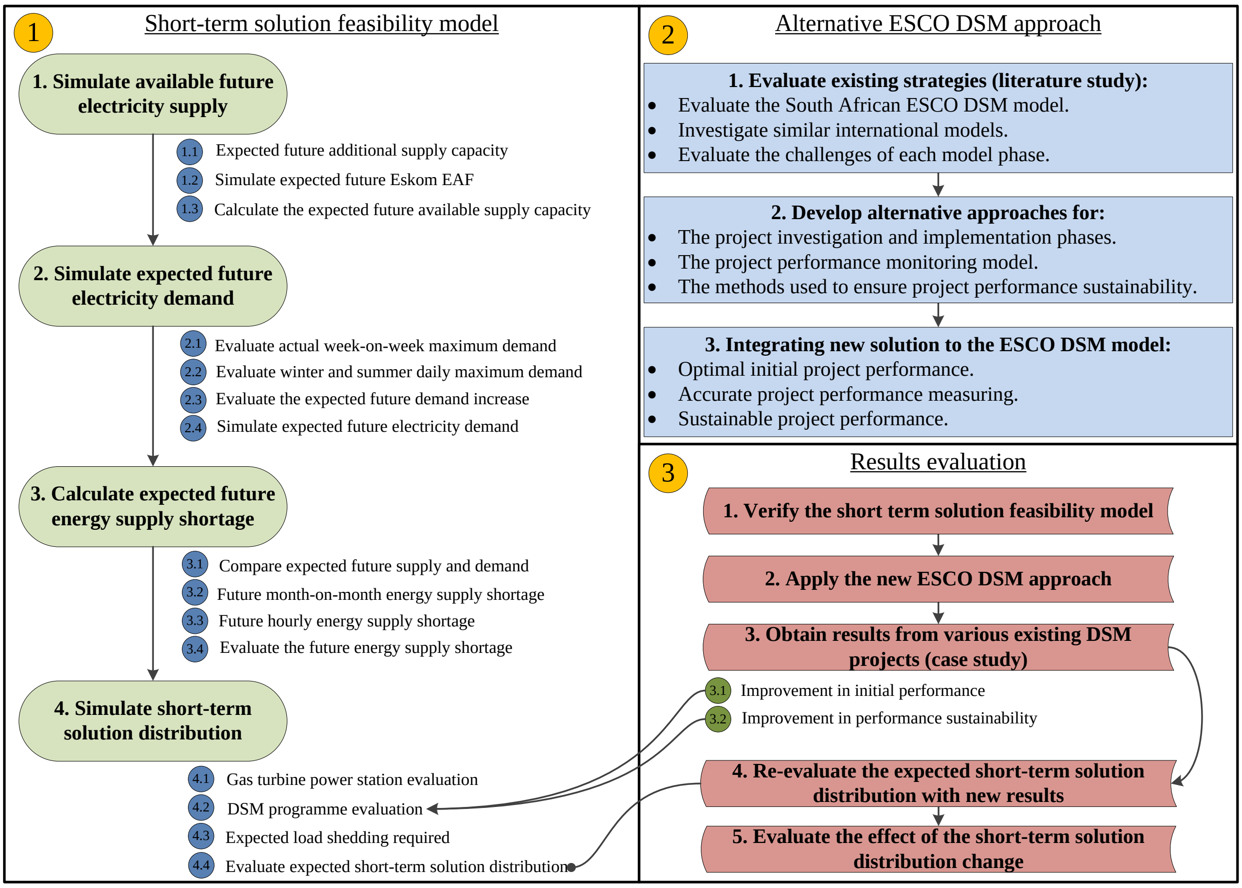

Figure 28: Methodology summary

3.3 Alternative project investigation and implementation approach

3.3.1 Introduction

In the following section, an alternative approach to the industrial DSM ESCO model will be proposed. As mentioned in section 3.1.4, the objective of the alternative approach is to improve the initial project saving and the sustainability of industrial DSM projects. Eskom recently made some changes to the DSM ESCO model. These changes and the expected effect on the initial project impact and the project sustainability will be discussed.

For the purpose of this study, the DSM ESCO model (before Eskom made changes) will be referred to as the old DSM ESCO model. The DSM ESCO model with the changes already implemented by Eskom will be referred to as the new DSM ESCO model. Figure 29 provides a summary of the old DSM ESCO model and the new DSM ESCO model.

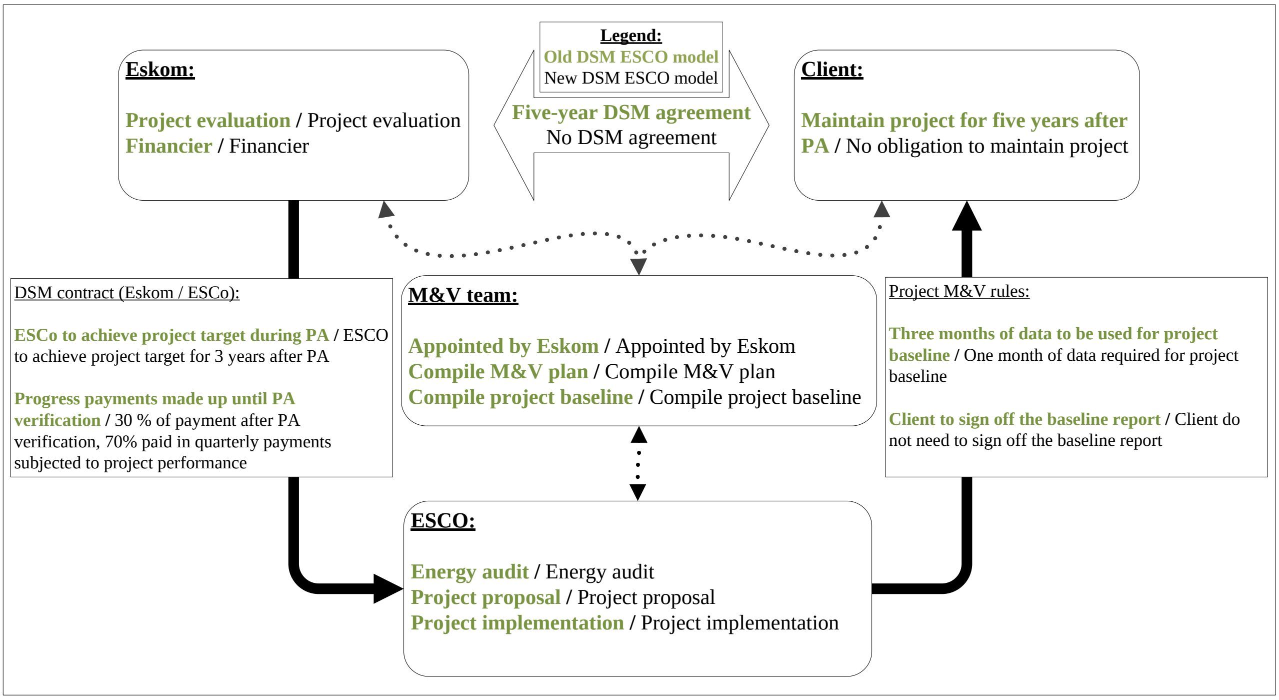

Figure 29: Old and new DSM ESCO model comparison

The new approach to the DSM ESCO model, which will be developed in the following sections, will be referred to as the alternative DSM ESCO model. The proposed changes to the new DSM ESCO model will be integrated in section 3.6 to formulate the alternative DSM ESCO model.

3.3.2 Project investigation

The first major challenge identified in section 2.4 was the relatively small South African ESCO market when compared with developed countries. It was found that the main reason other developing countries also have relatively small ESCO markets is because of a lack of funding available for new projects. In South Africa during the past decade, however, ample funding for new energy savings projects was provided through the Eskom DSM programme.

The main reason for the small ESCO market in South Africa was, therefore, not because of the lack of funding but rather because of the inconsistent availability thereof. It was found that small ESCOs find it difficult to enter the industrial ESCO market due to the uncertainty whether Eskom will allocate funding for future DSM projects. It was also found that various unique challenges of South African industrial DSM projects also contributed to the small ESCO market. These challenges were discussed in section 2.4.

The small ESCO market in South Africa has various negative effects such as insufficient competition between ESCOs. With only a limited number of ESCOs competing with each other, established ESCOs have the ability to ask more for their technology and skills. It is, therefore, in the best interests of Eskom that the ESCO market in South Africa expands. At the moment, only a few established ESCOs are in a position to submit new projects when ample funding becomes available.

Most of the newly submitted projects are investigated during times when Eskom provides less funding for new projects. Established ESCOs that have a healthy cash flow usually investigate new projects during times when less funding for new projects are available. The reason for this is that new projects will then be ready to be submitted when funding becomes available. It should be noted that ESCOs are responsible to fund the new investigations.

Due to the uncertainty of whether Eskom will provide future funding or not, established ESCOs tend to allocate only a limited amount of funds to new investigations. New investigations are, therefore, not always done properly. Section 2.4 mentioned the example of using equipment running statuses to establish baselines instead of installing proper power data loggers.

Improper project investigations can lead to projects not achieving their targets. This has a direct effect on the return on investment of the funding spent by Eskom. When projects are investigated, the payback period of a project is usually a good indication of its feasibility. Projects also have limited lifespans due to the aging of equipment that was installed. Projects not achieving their targets can, therefore, result in payback periods exceeding the expected lifespan of the project.

It is clear that a small ESCO market can have a snowball effect on the performance of future DSM projects. As part of this study, the first step of the alternative DSM ESCO model is to establish a large ESCO market. To achieve this objective, it is necessary to have a constant drive towards the DSM programme. Eskom should have a long-term goal with their DSM programme, with a constant drive to achieve this goal. This will allow new ESCOs to enter the market with more certainty of future opportunities.

Due to the existing financial constraints of Eskom, it is understandable that Eskom cannot commit to constant annual funding for the DSM programme. Considering the fact that the electricity supply shortage affects the whole country, it is proposed that the Department of Energy gets involved to ensure constant future funding for the DSM programme.

In addition to the unique challenges of the small South African ESCO market, various other challenges were also identified during the project investigation phase discussed in section 2.4. These challenges include:

- lack of cooperation from the client,
- ESCOs proposing unrealistic savings targets, and
- effect of seasonal changes not taken into consideration.

During the literature study, it was found that clients in developed countries tend to identify the need for energy savings or load management strategies on their systems. The clients then approach ESCOs to do a site visit and a detailed project proposal. A tender procedure is followed by the client to select the most appropriate ESCO to do the project.

The next step is for the selected ESCO to do a proper energy audit on the system. This detailed audit, or in other words the project investigation, is financed by the client. Due to the client financing the energy audit, full cooperation is provided. The ESCO also tends to do a more thorough investigation due to the availability of client funding. More resources can be used to do the energy audit, and required equipment to do a detailed investigation can be purchased.

The South African situation is, however, different than developed countries. Energy savings are not currently a high priority for industrial clients in South Africa. Production outputs, for example, tend to have a higher priority. One reason for this occurrence is the relatively low energy cost of South Africa compared with other countries. As electricity cost increases, industrial clients tend to realise the importance of energy savings and effective load management.

Due to the electricity supply shortages experienced by Eskom, it is believed that energy savings and effective load management are more important to Eskom at this stage. If projects do not achieve their savings targets because of improper investigations, the return on investment of the project funding will also be affected. Thorough investigations should therefore be important to Eskom.

The second step of the alternative DSM ESCO model is for Eskom to become involved with the investigation of new projects. But, Eskom specialises in generating electricity. They do not have the necessary expertise required for energy-saving and load-management projects. It is, therefore, proposed that Eskom takes the role that a client in developed country would play. Eskom should:

1. Identify large electricity-consuming systems in industry.
2. Approach various ESCOs to submit project proposals.
3. Identify an appropriate ESCO through a formal tender process.
4. Finance a detailed investigation that will be done by the selected ESCO.
5. Make an informed decision based on the findings whether a project on the specific system will be feasible.

With the old and new DSM ESCO model, the ESCO takes initiative to approach the client to do a new investigation. If Eskom approaches the client instead, it is believed that the client will realise the seriousness of the situation, thus resulting in better client cooperation. The next step of the alternative DSM ESCO model is for Eskom to develop an ESCO grading model.

This grading model can be used to select the ESCOs who should be involved with a tender process. It is proposed that the model should evaluate ESCOs in terms of:

1. The period during which the ESCO completed previous investigations.
2. The accuracy of the previous project investigations (if the expected savings target was achieved).
3. The cost of the technologies proposed by the ESCO to achieve the previous project targets.
4. The sustainability of the savings achieved by previous projects implemented by the ESCO.

By evaluating ESCOs in terms of these criteria, the possibility of ESCOs proposing unrealistic targets or not considering seasonal changes will be reduced. The next step in the alternative DSM ESCO model is to reduce the time period of the Eskom project approval phase. The longer Eskom takes to approve a project after the project investigation has been completed, the larger the possibility of system changes which could affect project savings.

The next challenge identified in section 2.4 is the challenge of political transformation regulations enforced by Eskom on the ESCOs. These regulations force ESCOs to only use sub-contractors who comply with the regulations instead of using sub-contractors who have the necessary skills to implement the projects successfully. This can have the following result:

- projects not being implemented correctly, and
- implementation cost higher than expected due to the sub-contractor contracting another company to implement the project.

Due to the fact that the impact of the DSM programme is important to assist Eskom with the supply shortage, optimal savings are required. Transformation policies are also important to Eskom. It is, therefore, proposed that the regulations first focus on developing the necessary skills of the complying contractors before obliging ESCOs to use contractors who comply with the regulations.

3.3.3 Conclusion

In section 3.3, an alternative approach to the project investigation and implementation phases of the DSM ESCO model was discussed. Table 11 summarises the alternative DSM ESCO approach and compares it with the old and new DSM ESCO models.

Table 11: DSM ESCO model comparison – project investigation and implementation

No.	Old DSM ESCO model	New DSM ESCO model	Alternative DSM ESCO model
1	No constant drive from Eskom towards DSM. Small ESCO market.	No constant drive from Eskom towards DSM. Small ESCO market.	Constant drive towards DSM. Establishes larger ESCO market.
2	Eskom not involved with investigation.	Eskom not involved with investigation.	Eskom manages investigation and ESCO appointment.
3	Small ESCO market. No grading model.	Small ESCO market. No grading model.	ESCO grading model. Ensures ESCO competence.
4	Long project approval phase.	Long project approval phase.	Shorter project approval phase.

3.4 New approach to measure DSM impact

3.4.1 Introduction

In section 2.5, the importance of accurate and continuous project performance measurement has been discussed. This is mainly due to the following reasons:

- The performance of the project is used to quantify the benefits of the project.
- Clients could pay penalties due to underperforming projects.
- ESCO compensation depends on the project performance.

It was found during the literature study that various previous studies focused on the accuracy of M&V of project performance. Various procedures were developed to address the issues causing inaccurate M&V. The conclusion was drawn that ample information regarding M&V procedures already exists. The problem identified is not the existing M&V procedures, but rather the methods used to ensure that these M&V procedures are implemented correctly.

Despite the work that has been done to ensure accurate M&V, a large number of M&V reports still report inaccurate savings. There are also various projects still inside their contract periods and which are not continuously monitored by the appointed M&V teams. The main reasons for these occurrences are:

- M&V teams relying on ESCOs to obtain raw data for project performance tracking.
- Incorrect procedures used to calculate the project performance (such as incorrect baseline-scaling procedures).
- Incorrect interpretation of the available data (such as using backwards-filling instead of forward-filling).

3.4.2 Project performance measurement

It was already pointed out that the performance of the DSM programme is important to Eskom. The main reason is that the DSM programme is one of the short-term solutions assisting Eskom with the supply shortage. In order for Eskom to accurately determine the return on investment on the funding spent on the DSM programme, accurate M&V is required. Inaccurate M&V can lead to a delusion of the performance of the DSM programme, resulting in ineffective spending of future funding.

This study, therefore, suggests that Eskom gets involved with the M&V of industrial DSM projects. It is not proposed that Eskom takes over the responsibilities of the M&V teams appointed to monitor the performance of DSM projects. Instead, Eskom should appoint an M&V facilitating team with enough knowledge regarding M&V procedures and industrial DSM projects to guide M&V teams through the correct procedures.

It is proposed that the responsibilities of the Eskom M&V facilitating team should be to:

1. Verify that an accurate and appropriate baseline has been selected.
2. Verify the relevancy of the baseline-scaling methodology constantly.
3. Ensure that the correct infrastructure has been installed in order for M&V teams to obtain raw data independently.
4. Ensure appointed M&V teams track project performance constantly.

With the old DSM ESCO model, the ESCO, M&V team and client were involved with the baseline selection procedure. The ESCO was usually involved with selecting the equipment to be included in the baseline, supplying the raw data to the M&V team and assisting with developing the baseline. The M&V team developed the baseline using the raw data supplied by the ESCO. A minimum of three months of raw data had to be used to compile a baseline.

The M&V team was also responsible for developing the baseline-scaling methodology applicable to the project. The ESCO usually assisted the M&V team by consulting them during the baseline-scaling methodology development phase. This was because the ESCO usually has more knowledge regarding the applicable industrial system. By consulting the ESCO, a more accurate baseline-scaling methodology could be developed.

