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The Development, Implementation and Performance Evaluation of an Innovative Residential Load Management System

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Philosophiae Doctor

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Promoter: Prof LJ Grobler

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Special Awards of Power Alert

1. Power Alert project won the Roger Garlick gold award for the *Best Use of Television and Special Events/Stunts* from the Advertising Media Association of South Africa (AMASA) in 2007.
2. Power Alert was awarded *International Energy Project of the Year* in 2007 by the Association of Energy Engineers (AEE).
3. Power Alert was a finalist for the 2008/9 National Science and Technology Forum (NSTF) awards.
4. Power Alert was a finalist in the Energy Project Award category of the South African National Energy Association (SANAE) of 2009.

Abstract

Title: The development, implementation and performance evaluation of an innovative residential load management system.

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Degree: Philosophiae Doctor in Engineering.

The power utility of South Africa, Eskom, expected a supply shortfall of approximately 400MW between February and August 2006 in the Western Cape. The peak of the crisis was in mid-winter (June to August). This shortfall was firstly caused when Eskom experienced a breakdown on the one of the two nuclear supply units. Secondly the remaining of the Koeberg units was due for refuelling which necessitated the shut-down of the reactor. No electricity was therefore generated by both units. It was clear that if electricity demand was not effectively curbed, extensive power outages would be experienced; which was the case.

Various demand side management (DSM) programmes were rolled-out to address lighting, switching from electricity to gas for cooking, compensating customers that could generate own electricity, energy efficiency and load curtailment in the education, commercial, and industrial sectors, as well as an extensive energy efficiency campaign. It is shown in this study that the most constrained periods were expected during the evening peak and was a consequence of electricity consumption in the residential sector. The residential evening peak is very prominent and primarily caused by water heating, cooking, space heating, lighting, and appliances. None of the mentioned programmes focused on the residential evening peak. Traditional residential DSM technologies were almost impossible to implement in the short timeframe because there are more than 625,000 residences in the Western Cape. A solution was looked for that could be implemented in a relatively short period to address the residential evening peak.

This study focuses on the development, implementation, and performance evaluation of Power Alert – An innovative residential load management system. The need for such a system was identified and the expected impact was determined through a feasibility study. Power Alert was designed to be a link between Eskom and the public through the national television broadcaster. It was operational during the whole Western Cape winter. A methodology to determine the impact of Power Alert was also developed to demonstrate the actual load reductions. The methodology was applied and Power Alert demonstrated that it was a valuable residential load management tool that could be designed and implemented in a much shorter time than conventional residential DSM measures.

Keywords:

Residential Load Management, Demand Side Management, Power Alert, Human Behaviour, Measurement and Verification.

Uittreksel

Titel: Die ontwikkeling, implementering, en verrigting evaluering van 'n innoverende residensiële lasbeheerstelsel.

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Die kragvoorsiener van Suid-Afrika, Eskom, het 'n voorsieningstekort van ongeveer 400MW tussen Februarie en Augustus 2006 in die Weskaap verwag. Die piek van die krisis was in die middel van die winter (Junie tot Augustus). Hierdie tekort was eerstens as gevolg van 'n onverwagte faling van een van die twee kerneenhede van Koeberg. Tweedens moes die ander eenheid noodgedwonge herlaai word wat veroorsaak het dat die eenheid afgeskakel moes word. Nie een van die twee eenhede het dus krag gelewer nie. Dit was duidelik indien die aanvraag na elektrisiteit nie ordentlik bestuur word nie, uitgebreide kragonderbrekings (soos ook die geval was) aan die orde van die dag sou wees.

Verskeie aanvraagkantbestuurprogramme was van stapel gestuur. Hierdie programme het gefokus op beligting, omskakeling van elektrisiteit na gas vir kookdoeleindes, vergoeding van kliënte wat hulle eie krag kon opwek, energie effektiwiteit en lasbeheer in die onderwys, kommersiële, en industriële sektore asook 'n omvattende energie effektiwiteit veldtog. Dit word bewys in hierdie studie dat die aandpiek periode die grootste onderdruk periode was en dat dit hoofsaaklik as gevolg van die residensiële sektor was. Die residensiële aandpiek is 'n prominente piek wat hoofsaaklik veroorsaak word deur waterverhitting, gaarmaak van voedsel, verhitting, beligting, en ander toerusting. Geen van bogenoemde programme het gefokus op die residensiële aandpiek nie. Met die byna 625,000 huise in die Weskaap was tradisionele DSM tegnologie ook buite die kwessie vanweë die tydsbeperking. ‘n Oplossing wat die residensiële aandpiek kan aanspreek en ook in ‘n relatiewe kort tyd geïmplementeer kon word moes dus gevind word.