The M&V team then compiled a baseline report containing information such as:

- project objectives,
- raw data source,
- baselines developed, and
- the baseline-scaling methodology.

As part of the old DSM ESCO model, the client had to sign off the baseline report compiled by the M&V team before the project could proceed. This was an important step in verifying the accuracy of the baseline and scaling methodology developed. The client usually has the most knowledge regarding their industrial system. The client's signature on the baseline report was, therefore, a good indication to Eskom that the baseline development procedure was done accurately.

With the new DSM ESCO model, the last mentioned baseline and scaling methodology development procedures remain the same. The only changes are:

- A minimum of one month of raw data is required to compile a baseline.
- The client does not need to sign off the baseline report anymore.

In addition to the Eskom facilitating team, it is proposed that the above-mentioned changes to the old DSM ESCO model are altered as part of the alternative DSM ESCO model. It is argued that one month of data will not provide an accurate baseline and it is proposed that the old requirement of a minimum of three months raw data is reinstated. It is also proposed that the client should still approve the developed baseline and scaling methodology to ensure proper baseline and scaling methodology verification.

The involvement of the ESCO during the baseline and scaling methodology development phase was identified as a problem with the old DSM ESCO model. The fact that the compensation of the ESCO depends on the performance of the project can affect the accuracy of the information supplied by them. It is proposed that the Eskom facilitating team should also have sufficient knowledge regarding the applicable industrial systems. The Eskom facilitating team should then take the role of the ESCO by consulting the M&V team during the baseline and scaling methodology development.

As part of the old and the new DSM ESCO models, the baseline-scaling methodology developed by the M&V team was never revised after the baseline report was compiled and accepted. Due to system changes after the implementation of an industrial DSM project, the need may arise to revise the baseline-scaling methodology. The Eskom facilitating team should communicate constantly with the client to realise any system changes that will require the baseline-scaling methodology to be revised. This will ensure accurate long-term project performance tracking.

It was found that M&V teams sometimes rely on ESCOs to send them the required raw data to do project performance tracking. As part of the old DSM ESCO model, the ESCO did not have any responsibility to maintain the project performance after the three months of PA. ESCOs were also not responsible to send the raw data to the M&V team for project performance tracking after the PA period. This resulted in the performance of a large number of industrial DSM projects not being monitored constantly after the PA period.

The new DSM ESCO model stipulates that the ESCO should maintain the project performance for three years after PA. The compensation of the ESCO also depends on the performance of the project. The ESCO will, therefore, ensure that the M&V team receives the required raw data to constantly report on the project performance. Although this method of raw data collection may be convenient, it is not ideal and defeats the purpose of an independent M&V team measuring the project performance.

Because the compensation of the ESCO depends on the project performance, independent raw data collection by the M&V team is proposed. The Eskom facilitating team should ensure that the correct equipment is installed during the project installation phase to ensure independent M&V data collection. It should be the responsibility of the M&V teams to audit the electrical network of the client in order to determine the required equipment to obtain the raw data. This process should be managed by the Eskom facilitating team.

It is the responsibility of the M&V team to report on the performance of an industrial DSM project. Depending on the Eskom requirements, a performance-tracking report should be issued by the M&V team on either a monthly, quarterly or yearly basis. It should be part of the responsibilities of the Eskom facilitating team to ensure that the M&V team issues these performance-tracking reports.

3.4.3 Conclusion

In section 3.4, an alternative approach to the project performance measurement procedure of the DSM ESCO model was discussed. Table 12 summarises the alternative approach and compares it to the old and the new DSM ESCO models.

Table 12: DSM ESCO model comparison – project PA

No.	Old DSM ESCO model	New DSM ESCO model	Alternative DSM ESCO model
1	ESCO, M&V and client select baseline.	ESCO and M&V select baseline.	Eskom, M&V, ESCO and client select baseline.
2	M&V and ESCO select M&V procedures.	M&V and ESCO select M&V procedures.	Eskom and M&V select M&V procedures.
3	ESCOs facilitate obtaining of raw data.	ESCOs facilitate obtaining of raw data.	Eskom facilitates to ensure independent M&V raw data collection.
4	M&V responsible for monitoring project performance constantly.	M&V responsible for monitoring project performance constantly.	Eskom ensures constant project performance monitoring.

3.5 Solution to ensure project sustainability

3.5.1 Introduction

Another problem identified during the literature study was that Eskom reports on the annual cumulative DSM impact measured in MW. Only the initial project performance during the PA period is considered when the annual cumulative DSM impact is calculated. Due to the poor sustainability of industrial DSM projects, this is not an accurate reflection of the actual current impact of the DSM programme. This can lead to misinterpretation of the performance of the DSM programme.

As part of the alternative approach to the DSM ESCO model, it is proposed that Eskom also reports on the actual annual impact in terms of MWh savings achieved. The reason why Eskom has not previously reported on this figure might be due to the lack of available M&V performance-tracking information. With the alternative approach to ensure more accurate and continuous performance tracking, sufficient future performance-tracking information should be available. This will enable Eskom to report on the actual annual DSM programme performance in terms of total MWh savings during the evening peak period.

Key performance indicators (such as the cost per energy unit savings during the evening peak period) should also be reported. By considering the amount of funds that Eskom spent on the DSM projects and the actual annual DSM programme performance, the cost per MWh of evening peak savings can be calculated. The cost effectiveness of the DSM programme can then be compared with the cost effectiveness of other short-term solutions such as using the gas turbine power stations.

3.5.2 Project sustainability improvement

A study completed by Groenewald *et al.* during 2015 focused on developing a performance-centred maintenance strategy for industrial DSM projects [69]. This new maintenance strategy focused on optimising the electricity cost savings by improving the sustainability of industrial DSM projects. A case study, which consisted of eight industrial pumping projects, was evaluated as part of the study.

It was revealed that five of the projects were maintained by the client after the project PA period. For the remaining three projects, the client contracted an ESCO to maintain the projects. The case study results indicated that the projects maintained by the client only achieved an average of 49% of the original project target after PA. The projects maintained by the ESCO achieved an average of 106% of the original project target after PA [69].

The study also revealed that by implementing a performance-centred maintenance strategy for industrial DSM projects, the electricity cost savings could be improved with 64.4%. Maintaining the performance of industrial DSM projects, therefore, benefits the client as well as Eskom. The cost of implementing such a maintenance strategy is approximately 6% of the total benefit generated because of it. The study also indicated that the cost to maintain the project would be 25% of the electricity cost saved by the project as a worst-case scenario.

As part of the old DSM ESCO model, the ESCO was responsible for achieving the project target during the PA period of the project. The ESCO can be penalised in terms of compensation received from Eskom if the project performance is not at least within 90% of the target. After the PA period, the responsibility for maintaining the savings achieved by the ESCO during the PA period lies with the client for the remaining contract period.

The client can also be penalised by Eskom if the project performance is not maintained within 90% of the savings achieved during the PA period. This process was designed in order to ensure that the savings of industrial DSM projects are maintained for the duration of the contract period. During the literature study, it was discovered that different scenarios could make it difficult for Eskom to enforce the penalties on clients.

Some clients assist Eskom by switching off large electricity-consuming equipment if requested. This could influence the performance of DSM projects implemented on the same systems. Inaccurate and inconsistent project performance tracking by appointed M&V teams also makes it difficult for Eskom to enforce penalties. It is concluded that penalising clients when projects underperform is not an effective method for ensuring project performance sustainability.

The new DSM ESCO model stipulates that the ESCO is responsible for achieving the project target during the PA period. If the ESCO achieves the project target during the PA period, 30% of the ESCO compensation will be paid to the ESCO. It is then the responsibility of the ESCO to maintain the project performance for a period of three years after PA. The remaining 70% of the ESCO compensation will be paid out in quarterly segments during the three years after PA. Each quarterly payment will be dependent on the performance of the project.

The new ESCO model has just been implemented by Eskom and the sustainability of the industrial projects implemented, based on the new model, still has to be evaluated. Due to the fact that the compensation of the ESCO is dependent on the project performance, it is expected that the performance sustainability of industrial DSM projects will improve. After the three-year contract expires, it is expected that the sustainability of the project performance will once again deteriorate.

The cost of maintaining an existing project is only a fraction of the cost of implementing a new project. As part of the alternative approach to the DSM ESCO model, it is therefore proposed that Eskom should be involved with maintaining out-of-contract DSM projects. By maintaining the performance of existing industrial DSM projects for longer periods, the return on the initial capital investment is increased.

It is understandable that Eskom might not have the expertise to maintain the performance of an industrial DSM project effectively after the contract has expired. It is, therefore, proposed that

Eskom contracts ESCOs to maintain the performance of industrial DSM projects after the contract periods expire.

3.5.3 Conclusion

In section 3.5, an alternative approach for ensuring project sustainability of existing industrial DSM projects was discussed. Table 13 summarises the alternative approach and compares it to the old and the new DSM ESCO models.

Table 13: DSM ESCO model comparison – maintaining project performance

No.	Old DSM ESCO model	New DSM ESCO model	Alternative DSM ESCO model
1	Only reports on the cumulative performance of the DSM programme, measured in MW.	Only reports on the cumulative performance of the DSM programme, measured in MW.	Also reports on the annual performance of the DSM programme measured in MWh.
2	Does not compare the cost effectiveness of the DSM programme with other short-term solutions.	Does not compare the cost effectiveness of the DSM programme with other short-term solutions.	Compares the DSM programme with other short-term solutions in terms of cost effectiveness.
3	Client responsible for maintaining the project after PA.	ESCO responsible for maintaining the project after PA.	ESCO responsible for maintaining the project after PA.
4	No action plan for maintaining projects after the contract period.	No action plan for maintaining projects after the contract period.	Eskom should be involved in maintaining projects after the contract period.

3.6 Integrating the new solution with the DSM ESCO model

In section 3.3 to section 3.5, various alternative approaches to the DSM ESCO model were proposed. During this section, these alternative approaches will be combined to formulate an integrated alternative approach to the industrial DSM ESCO model. Figure 30 summarises the alternative approaches suggested during the previous sections of Chapter 3.

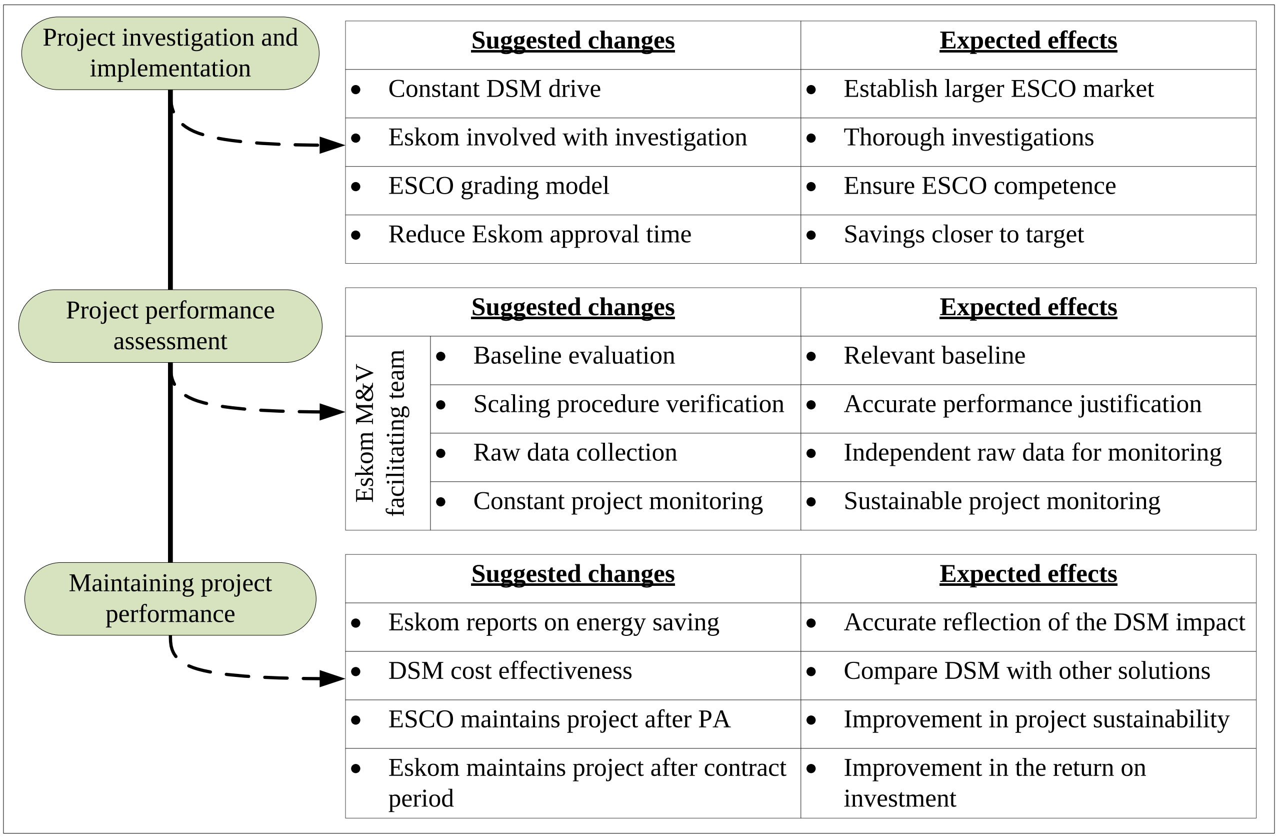

Figure 30: Alternative approaches to the DSM ESCO model – summary

The integrated alternative approach to the DSM ESCO model is divided into three sections:

1. Project investigation and implementation section.
2. Project PA section.
3. Maintaining project performance section.

Each of the above-mentioned sections has a different primary objective. The primary objective of the “project investigation and implementation” section is to improve the initial project performance during the PA period. The primary objective of the “project PA” section is to improve the accuracy and sustainability of project performance tracking. Improving the sustainability of the project performance after the PA and the project contract period is the primary objective of the “maintaining project performance” section.

3.7 Conclusion

In section 3.2, a short-term solution feasibility model was developed. The function of the feasibility model is to predict future electricity supply shortages in South Africa. The feasibility model has the functionality to predict the daily electricity shortages during the different hours of the day. The supply shortages are then calculated on a monthly and yearly basis.

The feasibility model also evaluates the different short-term solutions in terms of the available impact and the time of availability. For example, because of the current DSM objective to reduce load during the Eskom evening peak period, the impact of the DSM programme is limited to the evening peak period only. Although the gas turbine power stations are only meant to operate during Eskom peak periods, the model schedules the use of these power stations when needed.

The model also calculates the cost involved with operating the gas turbine power stations. The DSM programme cost at different DSM programme sustainability factors is also evaluated and compared with the running cost of the gas turbine power stations. This is done by taking the amount that Eskom budgeted to spend on the DSM programme, the savings target and the sustainability of the savings into consideration.

To account for the expected electricity supply shortage, the feasibility model utilises the short-term solutions in the following order:

1. Available DSM impact.
2. Gas turbine power stations.
3. Load shedding.

Due to the impact of the DSM programme not being immediately controllable, the feasibility model uses the available impact of the DSM programme first. Should the electricity supply shortages be more than the available DSM impact, or during different hours than the evening peak period, the model uses the available impact of the gas turbine power stations. Should the impact of the DSM programme and gas turbine power stations not be sufficient, load shedding is scheduled to avoid a total network blackout.

The feasibility model indicated that the sustainability of the DSM programme should be more than 69% to be more cost effective than operating the gas turbine power stations. A recent study indicated that the savings of industrial DSM projects could deteriorate with up to 51% of their original targets after the PA period. It was also indicated that the initial impact of industrial DSM projects was affected by various challenges during the investigation and implementation phases.

Inaccurate and inconsistent project performance measurement was also identified as a challenge of the existing DSM ESCO model. These challenges prompted the need to propose an alternative approach to the South African DSM ESCO model. An integrated alternative approach was developed in order to:

- Improve the initial impact of industrial DSM projects.
- Ensure accurate and continuous project performance tracking.
- Improve the sustainability of project performance.

The next step in the methodology is to evaluate the impact of the alternative DSM ESCO model in terms of the above-mentioned objectives. The results will be used as new inputs into the short-term solution feasibility model. The following results will then be evaluated:

- the improvement in the initial impact of industrial DSM projects,
- the improvement in the sustainability of industrial DSM project saving,
- cost savings as a result of less frequent use of gas turbine power stations, and
- a reduction in load shedding required and the economic impact thereof.

Chapter 4: Verification and validation of the alternative industrial DSM ESCO model

[20]

During this chapter, the short-term solution feasibility model will be verified. Results of existing studies and applicable industrial DSM projects will be used to verify the effect of the alternative approach to the DSM ESCO model. The short-term solution feasibility model will then be used to validate the impact of the alternative approach.

[20] Are mining companies really detrimental to the society? (2015). [Online]. Available: http://thompson2009.com/are-mining-companies-really-detrimental-to-the-society/. [Accessed: 08 September 2015]

4.1 Introduction

A feasibility model was developed in Chapter 3 to predict the expected electricity supply shortage for the next three years. The impact of each short-term solution is scheduled to account for the expected shortage in electricity supply. Case studies revealed the initial impact and sustainable savings of industrial DSM projects. The model was used to evaluate the use of short-term solutions with the initial impact and sustainable savings of industrial DSM projects as inputs.

An alternative approach to the DSM ESCO model was developed with the following main objectives:

- Improving the initial impact of industrial DSM projects.
- Ensuring more accurate and continuous project performance measurement.
- Improving the sustainability of the savings achieved with industrial DSM projects.

During this chapter, the accuracy of the feasibility model developed in Chapter 3 will be verified. Following the verification of the feasibility model, the impact of the alternative approach to the DSM ESCO model will be verified in terms of the above-mentioned objectives. A case study will be conducted where the initial impact and sustainability improvements of industrial DSM projects will be evaluated using the feasibility model.

The results of the feasibility model obtained in Chapter 3 will be compared with the model results after the impact of the alternative DSM ESCO model has been considered. The impact of the improvements because of the alternative approach to the DSM ESCO model will be evaluated in terms of the:

- reduction in the required use of gas turbine power stations,
- reduction in load shedding required,
- financial benefits to Eskom, and
- effect on the economy of South Africa.

4.2 Verification

4.2.1 Feasibility model

As part of the feasibility model developed in Chapter 3, the total electricity supply shortage is simulated for the next three years. The model then uses the short-term solutions based on their time of availability, expected impact and feasibility. The future DSM impact, required use of gas turbine power stations and the necessary load shedding can then be calculated.

To verify the model accuracy, a case study is done using 2013 actual data as inputs to the model. Table 14 summarises the most important model inputs used during the model verification case study. The resources used to obtain the input values are also provided. The model results are then compared with the actual data from 2014, which was obtained from the same resources.

Table 14: Feasibility model – verification case study inputs

No.	Input description	Value	Unit	Resource
1	Eskom installed capacity (2013)	41 808	[MW]	[75]
2	Additional installed capacity (2013)	120	[MW]	[1]
3	Additional installed capacity (2014)	100	[MW]	[73]
4	Weekly max. demand profile (2013)	Profile	[MW]	[71]
5	Avg. daily demand profiles (2013)	Profile	[MW]	[1]
6	Annual demand increase (2013)	5	[%]	[71]
7	Annual demand increase (2014)	5	[%]	[74]
8	OCGT installed capacity (2013)	2 067	[MW]	[75]
9	OCGT availability factor	95	[%]	[76]
10	Diesel cost during 2014	9.4	[R/ℓ]	[77]
11	DSM sustainability	83	[%]	Case study
12	DSM savings achieved (2013)	410	[MW]	[1]
13	DSM savings achieved (2014)	172	[MW]	[73]
14	Funding allocated to DSM (2013)	1 314	[R million]	[75]
15	Funding allocated to DSM (2014)	656	[R million]	[71]

The feasibility model simulated a total electricity supply shortage of 4 537 GWh for the 2014 financial year. In order to account for the shortage in electricity supply, the model allocated the short-term solutions in terms of available impact and time of availability. The results of the verification case study are summarised in Table 15.

Table 15: Feasibility model – verification case study results

Description	**Unit**	**Winter**	**Summer**	**Total**
Electricity supply shortage	[GWh]	1 278	2 981	4 259
Gas turbine power stations	[GWh]	944	2 534	3 478
DSM programme	[GWh]	64	142	206
Load shedding	[GWh]	270	305	575

The model simulated a contribution of 206 GWh by the DSM programme during the 2014 Eskom financial year. The gas turbine power stations would be able to contribute 3 478 GWh to account for the electricity supply shortage. The expected load shedding required to account for the electricity supply shortage which cannot be supplied by the DSM programme and the gas turbine power stations is 575 MWh. Figure 31 shows the simulated average daily short-term solution distribution for 2014.

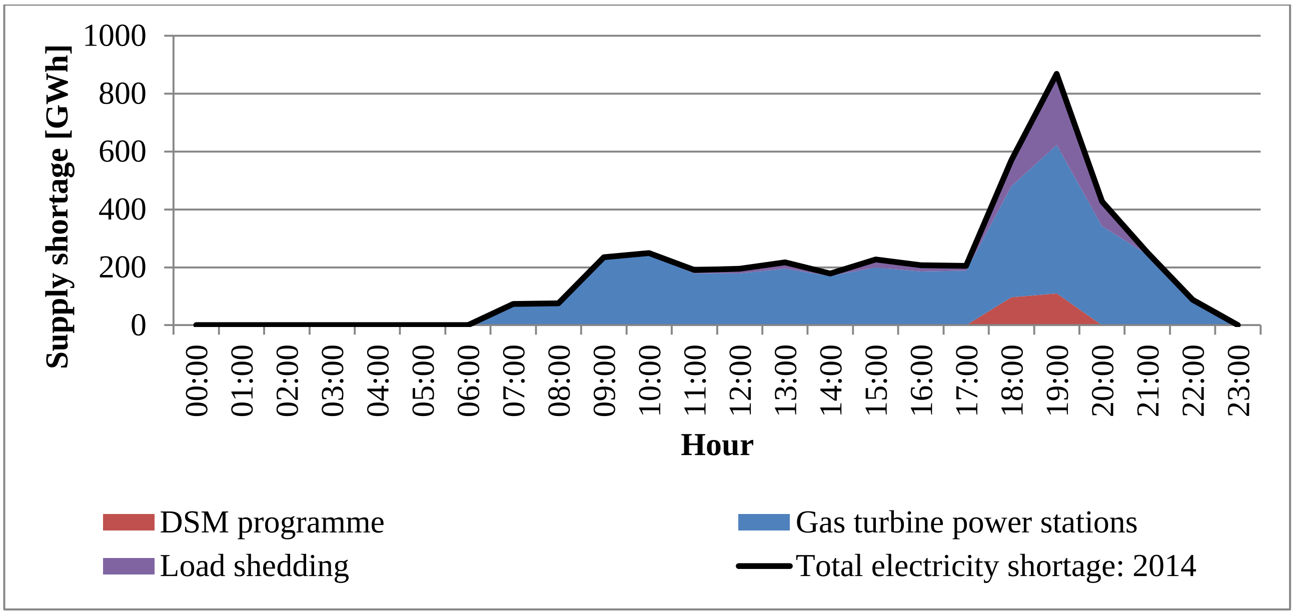

Figure 31: Simulated short-term solution distribution for 2014

From Figure 31 it should be noted that the DSM programme is simulated to have an impact during the evening peak period only. The use of gas turbine power stations are simulated between 07:00 and 22:00, with an increase in use during the morning and evening Eskom peak periods. Required load shedding is simulated to take place mostly during the evening Eskom peak period.

The Eskom Integrated Report for the 2014 financial year indicated that the gas turbine power stations generated 3 709 GWh of electricity [73]. With the inputs summarised in Table 14, the feasibility model simulated that the gas turbine power stations would generate 3 478 GWh during the 2014 Eskom financial year. The simulated electricity required from the gas turbine power stations is within 7% of the actual reported electricity supplied by the gas turbine power stations during 2014.

The model calculated the total diesel cost required to generate 3 478 GWh of electricity using the gas turbine power stations to be R8 966 million. The Eskom Integrated Report for the 2014 financial year indicated that a total amount of R9 546 million was spent on diesel to operate the gas turbine power stations [73]. The simulated diesel cost was within 6% of the actual cost spent on diesel in 2014, as reported by the Eskom Integrated Report.

4.2.2 Impact of accurate and continuous M&V reporting

During this section, the effect of accurate and continuous reporting on the performance of existing DSM projects will be verified. A case study was done on a cement plant where an industrial DSM project was implemented on the raw milling and finishing milling sections of the plant. The DSM project considered the Eskom TOU periods, the required silo levels and the expected cement demand to simulate the optimal mill running schedules. The system displayed the optimal running schedules on a screen in the control room.

The system only proposed a running schedule for each mill and did not stop and start the mills automatically. This was because most cement plants prefer that operators stop and start their mills manually. By operating the mills according to the optimal running schedule simulated by the system, the plant had a cost benefit due to the power being shifted out of the expensive Eskom peak periods. Eskom benefited from the project due to the reduction during the evening peak period.

It was found that due to a lack of accurate and continuous reporting, savings deteriorated. This is because plant personnel are not continuously reminded about their project performance and lost savings. The case study entailed implementing a detailed and accurate reporting system on the industrial DSM project implemented on the cement plant. The reporting system was only implemented nine months after the commissioning of the project.

The reporting system not only reported on the amount of load shifted out of the evening peak period, but also included the following information:

- average weekday power profile of the system,
- electricity cost related to the power consumed,
- load-shifting opportunities missed, and
- cost savings lost as a result of missed opportunities.

As part of the case study, the report was sent to the relevant plant personnel on a weekly basis. The ESCO who initially implemented the DSM project was not appointed by the cement plant to maintain the project after the PA period. The project was commissioned in May 2014, just before the start of the Eskom TOU winter months. The reporting system was implemented in February 2015.

It should also be noticed that Eskom temporarily shifted the TOU peak periods an hour earlier for the 2015 winter months. This information was communicated to the cement plant through the reporting system implemented as part of the case study. The Eskom peak periods for 2014 and 2015 were:

- 2014 winter months: 07:00–10:00 and 18:00–20:00
- 2015 winter months: 06:00–09:00 and 17:00–19:00

Figure 32 shows the average weekday power profiles for the 2014 and 2015 winter months. The raw milling and finishing milling systems of the cement plant are included in the power profiles. The colour codes on the bottom of the graph indicate the TOU periods during the 2014 winter months. The colour codes on the top of the graph indicate the TOU periods during the 2015 winter months. The colour codes are:

- Green: Off-peak period
- Yellow: Standard period

- Red: Peak period

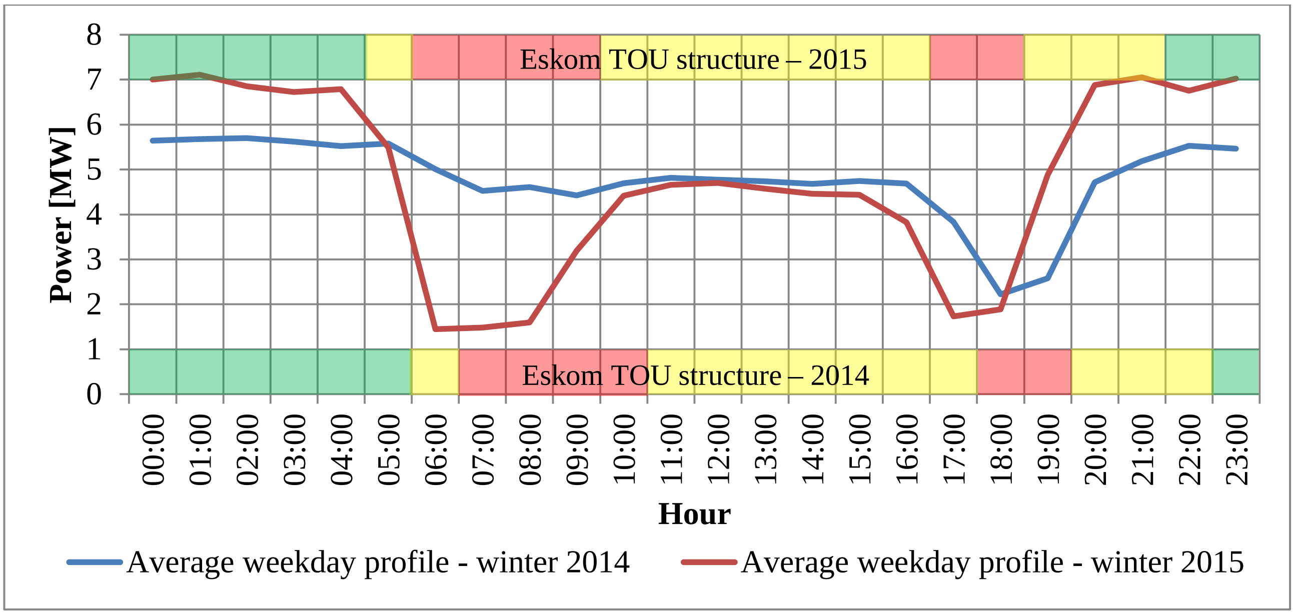

Figure 32: Effect of accurate and continuous reporting

It should be noticed from Figure 32 that the plant managed to adapt their load-shifting strategy successfully to account for the change in the Eskom peak periods. Not only did the plant manage to adapt to the new Eskom peak hours, but it also managed to shift an additional load of 0.43 MW out of the evening peak period. Due to the awareness caused by the reporting system implemented as part of the case study, the plant also started to shift load out of the expensive Eskom morning peak period.

The performance of another cement plant during the 2015 winter months was evaluated. A similar industrial DSM project was implemented on this cement plant, but no accurate and continuous reporting was done on the performance of the project. The appointed M&V team only reported on the project performance once a year. Figure 33 shows the average weekday power profile of the raw milling and finishing milling systems of this cement plant during the 2015 winter months.

From Figure 33 it should be noticed that the project does not shift load successfully out of the evening peak period anymore. The load shifted out of the morning peak periods during the 2015 winter months is also less effective than the baseline. The situation could have looked differently if accurate and continuous reporting was done to the client and Eskom.

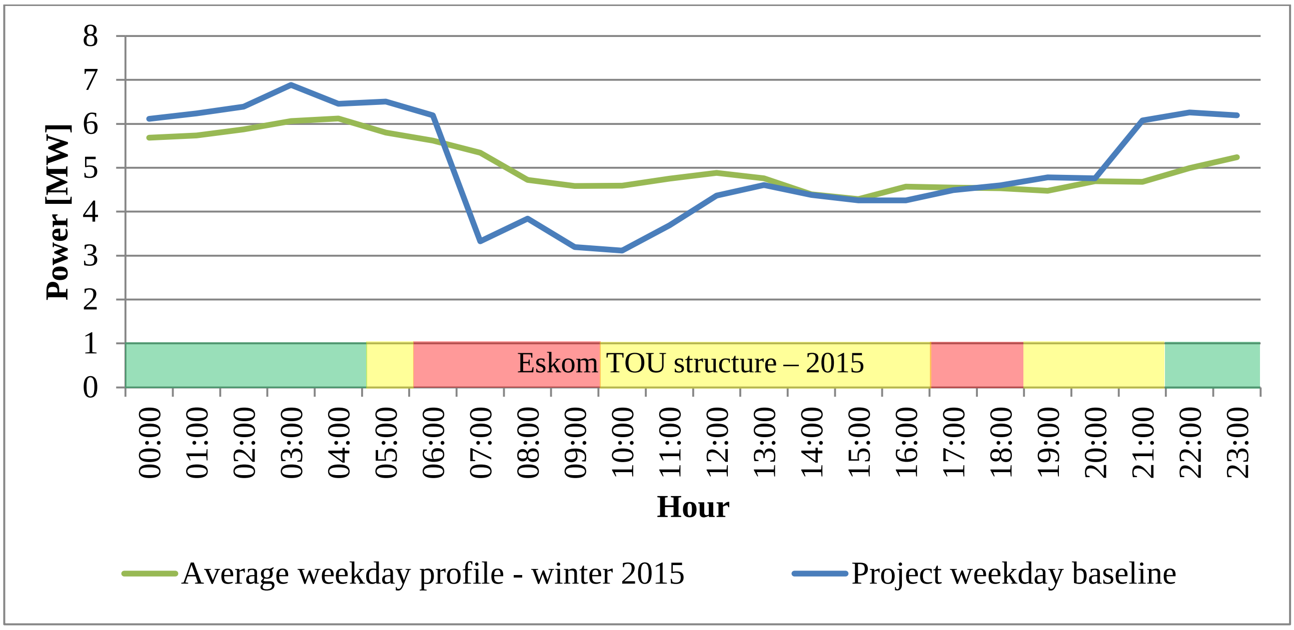

Figure 33: Project performance without accurate and continuous reporting

To determine the actual long-term effect of accurate and continuous reporting, the system should be tested for a longer period. The long-term results of the accurate and continuous reporting case study should be compared with the results of the DSM project implemented on the cement plant without accurate and continuous reporting. From the results of these case studies, however, the conclusion can be drawn that the sustainability of a project can be improved with accurate and continuous reporting.

This case study only reviewed the performance of an industrial DSM project implemented on a cement plant one year after an accurate and continuous reporting system was implemented. It was found that the load shifted from the evening peak period improved with 27% from the 2014 winter months (when no accurate and continuous reporting was done) to the 2015 winter months (when accurate and continuous reporting was implemented).

4.2.3 Improved initial impact of industrial DSM projects

Chapter 3 proposed an alternative approach to the existing industrial DSM project investigation and implementation model. The first challenge regarding the existing model was the relatively small South African ESCO market compared with other countries. It was mentioned that a small ESCO market could have various negative effects due to insufficient competition between established ESCOs.

The Eskom DSM programme has been the main source of funding for new energy savings projects implemented by ESCOs over the past decade. It was mentioned in section 3.3.2 that the inconsistent availability of funding was the main reason identified as to why South Africa has such a small ESCO market compared with other countries. It was suggested that Eskom should have a constant drive towards the DSM programme, allocating funding for DSM projects with more consistency.

Energy-saving and load-management projects are important from an environmental and economic point of view. Improving the efficiency of existing systems can reduce the negative impact of the system on the environment. Energy efficiency and load management projects also assist with the electricity supply shortage in South Africa, which in turn has a positive impact on the economy of the country. Therefore, should Eskom not be able to follow a more constant drive towards the DSM programme, it is suggested that the Department of Energy becomes more involved.