Hierdie studie fokus op die ontwikkeling, implementering, en verrigting evaluering van Power Alert – ‘n innoverende residensiële lasbeheerstelsel. Die nodigheid van so ‘n stelsel was geïdentifiseer tesame met die verwagte impakte deur ‘n lewensvatbaarheidstudie. Power Alert was ontwerp om ‘n skakel te wees tussen Eskom en die publiek deur die nasionale televisie-uitsaaier. Dit was in werking tydens die hele winter in die Weskaap. ‘n Metodologie om die impak van Power Alert te bepaal was ook ontwikkel en toegepas. Power Alert was geïmplementeer en het bewys dat dit ‘n waardevolle residensiële lasbeheerstelsel is wat in ‘n baie korter tyd ontwerp en geïmplementeer kon word as konvensionele residensiële DSM maatstawwe.

Sleutelwoorde:

Residensiële Lasbeheer, Aanvraagkantbestuur, Power Alert, Menslikegedrag, Meet en Verifieër.

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I thank all my colleagues that worked on this project for their wonderful teamwork that made this project and study a great success.

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I thank the public of South Africa for their reaction and attitude to be part of the solution.

Major Contributions of this Study

The major contributions of this study are the following:

1. An article published in Energize; “An innovative method to control the electrical load of residential households”, June 2007, pp. 13-15.
2. An article published in Strategic planning for energy and the environment; “Power Alert: An Innovative System to Control Residential Loads Under Peak Conditions Using National TV”, 2008, vol. 27, n 4, pp. 36-46.
3. An article published in Energize; “Verification of accelerated DSM initiatives in the Western Cape”, September 2007, pp. 69-75.
4. Conference paper delivered at the International Domestic Use of Energy Conference, Cape Town, “Power Alert - An Innovative Method to Control the Electrical Load of Residential Households”, April 2007.
5. Conference paper delivered at the South African Energy Efficiency Convention, Johannesburg, “Power Alert - An Innovative Method to Control the Electrical Load of Residential Households”, October 2007.
6. An integrated method and operational system to manage the residential load during evening peak times based on the strain on the network.
7. An integrated approach to measure and verify (M&V) the impacts of a residential awareness campaign.
8. An integrated approach to measure and verify (M&V) the regional impact of various DSM interventions by means of a “top-down” methodology.
9. A communication channel between South Africa’s electricity utility (Eskom) and the general public that could be utilised in very short time periods to request load reduction of the public during high strain periods on the electricity distribution network by utilising the national broadcasters of South Africa.

10. An extensive literature survey to identify the current residential load management technologies in use in the residential sector.
11. Impacts of up to 145MW during evening peak periods of the 2006 Western Cape Energy Crisis.
12. System that was so effective in the Western Cape during 2006, that it was expanded to include all regions as well as the National grid.

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List of Abbreviations

General

ADMD	After Diversity Maximum Demand
APS	Acacia Power Station
c	South African Cent
CC	Candidate Countries
CCGT	Combined Cycle Gas Turbine
CEC	California Energy Commission
CFL	Compact Fluorescent Lamp
CPP	Critical Peak Pricing
CV(RMSE)	Coefficient of the Root Mean Square Error
DMP	Demand Market Participation
DSM	Demand Side Management
DVD	Digital Versatile Disc
ECMS	Energy Consumption Management System
EU	European Union
FC	Forecast
FTP	File Transfer Protocol
GHG	Greenhouse Gas
ICU	Intensive Care Unit

IEA	International Energy Agency
IPMVP	International Performance Measurement and Verification Protocol
IT	Information Technology
LED	Light Emitting Diode
LP	Liquefied petroleum
LSM	Living Standard Measure
M_{value}	Slope of trend line between temperature and energy
M&V	Measurement and Verification
MBE	Mean Bias Error
NMS	New Member States
NPLC	Narrowband Power Line Communication
NPV	Net Present Values
NWU	North-West University
OCGT	Open Cycle Gas Turbine
OECD	Organisation For Economic Co-Operation And Development
PA	Power Alert
PACC	Power Alert Control Centre
PIER	Public Interest Energy Research
PV	Photovoltaic