To verify the effect of constant funding availability for new DSM projects on an ESCO market, the US ESCO market can be evaluated. The guaranteed-savings financing model is mostly used in the US to finance projects implemented by ESCOs [34]. As mentioned in section 2.2.1 with this financing model the client takes responsibility to finance the initiative.

Revenues generated by the ESCO industry in the US are used as an indicator for consistent funding spent on projects. The argument is based on the fact that clients need to arrange funding for new projects to be implemented in order for ESCOs to generate revenue. During 2005, a study on the US ESCO industry market trends was done. As part of the study, 63 companies that qualified as ESCOs were identified in the US. To obtain data for the study, interviews were conducted with these companies [78].

A study completed in 2012 focused on determining the size and remaining market potential of the US ESCO industry. This study also obtained some of its information by conducting interviews with established ESCOs. A total of 144 companies that qualified as ESCOs were identified in the US. The study indicated that the revenues generated by the US ESCO industry grew with approximately 12% per annum from 2004 to 2012 [79]. Figure 34 indicates the annual revenue generated by the US ESCO industry.

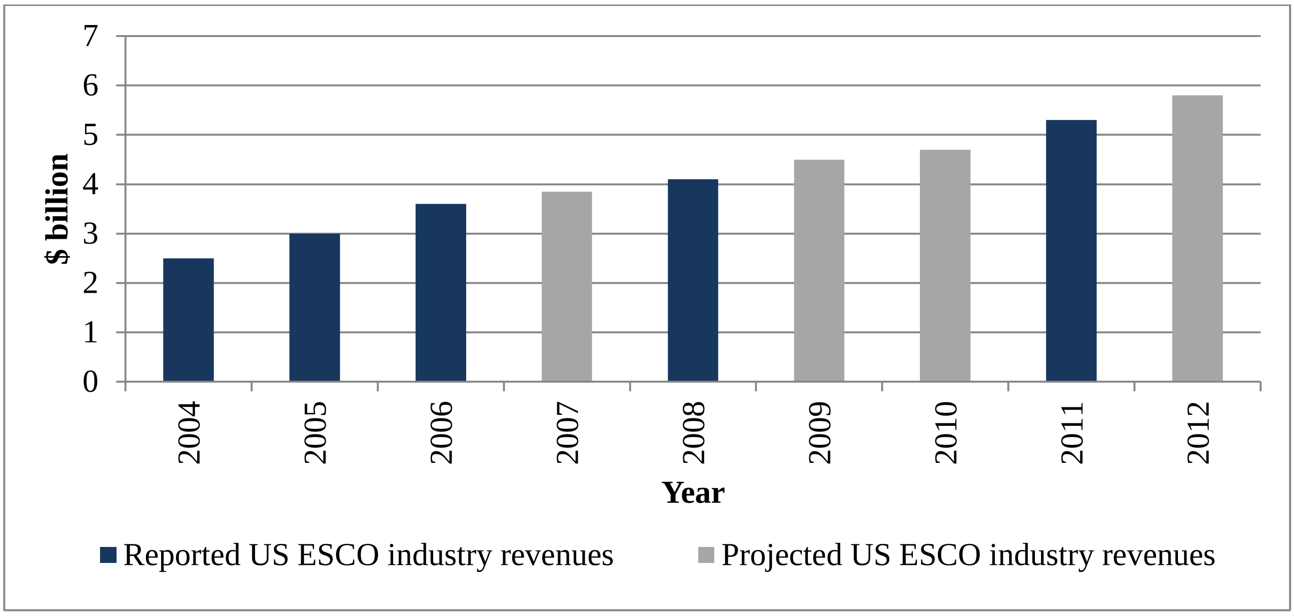

Figure 34: Revenues generated by the US ESCO industry

From Figure 34 it should be noted that there was a relatively constant growth in revenues generated by the US ESCO industry from 2004 to 2012. This means that the funding spent by clients during that time also grew with the same consistency. When considering the number of companies classified as ESCOs by the studies done in 2005 and 2012, the amount of ESCOs in the US grew with approximately 128% from 2004 to 2012. This is mainly due to the constant growth in the need by clients in the US to implement energy savings strategies.

A more recent study indicated that the expected revenue generated by the US ESCO industry will be approximately $6.3 billion in 2015, which will grow to $11.5 billion in 2024 [80].

Industrial DSM projects submitted to Eskom between 2004 and 2012 were evaluated. It was found that the number of industrial projects processed by Eskom fluctuated between 16 and 38 projects per annum. Considering that there was a worldwide recession from the end of 2007 to mid-2009, it is understandable that the Eskom funding for DSM projects would have been less during this period. This phenomenon can be noted in Figure 35.

From 2004 to 2006, the number of industrial DSM projects processed by Eskom was relatively consistent with an average of 34.6 projects per annum. During this period, the number of ESCOs submitting new industrial DSM projects increased from seven ESCOs in 2004 to twelve ESCOs in 2006.

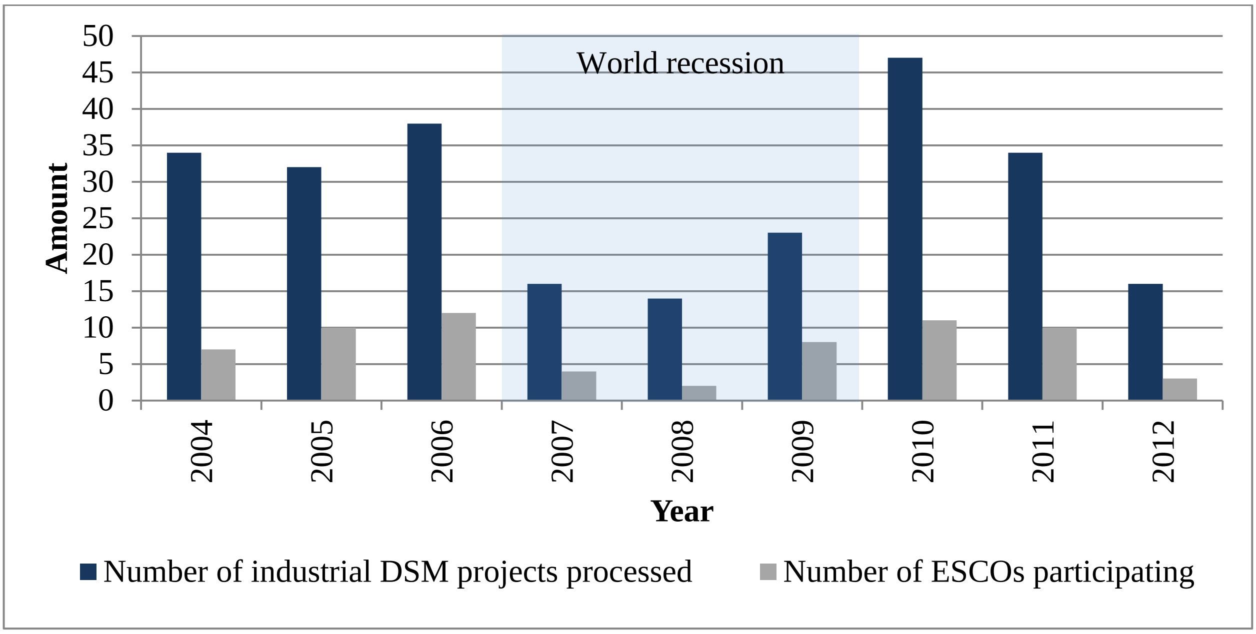

Figure 35: Industrial DSM projects and ESCO involvement from 2002 to 2012

During the period from 2010 to 2012, there was a steep decline in the number of projects processed by Eskom. The number declined by an average of 15.5 projects per annum during this period. The number of ESCOs participating in submitting new industrial DSM projects decreased with eight. These results verify the statement that an inconsistent drive towards the DSM programme and uncertainty regarding future available funding influence the ESCO market.

Section 2.4 mentioned that various challenges could arise if the project procurement process takes too long. The project procurement process takes place after the project investigation and proposal submission phases. Challenges identified in section 2.4 include scope changes, system alterations and project cost inflation. It was mentioned that these challenges could affect the project performance during the PA period.

To verify if the time that Eskom takes to approve a project influences the performance of the project during the PA period, a case study was done on 127 industrial DSM projects. The first step was to evaluate the project performance of each project against the original project target, as was stipulated in the project proposal. It was found that 36% of the industrial DSM projects investigated as part of the case study underperformed during their PA period.

The next step was to determine if the time Eskom takes to approve a project and the project performance correlate. At first, only the projects that underperformed during the PA period were considered. A regression analysis was done on the underperformance of the projects and the days Eskom took to approve these projects. This regression analysis is displayed in Figure 36.

The coefficient of determination (R^2) is an indication of the variance of the data points from the linear regression line. A coefficient of determination value close to 1 indicates a good data point distribution along the regression line. A coefficient of determination value close to 0 indicates a wide scattering of data points along the regression line. The regression analysis in Figure 36 has a coefficient of determination value of 0.0084, which indicates that there is almost no correlation between the underperformance of projects and the days Eskom took to approve the projects.

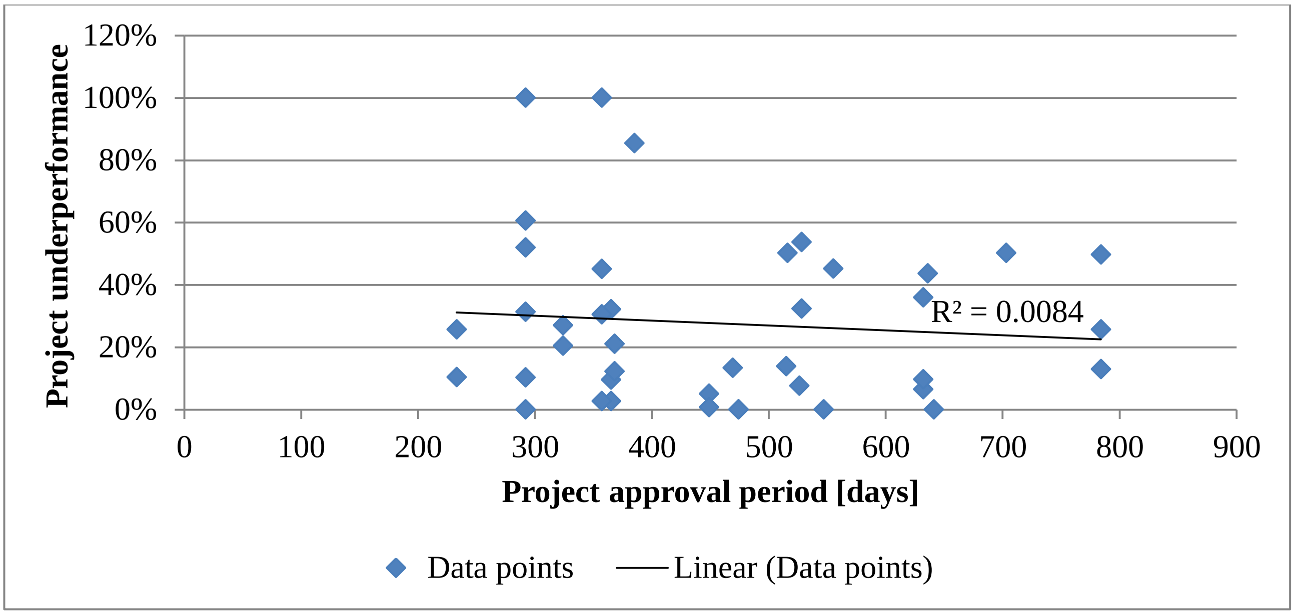

Figure 36: Regression analysis – project underperformance and procurement period

The performance of some projects may be positively affected by the time Eskom takes to approve the projects. An example of such a case is when system changes occur which will result in the baseline being inaccurate. Measured against the original baseline, the project could show savings without the project being implemented. This is, however, not a true reflection of the actual impact of the projects.

For this reason, the 127 projects were re-evaluated. The percentage of deviation from the project target, irrespective of whether the project underperformed or overperformed, was evaluated. This regression analysis resulted in a coefficient of determination value of 0.0039, which also indicated a poor correlation. The reason for the poor correlation could be because of the wide range of challenges that could influence the performance of projects.

Each project is also affected differently by the challenges that arise when Eskom takes too long to approve a project. An example is where the cost of a project is influenced by the time Eskom takes to approve the project. Because Eskom takes a long time to approve the project, the cost of the equipment that needs to be installed could be higher than what was originally budget for.

To illustrate that the inflation cost of the equipment that needs to be installed can have a different effect on the performance of each project, an example of two industrial DSM projects is provided. Each of the projects is installed on the underground compressed air system of a deep level mine. The main objective of each project is to reduce the compressed air pressure supply to each production level during non-drilling periods. By doing so, the compressed air being lost in the levels because of open-ended pipes and leaks is reduced.

The savings target and the funding available for each project were within 10% of each other. On Mine A, the mine personnel installed a series of butterfly valves on each production level. These butterfly valves were automated and could be opened or closed remotely from surface. On Mine B, the mine also installed butterfly valves on each production level, but the valves could only be opened or closed by hand.

The proposed projects were to install globe control valves on a bypass line over the existing butterfly valves on each of the mines. The butterfly valves of Mine B should have been automated as part of the DSM project scope. The butterfly valves could then have been closed during non-drilling shifts, and the pressure supplied to the levels could have been controlled effectively through the bypass globe control valves. Figure 37 illustrates the control system that had to be installed on the production levels of both mines.

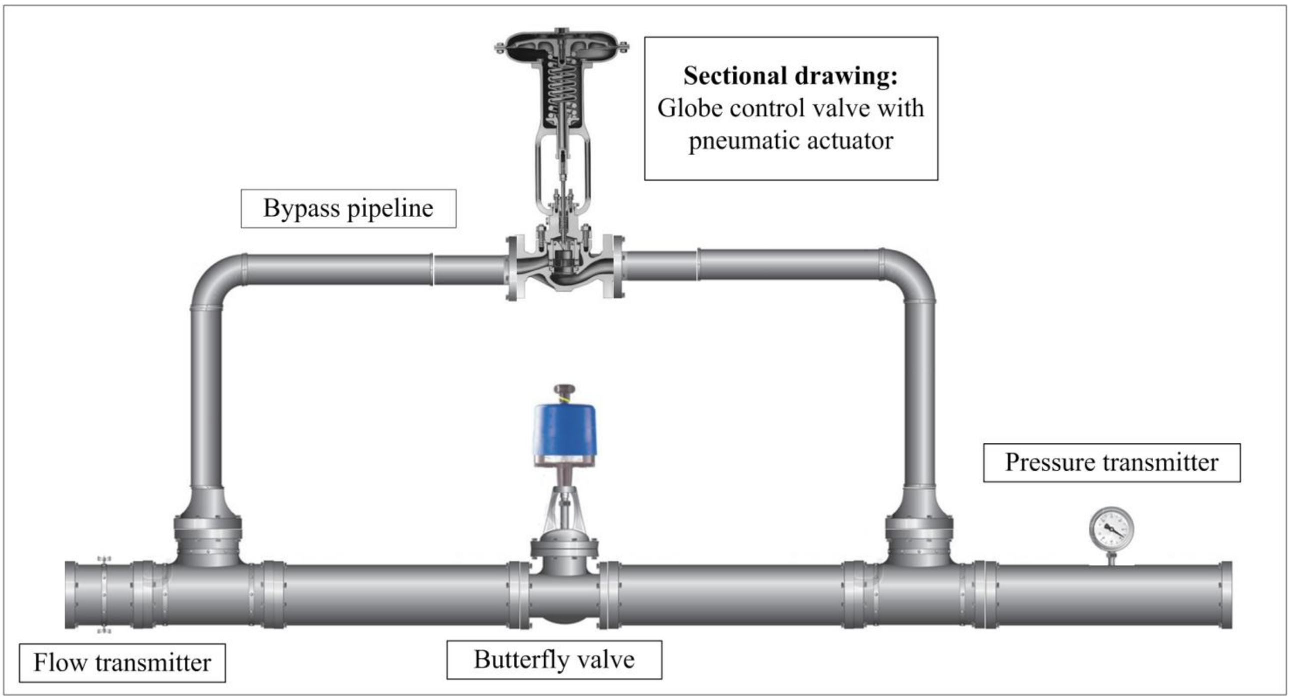

Figure 37: Globe control valve bypass configuration

Due to the long delay in approving the projects, the cost of the globe control valves and the equipment needed to automate the butterfly valves on Mine B escalated. In order for the ESCO to remain within their project budgets, the scope of the projects had to be revised. On Mine A, the scope was not affected significantly because the butterfly valves were already automated. On Mine B, the number of control stations that could be installed had to be reduced in order to pay for the automation of the butterfly valves.

The scope changes resulted in the compressed air control system being implemented on fewer production levels on Mine B than what was originally planned. On Mine A, the control system was installed on the same number of production levels than what was initially planned. The scope changes on Mine B resulted in the project underperforming with 26%, while the project implemented on Mine A still achieved its original project target.

Following the case study, it was verified that the time Eskom takes to approve a project and the deviation of the project performance from its original target do not correlate. This is mainly because each project is affected differently by the challenges that arise when Eskom takes a long time to approve a project. The case study, however, revealed that a long project approval period could result in projects not reaching their original project target.

4.2.4 Improved project sustainability

In Chapter 1, a case study consisting of 37 industrial DSM projects, which were already out of their contract period, was evaluated. This case study was done to determine if the savings of industrial DSM projects tended to deteriorate after the PA period. It was found that the performance of the industrial DSM projects included in the case study deteriorated an average of 17% per annum. Based on these findings, the need was identified to re-evaluate the existing model used to maintain these projects.

During this section, results from existing studies will be used to verify the impact on the sustainability of industrial DSM projects if they are actively maintained. The new approach (developed in section 3.5 to improve the sustainability of industrial DSM projects) stipulated that Eskom should play an active role in maintaining existing DSM projects. It was proposed that Eskom should:

- either appoint a team with sufficient knowledge regarding industrial DSM projects who can maintain the projects effectively, or
- appoint an ESCO with sufficient experience on the applicable industrial system who should maintain the project.

The above-mentioned proposals will only be feasible if it benefits Eskom in terms of additional savings achieved due to an increase in project sustainability. The benefit to Eskom should be determined by considering the following factors:

- additional cost to do proper maintenance on the projects,
- the cost savings due to reduced gas turbine power station use as a result of a larger impact of the DSM programme, and
- the impact on the economy due to reduced load shedding.

The feasibility of the alternative approach will be evaluated during the next section. At first, the expected increase in project sustainability by actively maintaining existing industrial DSM projects will be verified. In section 3.5, an existing study done on the development of an effective strategy to maintain industrial DSM projects was evaluated. This study evaluated eight industrial DSM pumping projects.

Projects that were not maintained by appointed ESCOs achieved an average of 49% of the original project target after PA. Projects that were maintained by appointed ESCOs achieved an average of 106% of the original project target after PA. To verify the effect of an ESCO being involved with maintaining an industrial DSM project, two case studies will be presented. For the first case study, an industrial DSM project implemented on the dewatering system of a gold mine will be evaluated. This mine will be referred to as Mine A.

The industrial DSM project implemented on Mine A was actively maintained by an appointed ESCO after the PA period. According to the Eskom DSM contract, the project had to achieve a load reduction of 3 MW during the evening peak periods for five years after the PA period. The project contract period commenced in January 2006 and ended in December 2010. Figure 38 indicates the cumulative project performance during the project contract period and a period of four years after the DSM contract expired.

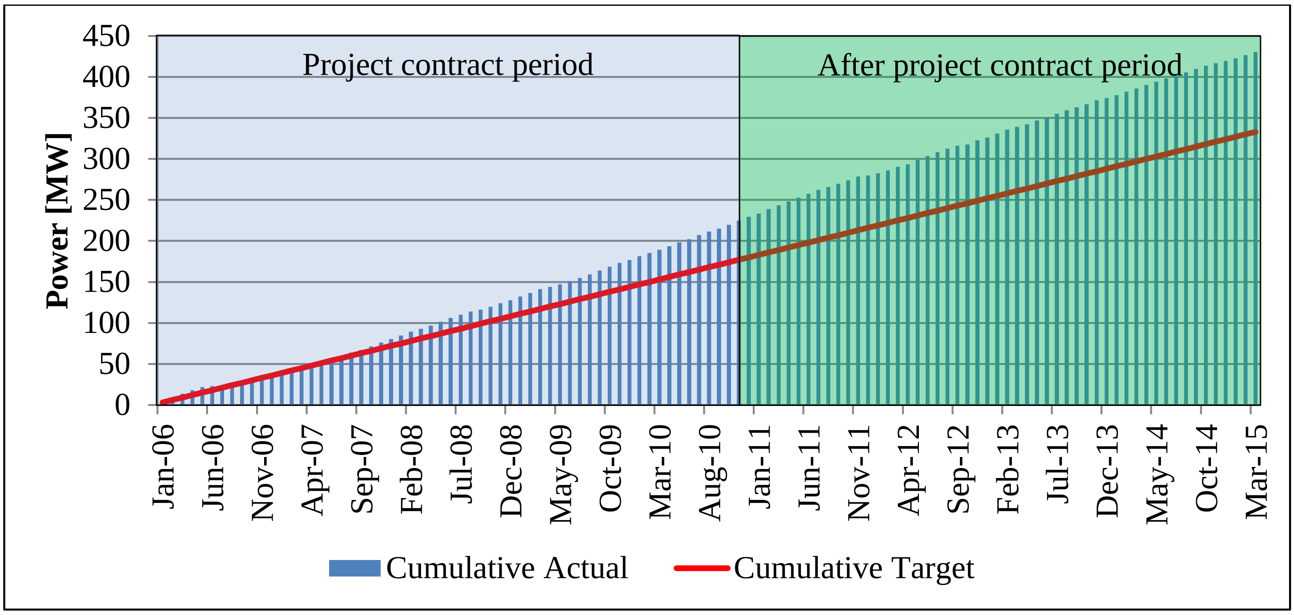

Figure 38: Cumulative performance of a pumping project that was actively maintained

During the project contract period, indicated by the blue transparent block in Figure 38, the project overperformed with 28%. After the DSM contract expired at the end of December 2010, the client extended the contract with the ESCO to maintain the project due to the financial benefit of maintaining the project savings. During the period after the DSM contract expired, indicated by the green transparent block in Figure 38, the project overperformed with 29%.

The cumulative electricity savings target was 7.2 GWh for the Eskom evening peak period for the duration of the DSM contract period. Due to the ESCO's involvement in actively maintaining the project, cumulative electricity savings of 9.18 GWh were achieved. Due to the involvement of the ESCO to maintain the project after the contract period, additional electricity savings of 8 GWh during the Eskom evening peak periods were achieved.

The second case study is also an industrial DSM project implemented on the dewatering system of a gold mine. This mine will be referred to as Mine B. This client did not see any value in appointing an ESCO to maintain the project actively after the PA period. The ESCO, therefore, handed the responsibility of maintaining the project savings over to the client after the PA period.

Due to various reasons, the client was not able to maintain the project performance. Some reasons could have been:

- limited knowledge regarding the technology implemented,
- following a run-to-failure maintenance approach instead of preventative maintenance, and
- a high level of employee turnover.

It was found that the industrial DSM project implemented on Mine B underperformed with an average of 13% over a period of 32 months. Over this period, the cumulative electricity savings target was 2.46 GWh. Cumulative electricity savings of 2.14 GWh were achieved during this period, with an underperformance of 320 MWh. Figure 39 indicates the cumulative project performance of the project after the PA period.

The majority of industrial DSM projects are implemented in the gold and platinum mining industry in South Africa. It was found that savings of DSM projects on compressed air networks and cooling auxiliary systems of mines also deteriorate if no active maintenance is done. The other large industry where DSM projects have been implemented during the past decade is the cement industry.

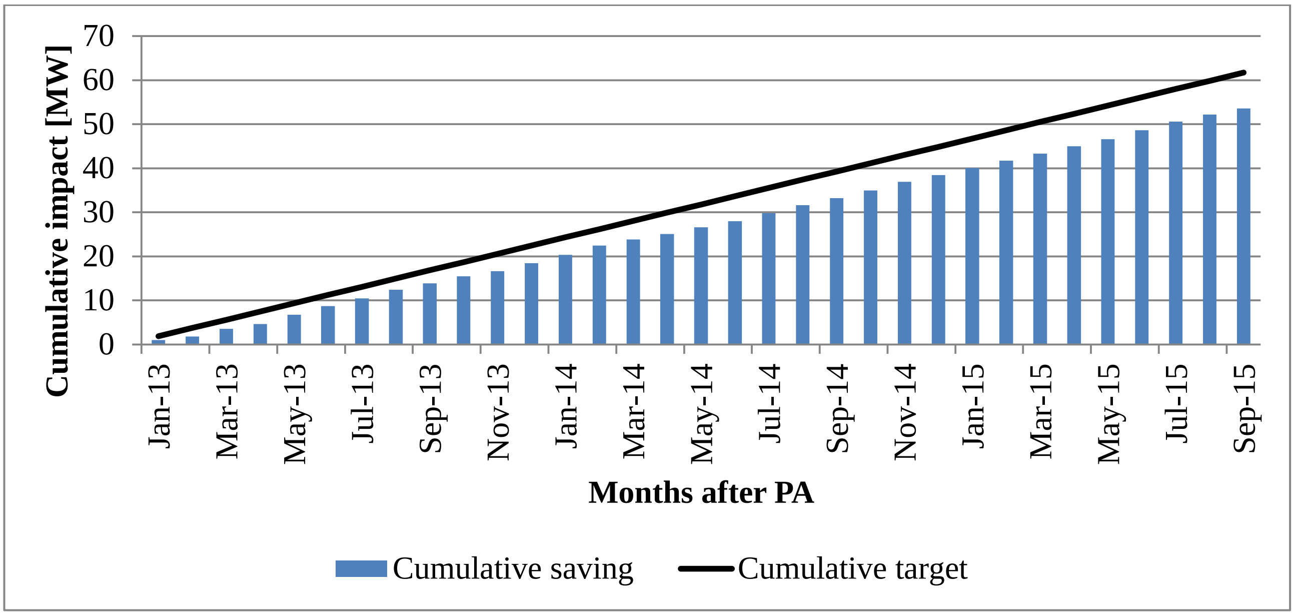

Figure 39: Cumulative project performance without maintenance – mining industry

A case study was done to determine the effect of not doing active maintenance on the existing DSM projects implemented in the cement industry. The case study evaluated the performance of six DSM projects implemented in the cement industry after the PA period. No maintenance was done on these projects and the projects had to be maintained by the clients. Figure 40 shows the average cumulative savings target and the average impact of the six projects after their PA periods.

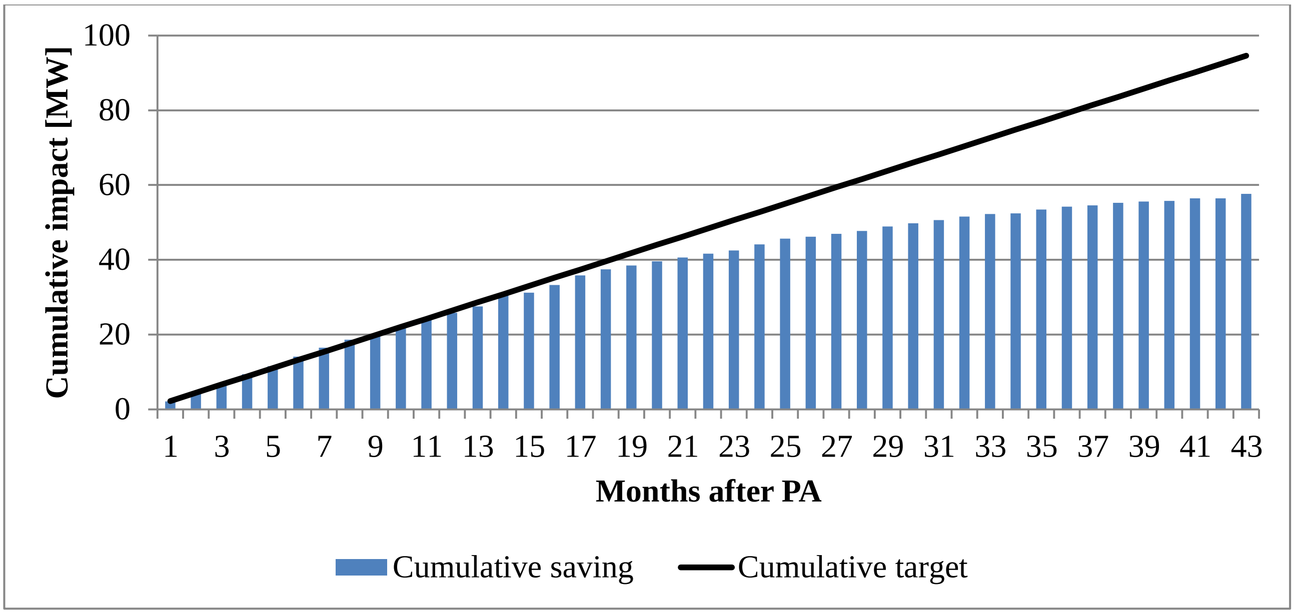

Figure 40: Cumulative project performance without maintenance – cement industry

It was found that the DSM projects implemented in the cement industry maintained their savings targets during the first 12 months after PA. After 12 months, the savings slightly deteriorated with 8% in Month 17. After Month 17, the savings deteriorated drastically with 27% only three and a half years after the PA period.

To verify the effect on the savings of an industrial DSM project if the project is actively being maintained, results from another study are evaluated. This study was done Groenewald while developing a performance-centred maintenance strategy for industrial DSM projects [69]. The study evaluated the performance of an industrial DSM project implemented on the dewatering system of a gold mine. Figure 41 shows the improvement in project performance after an ESCO got involved in maintaining the project.

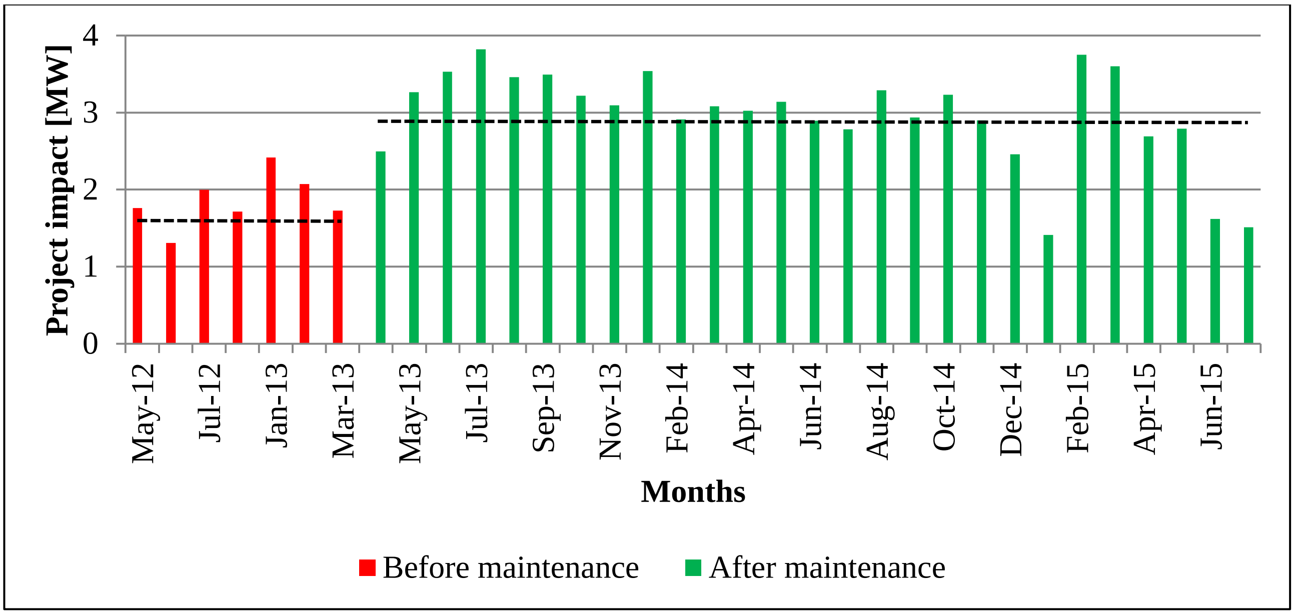

Figure 41: Effect of active maintenance on an industrial DSM project

At first, the client did not involve an ESCO to maintain the project after the PA period. Due to the rapid deterioration in project and cost savings, the client contracted an ESCO to maintain the project. The average impact of the project before the ESCO got involved was 1.86 MW. After the ESCO started maintaining the project, the average impact of the project improved to 2.96 MW. This is an improvement of 60% in project performance.

4.3 Applying the new approach

It is not practical to expect Eskom to implement the alternative approach to the industrial DSM ESCO model in order to test the improvement in the initial project impact and project sustainability. Such an experiment will be a time-consuming event. Although Eskom recently made some changes to the model that partly correlates to the alternative approach developed as part of this study, proper results are only expected in three years' time.

The verification of the alternative model indicated that by reducing the time it takes Eskom to approve a project, the initial impact of some projects could be improved. The conclusion can, therefore, be made that the percentage of projects underperforming during the PA period, and the margin by which they underperformed, can be improved. In section 1.3, a case study of 37 projects showed that 41% of projects did not achieve their initial targets. An underperformance of 26% when compared with their initial project targets was noticed.

Verifying the alternative model also indicated that the performance of a project could be improved by doing accurate and continuous reporting on the performance of the project. A case study showed that the impact of an industrial DSM project during the evening peak period could be increased with 30% after an accurate and continuous reporting system is implemented. By implementing an active maintenance strategy to maintain existing projects, the project target of industrial DSM projects could be maintained for the duration of the DSM contract.

The alternative approach was not implemented, but following the verification section, the alternative model will have a positive impact on the initial project performance and sustainability of industrial DSM projects. Following a case study in section 1.3, the sustainability of existing industrial DSM projects is 83% per annum. This sustainability factor and the percentage of projects underperforming during the PA period were used as input values to the short-term feasibility model.

The feasibility model was used to simulate the:

- future expected electricity supply shortage,
- expected use of gas turbine power stations,
- effect of the DSM model, and
- future required load shedding.