R	South African Rand
RMSE	Root Mean Square Error
SAARF	South African Advertising Research Foundation
SABC	South African Broadcasting Corporation
Sat	Saturday
SAWS	South African Weather Services
SSM	Supply Side Management
Sun	Sunday
SWH	Solar Water Heater
T&E	Tracking and Evaluation
TV	Television
TX	Transmission
UCT	University of Cape Town
URL	Uniform Resource Locater
WD	Weekday

Measuring

MW	Megawatts
MWh	Megawatt-hours

CHAPTER 1

Introduction

This chapter provides an overview and formulates the need for a Residential Load Management System during the winter of 2006 in the Western Cape. The electricity supply problems that resulted in power outages are identified. Solutions that formed part of the accelerated Demand Side Management initiatives to overcome the electricity shortages are also examined.

CHAPTER 1 INTRODUCTION

1.1. Background

The power utility of South Africa, Eskom, expected a supply shortfall of approximately 400MW between February and August 2006 in the Western Cape [1]. This shortfall was firstly caused when Eskom experienced a breakdown on the one of the two nuclear supply units. Secondly the remaining of the Koeberg units was due for refuelling which necessitated the shut-down of the reactor. No electricity was therefore generated by both units. Forecasts consequently predicted a winter shortfall of 400MW for the Western Cape. It was clear that if electricity demand was not effectively curbed, extensive power outages would be experienced; which was the case. Eskom initiated an Integrated Recovery Plan for the Western Cape [2] to overcome the shortfall of 400MW.

1.2. Western Cape Accelerated Demand Side Management Initiatives

The Integrated Recovery Plan included various accelerated Demand-side Management (DSM) initiatives to reduce the amount of electricity consumed as well as to reduce the peak load. The various accelerated DSM initiatives were grouped into five main groups as discussed in the following paragraphs.

1.2.1 Efficient Lighting and Other Energy Efficiency Products

The efficient lighting programme entailed the handing out of 5-million Compact Fluorescent Lamps (CFLs) to residents in and around Cape Town. The expected load reduction due to this programme was 155MW. Other energy efficiency products distributed to help reduce the demand for electricity in the Western Cape was low-flow shower heads as well as geyser blankets.

1.2.2 Customer Self Generation

The customer self generation programme included the extended operation of backup diesel generators by industries, commercial buildings, and hotels to free capacity elsewhere on the electricity distribution network. The expected load reduction due to this programme was 50MW.

1.2.3 Industrial and Commercial Energy Efficiency and Curtailment

This programme included energy audits on primarily the lighting systems of schools, hotels, shopping centres, and office blocks to identify where energy efficiency impacts could be achieved. Another part of this programme was voluntary load shedding by consumers at certain peak periods. The expected load reduction of this programme was 40MW.

1.2.4 Switching to Gas for Cooking and Heating

Electricity is widely used in South Africa for residential applications such as cooking and space heating. This programme entailed the swapping of two-plate stoves and electric hotplates and ovens with gas cylinders and gas stoves. The expected load impact of this programme was 50MW.

1.2.5 Extensive Energy Efficiency Campaign

One of the crucial factors for the success of the accelerated DSM initiative was communication. The challenge was to communicate to all consumers that the accumulated savings of all the little bits of energy saved by each consumer was substantial and that it would have an improvement on the reliability of the electricity supply. The message “every bit helps” had to be communicated to all electricity consumers even though the incremental savings seemed negligible to individual consumers.

Important aspects of communication were that:

- Awareness under the consumers was high enough to be aware that there was a very real problem that would impact on all consumers in terms of power outages.
- The correct savings messages or requests had to be relayed to consumers at the correct time.

Eskom desperately needed impacts of between 110MW and 160MW through energy efficiency campaigns.

1.3. Problem Statement

The projects and interventions mentioned in the previous section focused on all the different energy consuming sectors i.e. industrial, commercial and residential. The largest impacts were expected from the CFL hand-outs and the extensive energy efficiency campaigns. Both of these measures focused their efforts on the residential sector. The large difference between these two measures was that the CFL roll-out comprised a change of lighting technology and if installed the savings would be sustained over the life of the technology. The extensive energy efficiency campaign relied on communication to consumers to switch off appliances when they were not needed; a change in behaviour of the consumers instead of technology change was consequently essential.