The accuracy of the feasibility model was verified in section 4.2. The impact of the alternative approach to the industrial DSM ESCO model developed during this study will be evaluated using the feasibility model. The effect of the improvement in initial impact and sustainability of industrial DSM projects will be simulated with the feasibility model. This will be done for the following ranges:

- **Initial project impact:** from 94% of the original target to 100% of the original target.
- **Project sustainability:** from 83% per annum to 100% per annum.

During the following section, the impact of the improved DSM programme as a result of an improvement in initial project performance and project sustainability on the following aspects will be evaluated:

1. Reduced required use of the gas turbine power stations.
2. Eskom cost savings because of the reduced required use of the gas turbine power stations.
3. Reduced load shedding required.
4. Impact on the economy because of reduced load shedding.

4.4 Results

Chapter 1 identified the need for Eskom to evaluate the feasibility of each short-term solution to the electricity supply shortage. Chapter 3 determined that the savings of the DSM programme should be more than 69% sustainable to be more feasible than using gas turbine power stations. From a case study consisting of 37 industrial DSM projects, it was determined that the savings of industrial DSM projects are 83% sustainable. The DSM programme is, therefore, a more feasible approach than using gas turbine power stations.

The DSM programme, however, does not show immediate results and is therefore classified as a short- to medium-term solution. The gas turbine power stations are, therefore, still required to supply electricity in times when the demand threatens to exceed the available supply capacity. By investing more capital in the DSM programme and by ensuring an improved initial impact and sustainable savings, future required use of the gas turbine power stations can be reduced.

From literature it has been found that load shedding costs the economy approximately R75 000 per MWh of unserved electricity. Compared with the cost to generate electricity with the gas turbine power stations, which is approximately R2 489 per MWh, load shedding should be avoided at all times. In order to avoid a total electricity network blackout, the solutions should be implemented in the following order:

1. Impact of the DSM programme.
2. Use of gas turbine power stations.
3. Load shedding.

In sections 3.3 to 3.5, an alternative approach to the industrial DSM ESCO model was proposed to improve the initial impact and sustainable savings of industrial DSM projects. In doing so, the required use of the gas turbine power stations and future required load shedding can be reduced. Since the DSM programme was proved to be a more feasible approach than using the gas turbine power stations, this will also result in a cost benefit for Eskom.

The feasibility model developed in Chapter 3 simulated the contribution of the DSM programme over the next three years. Figure 42 indicates the contribution of the DSM programme for 2016 to 2018 if the DSM project sustainable savings are improved from the existing 83% to 100%. It should be noted that the simulated impact of the DSM programme is lower for each consecutive year from 2016 to 2018 at a sustainability of 83%. As the sustainability improves, the DSM impact increases each year. The impact for each year also moves closer to each other as the sustainability improves.

The reason for this occurrence is that if the DSM programme has poor sustainable project savings, the impact deteriorates as time progresses. At higher sustainable savings, the impact of the DSM programme will deteriorate at a slower rate as time progresses. From Figure 42 it should also be noted that the impact of the DSM programme during 2018 is much lower than the previous two years. This is due to Eskom’s installed capacity that is expected to increase when Units 3, 4 and 5 of the Medupi power station are to be commissioned early in 2018.

The increase in electricity supply capacity will reduce the electricity supply shortage. This will affect the DSM impact, the use of gas turbine power stations and the required load shedding.

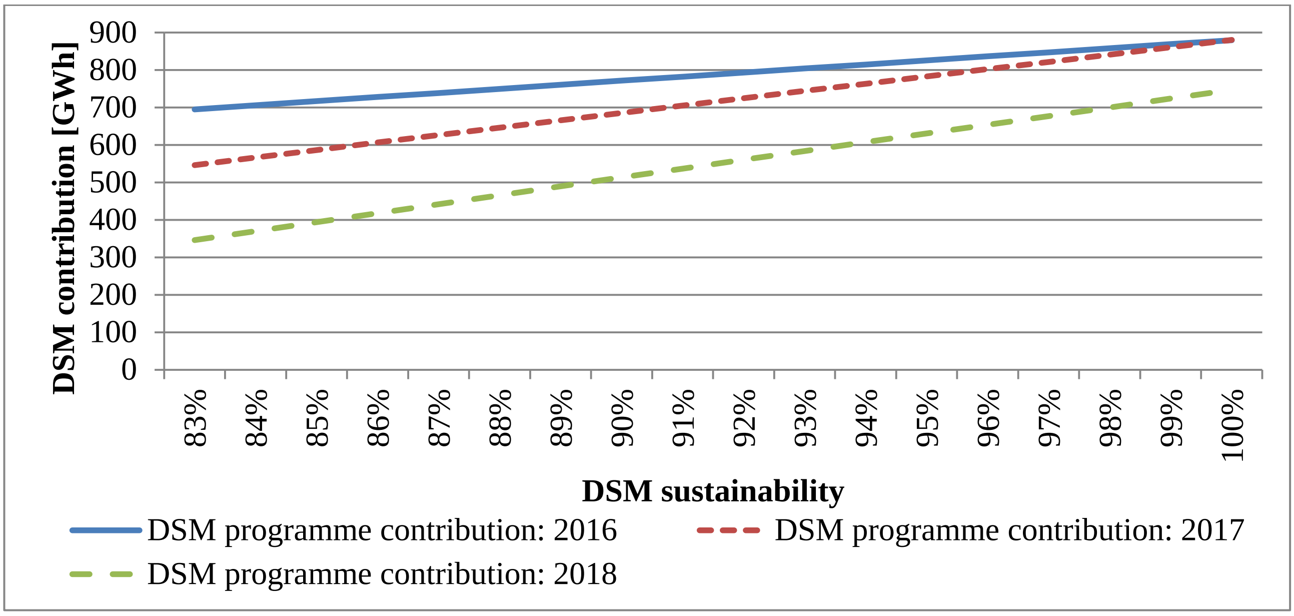

Figure 42: DSM programme contribution: 2016–2018

It is expected that gas turbine power stations will have to generate 7 211 GWh, 7 310 GWh and 6 501 GWh for the 2016, 2017 and 2018 Eskom financial years respectively. Although the demand for electricity is expected to increase during the next three years, the use of gas turbines is expected to decrease in 2018. This is also due to Eskom's installed capacity that is expected to increase early in 2018, which will affect the required use of gas turbine power stations.

Figure 43 indicates the expected gas turbine power station use from 2016 to 2018 if the sustainability of the DSM programme is increased from 83% to 100%. Should the new approach to the industrial DSM ESCO model succeed in improving the sustainable savings of DSM projects to 100%, the use of gas turbine power stations can be reduced by:

- 80 GWh in 2016,
- 128 GWh in 2017, and
- 110 GWh in 2018.

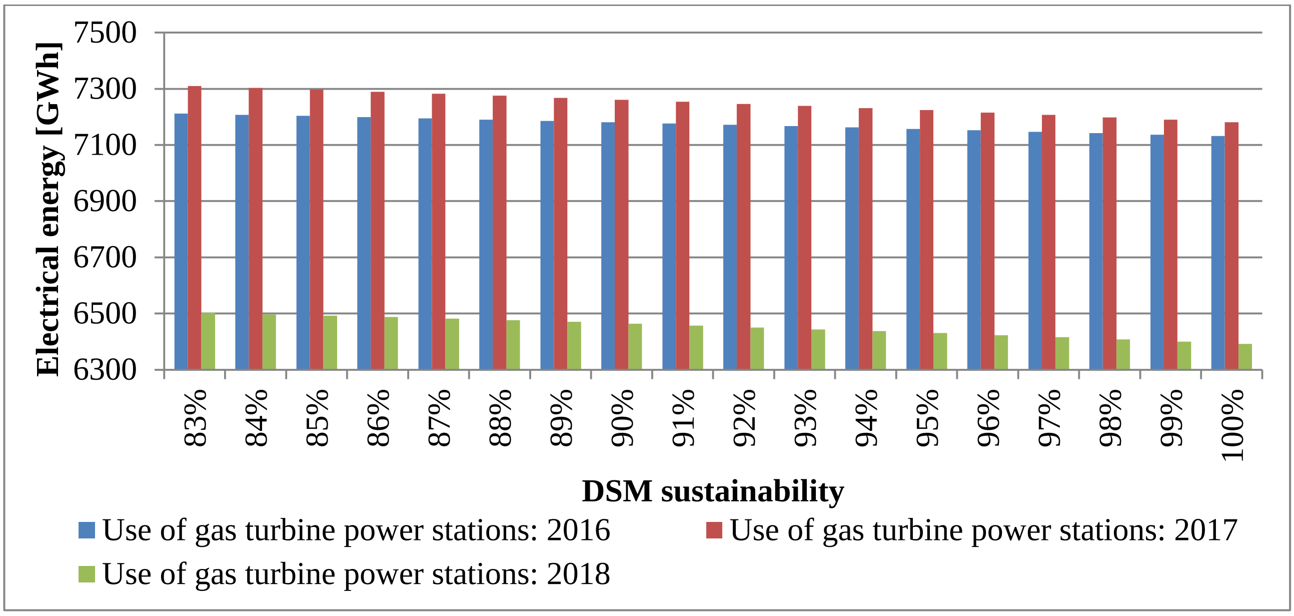

Figure 43: Expected gas turbine power station use: 2016–2018

If the cost to generate electricity using the gas turbine power stations is taken into consideration, the reduced required use can be expressed as a cost saving. An expected increase of 5% per annum in the cost to generate electricity with the gas turbine power stations is assumed. Figure 44 shows the cost savings from 2016 to 2018 with the increase in sustainable DSM project savings.

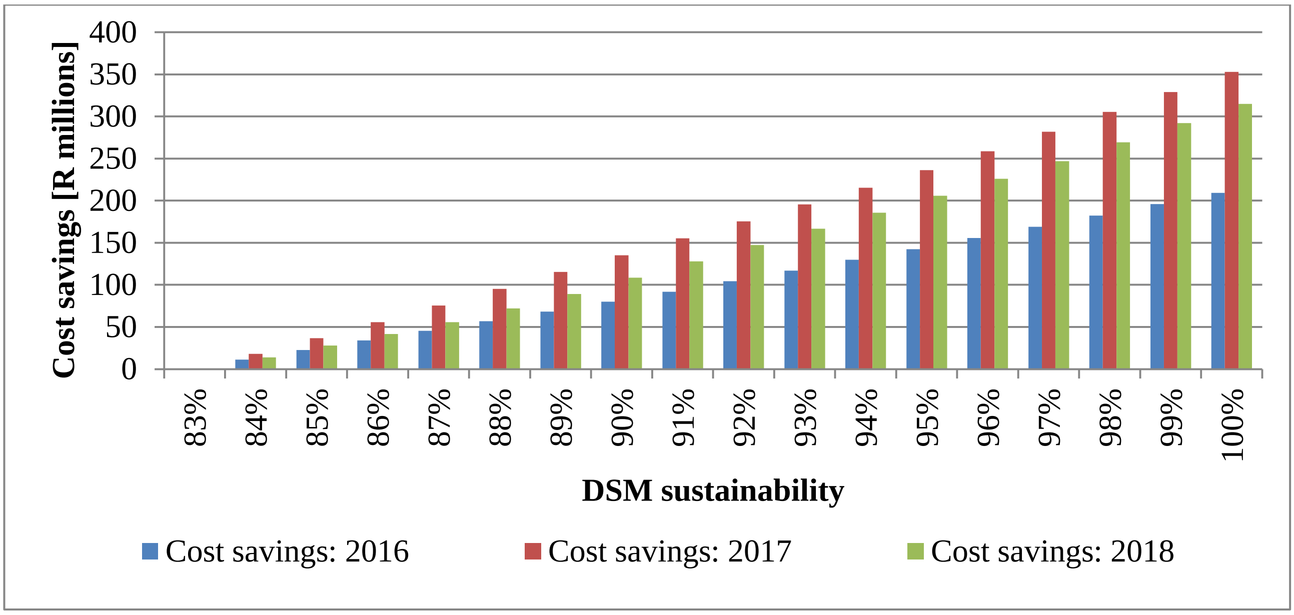

Figure 44: Gas turbine power station cost saving: 2016–2018

Should the new approach improve the sustainable savings of DSM projects to 100%, the cost savings as a result of the reduced use of the gas turbine power stations will be:

- R209 million in 2016,
- R353 million in 2017, and
- R315 million in 2018.

The alternative approach developed in Chapter 3 indicated that active maintenance should be done on existing DSM projects in order to improve the sustainable savings. The cost savings calculated above do not consider the additional cost to maintain the projects. During the literature review it was found that the cost to maintain an industrial DSM project actively will not exceed 25% of the total annual electricity cost savings generated by the project [69].

The annual electricity cost savings are the cost savings to the client as a result of shifting load out of the expensive Eskom peak periods. If the savings target of the Eskom DSM programme during the next three years is seen as one big load-shifting industrial DSM project implemented on one site, the annual electricity cost savings to the client can be calculated. For the purpose of this calculation, the Eskom Megaflex tariff structure will be used as this tariff structure is the most commonly used tariff structure on sites where industrial DSM projects are implemented.

The maintenance cost of this project can then be calculated as 25% of the total electricity cost savings. The net cost savings because of the reduced use of gas turbine power stations can then be calculated. These results are presented in Table 16.

Table 16: Annual gas turbine power station cost savings – improved project sustainability

Year	**Client electricity cost savings [R million]**	**Expected maintenance cost [R million]**	**Gas turbine power stations – Net cost savings [R million]**
2016	365	91	118
2017	394	99	254
2018	426	107	208

Up to now, only the improved sustainability of industrial DSM projects was taken into consideration. It was assumed that no improvement in the initial impact of newly implemented industrial DSM projects would be achieved. The initial impact value used was obtained by evaluating the initial project performance of 37 industrial DSM projects as a case study in section 1.3. The results from the case study and the percentage of industrial DSM projects were considered to determine the initial impact of newly implemented DSM projects. The initial impact was calculated to be an average of 94% of the original project target.

Should the initial impact of future industrial DSM projects be improved because of the alternative approach to the industrial DSM ESCO model, the overall improvement in the performance of the DSM programme will be achieved. An improved initial project impact means that a larger project performance can be sustained when active maintenance is done. This will affect the required use of gas turbine power stations and the load shedding required. The impact of the alternative approach to the industrial DSM ESCO model, should the initial impact and the sustainable savings of DSM projects be improved to 100%, is summarised in Table 17.

Table 17: Impact of the alternative approach to the industrial DSM ESCO model

Year	Improved DSM contribution [GWh]	Reduced gas turbine power station use [GWh]	Gas turbine power stations – Net cost savings [R million]
2016	239	104	271
2017	388	152	417
2018	447	125	360

If the initial impact and the sustainable savings of industrial DSM projects can be improved, the amount of load shedding can also be reduced. This will result in a positive impact on the economy of South Africa. The feasibility model developed in Chapter 3 indicated that the amount of load shedding can be reduced by:

- 134 GWh during 2016,
- 235 GWh during 2017, and
- 321 GWh during 2018.

This reduction in load shedding is based on the assumption that the alternative approach to the industrial DSM ESCO model succeeds in improving the initial project impact and sustainable savings of DSM projects to 100%. Literature indicated that load shedding costs the economy of South Africa R75 000 per MWh of unserved electricity. Should this be an accurate value, the reduction in load shedding will result in a positive impact of R51 billion on the South African economy from 2016 to 2018.

Figure 45 indicates the expected electricity supply shortage from 2016 to 2018. The short-term solution distribution to account for the supply shortage is also indicated in Figure 45. The initial impact of newly implemented DSM projects was taken as 94% of the project target, and the project sustainable savings as 83%. The model results with these values as inputs were taken as the baseline from where the expected improvements were measured.

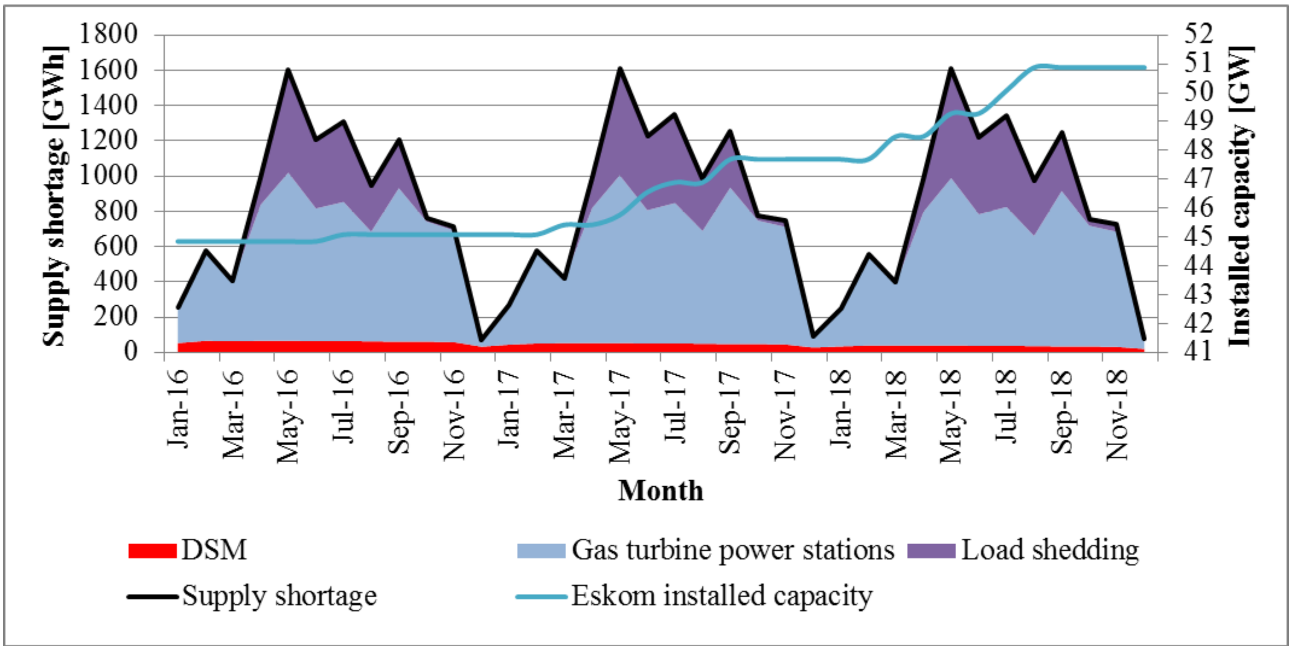

Figure 45: DSM impact – before alternative approach to industrial DSM ESCO model

From Figure 45 it should be noticed that the expected electricity supply shortage will be relatively constant from 2016 to 2018. Although the Eskom installed capacity is expected to grow due to the commissioning of new power stations over the next three years, it is expected to be just enough to meet the expected increase in electricity demand. The electricity supply shortage is, therefore, not expected to decrease as the supply capacity increases. It should also be noticed that the electricity supply shortage is much higher during the winter months because of the increase in demand.

The initial impact of newly implemented DSM projects and the sustainable savings of existing projects are expected to improve if the alternative approach to the industrial DSM ESCO model is implemented. Figure 46 shows the short-term solution distribution to account for the supply shortage from 2016 to 2018. An initial DSM project impact and sustainable savings of DSM projects of 100% were assumed.

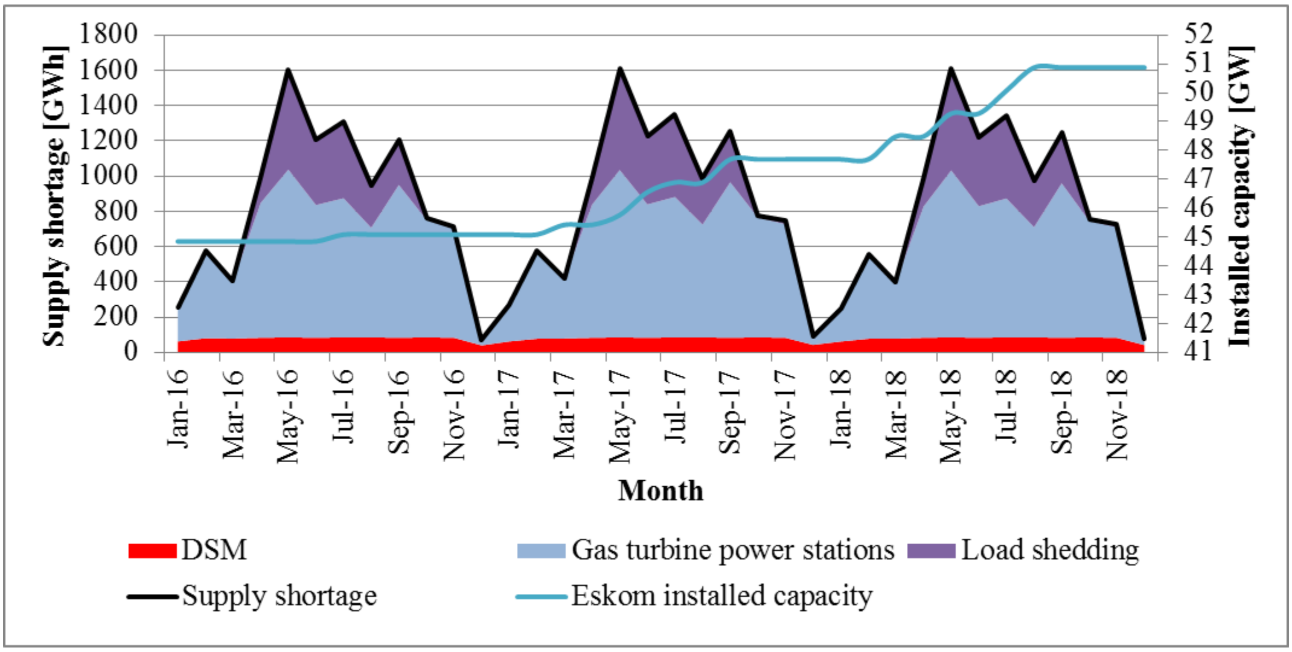

Figure 46: DSM impact – after alternative approach to industrial DSM ESCO model

The impact of the DSM programme is indicated with the red section in both Figure 45 and Figure 46. If Figure 45 is compared with Figure 46, an improvement in the impact of the DSM programme can be noticed between 2016 and 2018. This is mainly due to the improvement in the initial impact and sustainable savings of industrial DSM projects. Due to the improved impact of the DSM programme, the required use of gas turbine power stations and the required load shedding can be reduced. This has a cost benefit to Eskom and a positive impact on the economy of the country, of which the magnitude was already discussed in this section.

4.5 Conclusion

During this chapter, the alternative approach to the industrial DSM ESCO model was verified through relevant case studies. The results of existing studies were also used to verify certain aspects of the alternative model. It was found that there is not a correlation between the duration of the period Eskom takes to approve a project and the initial impact of a project. A case study showed that due to the uniqueness of each system, the impact of the duration of the period Eskom takes to approve a project would affect each project differently.

Although no correlation could be found, the case study verified that a long project procurement process could affect the initial impact of a project. The sustainability of projects could also be affected. Reasons for these occurrences are:

- cost inflation of the equipment needed to implement the project, and
- system changes that could affect the achievable savings of the project.

It was also verified that the consistency of available funding for new projects could influence the growth of the ESCO market. The US ESCO industry was compared with the South African ESCO industry as a case study. It was found that the revenues generated by the US ESCO industry grew with approximately 12% per annum from 2004 to 2012. During this period, the number of ESCOs in the US grew with approximately 128%.

In South Africa, it was found that there is a correlation between the number of ESCOs submitting new projects and the number of projects being approved for funding by Eskom. Since 2006, the number of industrial DSM projects approved for funding declined from 38 to 16 projects in 2012. During this period, the number of ESCOs actively submitting projects for approval declined with 75%. Therefore, the need for a more consistent drive towards the DSM programme in South Africa to ensure a growth in the ESCO market was verified.

The impact of accurate and continuous M&V reporting on the performance of an industrial DSM project was also verified. A case study on an industrial DSM project implemented on a cement plant was done. An accurate and continuous performance reporting system was implemented on this project. To verify the effect of the reporting system, the performance of the project before and after the system was implemented was evaluated. The impact of the project during the evening peak period increased with 30% after the reporting system was implemented.

As a result of the accurate and continuous reporting system implemented, the following improvements were also noticed:

- accurate system adjustments when changes to the Eskom TOU structure occurred, and
- more effective load shifting out of the Eskom morning peak periods.

The effect of actively maintaining an industrial DSM project on the performance of the project was verified by presenting results from previous studies. It was found that the performance of an existing industrial DSM project can increase with up to 60% after active maintenance is done on the project. It was found that projects where continuous maintenance is done after the PA period, savings can be maintained for the duration of the DSM contract period. Some projects were still found to overperform four years after the DSM contract expired due to continuous maintenance on the project.

The results from a case study done in section 1.3 were used to calculate the initial impact and sustainable savings of existing industrial DSM projects. It was found that the average initial impact of industrial DSM projects was 94% when compared with their initial project targets. The sustainable savings of the savings initially achieved by the projects was an average of 83%. The alternative approach to the industrial DSM ESCO model was verified to improve the impact and the sustainable savings of industrial DSM projects.

A feasibility model developed in section 3.2 to determine the short-term solution distribution in order to account for the electricity supply shortage was also verified during this chapter. This feasibility model was used to simulate the impact on the use of gas turbine power stations and the required load shedding if the impact of the DSM programme was improved. It was found that the expected use of gas turbine power stations can be reduced by 381 GWh over the next three years if the initial impact and sustainable savings of industrial DSM projects can be improved to 100%.

The expected reduction in the required use of gas turbine power savings will result in a net cost savings of R1 048 million over the next three years. An approximate 690 GWh reduction in the required load shedding over the next three years can be achieved if the initial impact and sustainable savings of industrial DSM projects can be improved to 100%. This will have a positive impact of approximately R51 billion on the economy of South Africa.

Taking into consideration that Eskom is experiencing financial difficulties, it is proposed that Eskom evaluates the new DSM ESCO model developed during this study. Although Eskom already made some changes to the old DSM programme, the newly developed DSM ESCO model can result in additional cost savings. Considering the impact the newly developed DSM ESCO model can have on the economy of our country, it is proposed that Government also becomes involved in implementing the new model.

Chapter 5: Conclusion and recommendations

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During this chapter, the final outcome of this thesis will be presented. Recommendations for future studies will also be discussed.

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5.1. Introduction

South Africa faces an electricity supply shortage, which has damaging effects on the economic growth of the country. Several electricity generation capacity expansion projects have been implemented by Eskom in order to reduce the electricity supply shortage being experienced. These projects, such as the building of the Medupi and Kusile coal-fired power stations, are long-term solutions. Due to the immediate nature of the problem, Eskom also had to implement short- to medium-term solutions to prevent the electricity demand from exceeding the supply capacity.

Short-term solutions implemented by Eskom are using gas turbine power stations and load shedding. For the purpose of this study, the demand response programme of Eskom is also classified as load shedding. As part of the Eskom demand response programme, Eskom asks large electricity-consuming clients to reduce their consumption in times when the electricity demand exceeds the available supply capacity. The demand response programme is, therefore, seen as controlled load shedding. The Eskom DSM programme is seen as a short- to medium-term solution.

Over and above the electricity supply shortage, Eskom is also experiencing financial problems that were recently made public. The Eskom Annual Report indicated that R10 billion was spent on diesel to operate the gas turbine power stations during the 2014 financial year. The approved budget was only R3 billion. In 2015, Eskom applied for an additional R15 billion loan from the government to operate the gas turbine power stations. To fund this loan, Eskom applied for an additional 25% increase in electricity tariffs, which was denied by Nersa.

Load shedding was also implemented regularly during 2014 and 2015. The Department of Energy estimates that load shedding has an impact of R75 000 per MWh of unserved electricity on the economy. Load shedding should, therefore, be avoided at all costs. Following the supply shortage, the financial constraints of Eskom and the negative effect of load shedding on the economy, the need has been identified to evaluate the performance of the DSM programme.

A case study consisting of 37 industrial DSM projects revealed that 41% of industrial DSM projects do not achieve their initial project targets during the PA period. Measured against their initial project targets, these projects underperformed with an average of 26% during the PA period. The case study also revealed that the savings achieved during the PA period deteriorated with 17% per annum throughout the project contract period. The need to improve the initial impact and the sustainable savings of industrial DSM projects was identified.

It was also found that the savings achieved through the DSM programme should be at least more than 69% sustainable to achieve a lower operating cost than using the gas turbine power stations. The DSM programme was found to be a more feasible solution than using gas turbine power stations. By improving the performance of the DSM programme, the required use of the gas turbine power stations and the required load shedding can be reduced. This will result in cost savings for Eskom and will in turn have a positive impact on the economy of South Africa.

The main focus of this study was, therefore, to develop an alternative approach to the existing industrial DSM ESCO model in order to improve the impact of the DSM programme.

5.2. Summary

In Chapter 1, the need to evaluate the feasibility of each short- to medium-term solution implemented by Eskom was presented. The cost involved with generating electricity using the gas turbine power stations was evaluated. It was found that the cost to generate 1 MWh using gas turbine power stations is approximately R2 573. This is seven times more expensive than generating 1 MWh with a coal power station. The need to improve the impact of the DSM programme to reduce the required use of the gas turbine power stations was highlighted.

In Chapter 2, the South African industrial DSM ESCO model was evaluated to identify possible problems that could influence the impact of the DSM programme negatively. Existing project investigation and implementation procedures, measurements and verification measures, and methods of sustaining project savings were evaluated. The DSM ESCO models of developed and developing countries were also investigated and compared with the South African approach.

In Chapter 3, a feasibility model was developed to evaluate each short-term solution in terms of impact, time of availability and cost. The model also predicted the electricity supply shortage for the next three years by considering the following parameters:

- the expected additional installed capacity,
- the availability of the installed capacity, and
- the expected electricity demand increase.

The feasibility model scheduled the impact of each short-term solution to account for the expected electricity supply shortage from 2016 to 2018. The expected impact of the DSM programme was considered first, followed by the use of gas turbine power stations. In times when the impact of the DSM programme and the gas turbine power stations was not enough to meet the electricity supply shortage, load shedding was scheduled.

Following the research done in Chapter 2 as part of the literature study, an alternative approach to the existing industrial DSM ESCO model was developed during the remaining part of Chapter 3. The alternative approach was developed to address the challenges of the existing model which affected the impact of the DSM programme negatively. The aim of the alternative approach is to improve the impact of the DSM programme by:

- improving the initial savings achieved by industrial DSM projects, and
- improving the sustainable savings of existing industrial DSM projects.

The feasibility model developed in Chapter 3 was used to evaluate the impact of the alternative approach to the industrial DSM ESCO model. This was done by calculating the required gas turbine power station use and the required load shedding with the existing DSM programme performance. These results were then used as a baseline from where the impact of the alternative approach was measured.

In Chapter 4, the accuracy of the feasibility model was verified. This was done by using actual data from 2013 as inputs to the feasibility model. The impact of the DSM programme, the expected gas turbine power station use and the required load shedding for 2014 were simulated with the feasibility model. These results were compared with actual data from 2014 to determine the accuracy of the feasibility model.

Through various case studies and results from previous studies, the following aspects of the alternative approach to the industrial DSM ESCO model were verified:

1. The effect of the inconsistent drive towards the DSM programme by Eskom on the South African ESCO market.
2. The impact of accurate and continuous M&V reporting on the performance of an industrial DSM project.
3. The effect of a reduced and more efficient project approval process on the initial impact of industrial DSM projects.

4. The impact of active maintenance on the sustainable savings of existing industrial DSM projects.

The expected improvement in the initial impact and sustainable savings of industrial DSM projects as a result of the alternative approach the industrial DSM ESCO model were used as inputs to the feasibility model. The effect of the improved impact of the DSM programme was evaluated with the feasibility model. The improved initial impact and sustainable savings were used as inputs to the feasibility model whereafter the results were compared with the results of the baseline model.

At first, the improved impact of the DSM programme was evaluated. The effect of the improvement in the DSM programme impact on the required use of the gas turbine power stations and the required load shedding was evaluated next. The cost savings to Eskom as a result of the reduced use of the gas turbine power stations were calculated. The effect of the reduction in the required load shedding on the economy of South Africa was also evaluated.

The next section will summarise the verification results of the feasibility model and the impact of the alternative approach to the industrial DSM ESCO model.

5.3. Verified impact

By using actual data from 2013 as inputs to the feasibility model and comparing the simulated results for 2014 with the actual data from 2014, the accuracy of the model was verified. It was found that the simulated use of the gas turbine power stations during 2014 was within 7% of the actual reported electricity supplied by the gas turbine power stations. The simulated diesel cost was within 6% of the actual cost spent on diesel to operate the gas turbine power stations.

To verify the impact of accurate and continuous M&V reporting on the performance of an industrial DSM project, two case studies were evaluated. The first case study evaluated the performance of an industrial DSM project before and after an accurate and continuous reporting system was implemented. It was found that the project impact improved with 26% after implementation. The following improvements were also noticed:

- more effective load shifting out of the morning Eskom peak periods, and
- effective system adjustments to accommodate changes in the Eskom TOU structure.

The second case study evaluated the performance of an industrial DSM project where no accurate and continuous M&V reporting was done. The appointed M&V team only reported once a year on the project performance. The objective of this project was to shift load out of the evening Eskom peak periods. It was found that this project did not shift any load out of the evening peak periods when compared with the project baseline. Following the results of these two case studies, it has been verified that accurate and continuous M&V reporting will have a positive impact on the performance of a project.

In Chapter 3, the negative effects of a small ESCO market were pointed out. As part of the alternative approach to the industrial DSM ESCO model, a more consistent drive towards the South African DSM programme was proposed in order to establish a larger ESCO market. In Chapter 4, the effect of the inconsistent drive towards the DSM programme by Eskom during the past decade was evaluated. It was found that from 2010 to 2012, the number of projects approved by Eskom reduced by 33% per annum. During this period, the number of ESCOs who submitted new project proposals declined with 72.3%.

From 2004 to 2006, the number of industrial DSM projects approved by Eskom was relatively consistent. During this period, the number of ESCOs submitting new industrial DSM projects increased with 71.4%. These results verify the fact that a more consistent drive towards the DSM programme will increase the ESCO market in South Africa.

To determine the effect of the project approval time on the initial performance of a project, 127 industrial DSM projects were evaluated. The time Eskom took to approve the project and the performance of the project during the PA period was evaluated for each project. A regression model between the initial project performance and the time Eskom took to approve the project was compiled. The regression model showed that there is not a correlation between the time Eskom takes to approve a project and the initial project performance.