To expect consumers to keep appliances switched off all the time was not reasonable, sustainable or viable. Also, it was unlikely to expect all consumers to know exactly what to do to save energy and when to save it without an intense awareness and educational campaign. Therefore, to "*manage"* the residential load during evening peak times was most critical for all parties involved because:

- The achieved load (MW) impacts during peak times resulted in enough electricity reserves for Eskom to minimise and even avoid load shedding.
- Consumers were inconvenienced to a minimum as co-operation was only requested during evening peak periods (18:00 to 21:00).

Traditionally, Residential Load Management (RLM) in South Africa entails the switching (mainly the hot water cylinder in a residence) from a central control point. Major barriers to the implementation of traditional Residential Load Management in any region, but specifically in the Western Cape, could be summarised by the following:

- In the Western Cape there are approximately 625,000 houses [4]. Each would require a physical visit if a residential load management technology were to be implemented. Resources and implementing agents would be too limited in this case on timeframe.
- Residential load management projects consequently take a very long time to implement due to the sheer number of houses that needs visiting (and revisiting).
- To install load management equipment in residences, especially in a short period, as was the case here, would require a major investment of both capital and labour resources. If you only have a month available to have an area wide load management system operational, even recruiting qualified personnel to install equipment would be a major obstacle.

Considering again what the aim of the energy efficiency campaign was, one will realise that no traditional control equipment, switches, or other conventional technology would be able to manage the load in the residential sector during peak times in the case of the Western Cape and in the available timeframes. Technology is only needed to ensure that impacts are sustained. Theoretically it is thus possible to switch off the entire residential load in a very short time without residential load control technology if:

- People are informed and engaged to switch off appliances only when needed; and
- All or a reasonable portion of the people cooperate when requested.

It is thus possible to overcome one of the major barriers of implementing a Residential Load Management project in a very short time by just asking people at the correct time to take the right action and reduce electricity consumption. This can be done by utilising real-time mass media such as television, radio, and the internet.

1.4. “Interactive” Load Management Through Mass Media in the Western Cape

An extensive awareness campaign was launched in the Western Cape regarding the looming electricity shortage and the possibility of load shedding during the winter. Capetonians were therefore aware that there was an electricity supply problem and that overcoming the problem was in their hands. Capetonians were eager to assist, but did not always know what to do and when to do it. The answer in controlling the residential load was locked in asking people to switch off specific appliances during times when it was necessary. Power Alert was born from the electricity supply crisis and the willingness of Capetonians to cooperate and not-be-left-in-the-dark.

The aim of Power Alert was to inform Capetonians on the strain of the electricity supply network during weekday evening peak periods through the national television broadcaster and to ask people to assist in reducing the strain on the network by switching off specific appliances during high strain periods, thereby preventing load shedding.

1.5. Purpose of this Study

The purpose of this study was to develop, implement and evaluate the performance of a residential load management system to assist alleviating the 2006 winter power crisis in the Western Cape.

1.6. Objective of this Study

The main objectives of this study were to:

- Research and develop a residential load management system that could be designed, implemented and operational in a relative short time.
- Implement the residential load management system to assist in alleviating the Western Cape power crisis.

Sub-objectives of this study were to:

- Investigate why the Western Cape expected and experienced a power crisis in winter of 2006.
- Explore what could be done to alleviate the crisis in terms of supply and demand of electricity.
- Identify the time of day that problems were expected.
- Establish what sector needed to be addressed to alleviate the crisis.
- Research existing Residential Demand Side Management (DSM) technologies.
- Identify an area that had not been addressed previously.
- Determine the potential for residential load management in the Western Cape through a feasibility study.
- Develop a methodology to determine the actual performance of the residential load management system.

- Develop a top-down M&V methodology to determine the DSM impacts of all interventions and programmes implemented in the Western Cape.

1.7. Scope of the Study

This thesis is concerned with the development, implementation and performance evaluation of Power Alert – an innovative residential load management system.