It was found that the reason for the poor correlation was that systems on which an industrial DSM project are implemented differ from each other. Although no correlation between the time Eskom takes to approve a project and the initial performance of the project could be found, a case study proved that a long project approval period can result in projects not reaching their original project target.

To verify the impact of accurate and continuous M&V reporting on the sustainable savings of industrial DSM projects, four case studies were done. The first case study was an industrial DSM project implemented on the dewatering system of a gold mine. This project was implemented in 2006 and an ESCO was appointed to maintain the project savings actively. It was found that the project overperformed with an average of 28% over the five-year contract period.

After the DSM contract expired, the ESCO was reappointed by the client to maintain the project savings. It was found that due to active maintenance being done on this project, the project still overperformed for four years after the DSM project contract expired. A similar industrial DSM project was evaluated as the second case study. No active maintenance was done to maintain the savings of this project. It was found that the project underperformed with an average of 13% over a period of 32 months after the PA period.

The third case study evaluated six industrial DSM projects implemented in the cement industry. The project performance of each project after the PA period was evaluated. No active maintenance was done to maintain the savings of these projects. It was found that the project savings deteriorated with an average of 8% within 12 months after the PA period. Over a period of three and a half years, the savings of the projects deteriorated with an average of 28%.

To verify the impact of active maintenance on the sustainability of industrial DSM projects, a fourth case study was done. This case study was done on a project where no active maintenance was done to maintain the project savings. An active maintenance strategy was then implemented in order to determine the effect on the sustainable savings. It was found that the project savings were improved with 60% after an active maintenance strategy was implemented to maintain the project savings.

A previous study found that the cost to maintain an industrial DSM project will not exceed 25% of the cost savings to the client. The cost to maintain an industrial DSM project is only a fraction of the cost Eskom initially spends to implement the project. It is, therefore, strongly recommended that Eskom ensures that existing industrial DSM projects are maintained. The impact of more sustainable savings in terms of cost savings to Eskom and impact on the economy of South Africa is discussed in the following section.

5.4. Results

The required use of gas turbine power stations can be reduced by 381 GWh from 2016 to 2018 if the initial impact and sustainable savings of industrial DSM projects can be improved to 100%. This will result in a net cost savings of R740 million to Eskom. A reduction of approximately 10% in the required load shedding from 2016 to 2018 is expected. This will have a positive impact of approximately R51 billion on the economy of South Africa.

The importance of a sustainable DSM programme impact is, therefore, highly important. Compared with using gas turbine power stations and load shedding, DSM has been found to be the most feasible solution. Using gas turbine power stations is still important considering the immediate impact thereof. But, with an improved impact of the DSM programme, the required use of gas turbine power stations and load shedding can be reduced.

Taking into consideration that Eskom is experiencing financial difficulties, it is proposed that Eskom evaluates the new DSM ESCO model developed during this study. Although Eskom already made some changes to the old DSM programme, the newly developed DSM ESCO model can result in additional cost savings. Considering the impact the newly developed DSM ESCO model can have on the economy of our country, it is proposed that Government also becomes involved in implementing the new model.

5.5. Recommendations

This study evaluated the performance of industrial DSM projects. An alternative approach to the industrial DSM ESCO model was proposed in order to improve the initial project performance and sustainable savings of industrial DSM projects. The DSM programme does, however, not only consist of industrial projects. Various DSM projects are also implemented in the residential sector. Recent information indicated that approximately 51% of the DSM programme consists of industrial projects.

The fact that industrial DSM projects only account for approximately 51% of the DSM programme was considered when the impact of the alternative approach to the industrial DSM ESCO model was evaluated. It is, therefore, recommended that the performance of residential DSM projects be critically evaluated. Should it be found that residential DSM projects also do not perform to their full potential, a study should be done to determine the causes. Due to the importance of optimal and sustainable DSM impact, a solution should be developed to improve the performance of residential DSM projects.

Operating gas turbine power stations has been found to be an expensive solution to the electricity supply shortage. Considering the impact of load shedding on the economy of the country, it is still a more feasible solution than load shedding. With the existing installed capacity of the gas turbine power stations, the commissioning of new coal power stations and optimal performance from industrial DSM project over the next three years taken into account, load shedding is still expected. The expansion of the gas turbine power stations installed capacity is, therefore, recommended in order to avoid future load shedding.

In order to reduce the operating cost of gas turbine power stations, the feasibility of changing the gas turbines from an open cycle to a combined cycle should be investigated. It is expected that the efficiency of the gas turbines can be improved from 34.7% to 52.4%. The possibility of using less expensive fuel to operate the gas turbine power stations is already being investigated by Eskom.

It is also recommended that less expensive solutions than gas turbine power stations are investigated.

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Appendix A: Siemens SGT5-2000E gas turbine specifications

The Siemens SGT5-2000E gas turbine is used in both the Ankerlig power station in Atlantis and the Gourikwa power plant in Mossel Bay. The Siemens SGT5-2000E gas turbine consists of a single-shaft, single-casing design with two large combustion chambers. A 16-stage compressor is used to supply compressed air to the combustion chambers. The SGT5-2000E can be operated with a variety of fuels, from low- and high calorific gaseous fuels, to liquid fuels such as diesel.

The off-board combustion process eliminates direct flame radiation on the turbine blades. The hot gas is directed through a four-stage turbine, which turns a shaft connected to an air-cooled generator. The generator is connected on the compressor side of the gas turbine. After the hot gas passes through the turbine, it is directed through an exhaust system into the atmosphere.

The hot exhaust gas can be used to heat water to produce steam, which can be used to power a secondary turbine. This system is called a closed cycle gas turbine (CCGT), which is more efficient than the open cycle gas turbine (OCGT). The SGT5-2000E gas turbine comes standard as an OCGT, but can be converted to a CCGT. The SGT5-2000E gas turbines used in the Ankerlig and Gourikwa power stations are OCGTs. The specifications of the SGT5-2000E gas turbine are displayed in Table 18.

Table 18: Siemens SGT5-2000E gas turbine specifications

Description	**Unit**	**Value**
Grid frequency	[Hz]	50
Power output	[MW]	166
Efficiency	[%]	34.7
Heat rate	[kJ/kWh]	10 375
Exhaust temperature	[ºC]	541
Exhaust mass flow	[kg/s]	525
Pressure ratio	[-]	12
Length; width; height	[m]	10; 12; 7.5
Weight	[t]	234

Appendix B: Siemens SGT5-2000E gas turbine calculations

1. To generate 1 MWh of power with an SGT5-2000E OCGT, the following power input is required:

Equation 2: Siemens gas turbine (SGT5-2000E) input power requirement

$$Input\ power\ required\ [P_{in}] = \frac{Power\ output\ [P_{out}]}{\eta}$$

$Where$:

$\eta = The\ efficiency\ of\ the\ gas\ turbine$

$P_{out} = 1\ MW$

$Thus$:

$$P_{in} = \frac{1}{0.347}\ MW$$

$$P_{in} = 2.88\ MW$$

2. If 1 MW of power is generated for a period of one hour, 1 MWh of energy is generated. Following the calculations above, 2.88 MWh of energy will be required to generate 1 MWh of energy. The required energy input can also be expressed as joules:

Equation 3: Siemens gas turbine (SGT5-2000E) energy requirement

$$Watt[W] = \frac{Joule\ [J]}{Second\ [s]}$$

$$J = Ws$$

$Thus$:

$$Energy\ input\ [E_{in}] = 2.88\ MWh$$

$$E_{in} = 2.88 \times 60 \times 60\ MWs$$

$$E_{in} = 10374.64\ MJ$$

3. If the specific energy for diesel is assumed to be 45.6 MJ/kg, and the density 0.832 kg/ℓ, the total litre of diesel required to generate 1 MWh of energy is:

Equation 4: Siemens gas turbine (SGT5-2000E) diesel requirement

$$Kilogram\ diesel\ required = \frac{E_{in}\ [MJ]}{Specific\ energy\ for\ diesel\ [\frac{MJ}{kg}]}$$

$Thus$:

$$Kilogram\ diesel\ required\ = \frac{10374.64}{45.6}\ kg$$

$$Kilogram\ diesel\ required\ = 227.51\ kg$$

$$Litre\ diesel\ required = \frac{Kilogram\ diesel\ required\ [kg]}{Density\ of\ diesel\ [\frac{kg}{l}]}$$

$Thus$:

$$Litre\ diesel\ required\ = \frac{227.51}{0.832}\ l$$

$$Litre\ diesel\ required\ = 273.45\ l$$

4. For the purpose of this study, the price Eskom pays for diesel is assumed to be R9.40 per litre.

Appendix C: Eskom Megaflex tariffs (2015/2016)

With the TOU tariff structure of Eskom, different electricity charges occur at different TOU periods and seasons. The Eskom TOU tariff structure was implemented to reduce electricity consumption during high demand periods, by increasing the cost of electricity during these periods. The different Eskom TOU periods are the peak, standard and off-peak periods. The TOU periods depend on the time of day and whether it is a weekday, Saturday or Sunday. There are also two TOU seasons, namely a winter season and a summer season, each with different electricity charges for the different TOU periods.

The peak period is the TOU period with relatively high system demand, and is indicated with the colour red. The peak period also has the most expensive electricity charges. The off-peak period is the TOU period with relatively low system demand, and is indicated with the colour green. The off-peak period also has the less expensive electricity charges. The standard period is the TOU period with relatively mid system demand, and is indicated with the colour yellow. The electricity charge during the standard period is in-between the peak and off-peak charges.

Eskom also have different TOU structures such as the Nightsave Urban Large, Miniflex, Ruraflex and Megaflex. The TOU periods are different for each TOU structure. Most industrial plants and mines are on the Eskom Megaflex TOU structure. Figure 47 shows the TOU periods for the Megaflex tariff structure for a weekday, Saturday and Sunday. Table 19 shows the 2015/16 electricity charges for the different TOU periods and seasons.

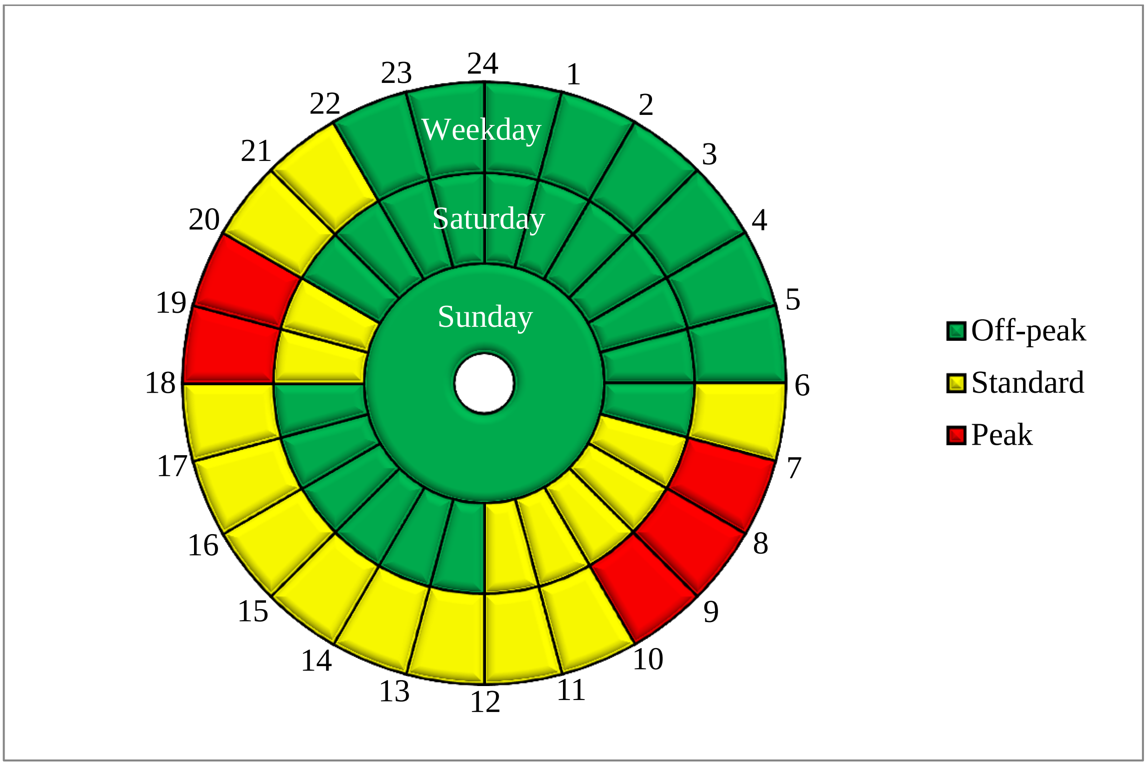

Figure 47: TOU periods for the Megaflex tariff structure

Table 19: Eskom Megaflex tariffs (2015/2016)[22]

TOU structure: Megaflex		**Active energy charge** [c/kWh]												**Transmission network charges** [R/kVA/m]	
Transmission zone	**Voltage**	**High demand season** [Jun–Aug]						**Low demand season** [Sep–May]							
		Peak		**Standard**		**Off Peak**		**Peak**		**Standard**		**Off Peak**			
			VAT incl		*VAT incl*		*VAT incl*		*VAT incl*		*VAT incl*		*VAT incl*		*VAT incl*
≤ 300km	< 500V	**258.53**	*294.72*	**78.67**	*89.68*	**42.93**	*48.94*	**84.65**	*96.50*	**58.41**	*66.59*	**37.23**	*42.44*	**R 7.20**	*R 8.21*
	≥ 500V & < 66kV	**254.45**	*290.07*	**77.09**	*87.88*	**41.86**	*47.72*	**83.01**	*94.63*	**57.13**	*65.13*	**36.25**	*41.33*	**R 6.57**	*R 7.49*
	≥ 66kV & ≤ 132kV	**246.42**	*280.92*	**74.64**	*85.09*	**40.53**	*46.20*	**80.38**	*91.63*	**55.33**	*63.08*	**35.09**	*40.00*	**R 6.40**	*R 7.30*
	> 132kV	**232.24**	*264.75*	**70.35**	*80.20*	**38.20**	*43.55*	**75.76**	*86.37*	**52.14**	*59.44*	**33.08**	*37.71*	**R 8.09**	*R 9.22*
> 300km and ≤ 600km	< 500V	**260.63**	*297.12*	**78.96**	*90.01*	**42.87**	*48.87*	**85.03**	*96.93*	**58.53**	*66.72*	**37.13**	*42.33*	**R 7.24**	*R 8.25*
	≥ 500V & < 66kV	**256.99**	*292.97*	**77.85**	*88.75*	**42.28**	*48.20*	**83.84**	*95.58*	**57.70**	*65.78*	**36.60**	*41.72*	**R 6.64**	*R 7.57*
	≥ 66kV & ≤ 132kV	**248.83**	*283.67*	**75.38**	*85.93*	**40.92**	*46.65*	**81.17**	*92.53*	**55.86**	*63.68*	**35.43**	*40.39*	**R 6.44**	*R 7.34*
	> 132kV	**234.55**	*267.39*	**71.06**	*81.01*	**38.58**	*43.98*	**76.50**	*87.21*	**52.66**	*60.03*	**33.40**	*38.08*	**R 8.17**	*R 9.31*
> 600km and ≤ 900km	< 500V	**263.23**	*300.08*	**79.74**	*90.90*	**43.30**	*49.36*	**85.86**	*97.88*	**59.10**	*67.37*	**37.49**	*42.74*	**R 7.33**	*R 8.36*
	≥ 500V & < 66kV	**259.58**	*295.92*	**78.63**	*89.64*	**42.70**	*48.68*	**84.69**	*96.55*	**58.26**	*66.42*	**36.97**	*42.15*	**R 6.69**	*R 7.63*
	≥ 66kV & ≤ 132kV	**251.36**	*286.55*	**76.14**	*86.80*	**41.34**	*47.13*	**81.98**	*93.46*	**56.42**	*64.32*	**35.79**	*40.80*	**R 6.50**	*R 7.41*
	> 132kV	**236.91**	*270.08*	**71.78**	*81.83*	**38.97**	*44.43*	**77.29**	*88.11*	**53.19**	*60.64*	**33.75**	*38.48*	**R 8.28**	*R 9.44*
> 900km	< 500V	**265.87**	*303.09*	**80.55**	*91.83*	**43.74**	*49.86*	**86.73**	*98.87*	**59.69**	*68.05*	**37.87**	*43.17*	**R 7.37**	*R 8.40*
	≥ 500V & < 66kV	**262.17**	*298.87*	**79.41**	*90.53*	**43.13**	*49.17*	**85.51**	*97.48*	**58.85**	*67.09*	**37.33**	*42.56*	**R 6.76**	*R 7.71*
	≥ 66kV & ≤ 132kV	**253.89**	*289.43*	**76.91**	*87.68*	**41.77**	*47.62*	**82.81**	*94.40*	**56.99**	*64.97*	**36.16**	*41.22*	**R 6.55**	*R 7.47*
	> 132kV	**239.24**	*272.73*	**72.51**	*82.66*	**39.40**	*44.92*	**78.08**	*89.01*	**53.75**	*61.28*	**34.12**	*38.90*	**R 8.34**	*R 9.51*

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