1.8. Thesis Roadmap

In Chapter Two existing DSM technologies that are available and applicable to the residential sector are investigated. Modern DSM technologies that could be implemented in the residential sector and that could be expected to lower electricity consumption were identified. No study or literature could be found that involved residents to participate in load reduction activities during network constrained periods and, through concerted efforts, prevented load shedding. This lack of involving the residents was certainly a gap in residential DSM that needed to be addressed. To involve the residents it was important to know where electricity was used in a house to ensure that involving the residents would result in a meaningful load reduction when it was needed most – the best bang for your buck. It was consequently determined how much electricity was used through different electricity consuming systems (lighting, heating, etc) and which of those technologies were expected to be present in a Western Cape residence through a Living Standard Measure (LSM) study. These studies helped to identify which common residential appliances should be targeted in order to perform efficient load management and avoid load shedding.

It was not known what the potential impact of residential load management in the Western Cape was. A feasibility study was therefore conducted to determine the potential impact of residential load management during the evening peak in the

Western Cape. The developed methodology and results of the feasibility study are the focus of Chapter Three.

The results of the feasibility study showed that there was a definite requirement for residential load management in the Western Cape during the evening peak period. A problem was that the time and budget was extremely limited to embark on implementing traditional DSM technologies and other hard-wired solutions. No other system existed that could unlock the load reduction potential through residential load management. The only way it would have been possible was to involve the Western Cape residents. A system therefore had to be developed and implemented to involve the residents in the Western Cape at the right time and without only requesting to switch everything off - in effect; the Western Cape residents should be the residential load managers instructed by the residential load management system on what to do and when. Chapter Four focuses on the development and implementation of the residential load management system as a residential DSM measure.

Stakeholders wanted to know how all the DSM measures performed in terms of the overall reduction target for the Western Cape. No M&V methodology existed that could be used to determine the impact of various DSM measures and programmes. Chapter Five focuses on the development of a unique top-down M&V methodology to determine the true impacts of all DSM measures implemented in the Western Cape during the energy crisis

Chapter Six focuses on the development of a methodology to assess the performance of the developed residential load management system. No impact calculation methodology that could be used to determine the impacts of a programme where human behaviour played a major role were identified. The chapter focuses on the development of an impact calculation methodology that could be used and also presents actual load reductions achieved due to the residential load management system using the developed methodology.

Chapter Seven discuss the work done in this Thesis in short and also presents final conclusions and recommendations for future considerations of similar residential load management systems.

1.9. References

1 Eskom. May 2006. www.eskom.co.za/live/loadshed.php?Item ID=1083. Date of access: June 2008.

2 Eskom. *Summary Western Cape Draft Integrated Recover Plan.* s.l. 2006.

3 Eskom. May 2006. http://www.eskomdsm.co.za/resfaq.php Date of access: June 2008.

4 Eskom. May 2006. http://www.eskom.co.za/live/loadshed.php?Item_ID=1385 Date of access: May 2007.

CHAPTER 2

Potential, Needs, and Barriers for Residential Demand Side Management in the Western Cape

In this chapter the need for Residential Demand Side Management in the Western Cape is argued. Residential Demand Side Management measures, activities, programmes, projects, and lessons are investigated through a comprehensive literature survey. The survey has shown that home owners were not actively engaged and involved at the correct times to actively participate in Residential Demand Side Management programmes. A load disaggregation study combined with a Living Standard Measure overview revealed which electricity end-use equipment and appliances are found in residences and should be focused on through Residential Demand Side Management programmes.

CHAPTER 2 POTENTIAL, NEEDS, AND BARRIERS FOR RESIDENTIAL DEMAND SIDE MANAGEMENT IN THE WESTERN CAPE

2.1. Introduction

South Africa's electricity supply is nationally under increased pressure mainly due to an economic growth rate of 4.5% over the past four years [1, 2, 3] and a lack of new base power station construction for more than 20 years [4]. These two driving forces resulted in a rapidly decaying reserve margin which ultimately culminated in widespread load shedding during the beginning of 2008 [5]. Many references and news of the load shedding that happened can be found at news websites as listed in References 6, 7, and 8. 2008 was the visible beginning of South Africa's power crisis for the broader public.

In 2005/6 the power problems were experienced on a regional level - the Western Cape. These power problems were not only due to economic growth and a shortage of generation capacity, but mainly due to technical problems and planned maintenance [9, 10, 11, 12]. A foreign object detected in Unit 1 of the Koeberg Nuclear plant led to a controlled shutdown of the plant resulting in interruption of supply from 25 December 2005 to the end of May 2006. Unfortunately the repairs to Unit 1 were not the end of the Western Cape's power crisis since Unit 2 was due for refuelling and was offline from June 2006 to 24 July 2006; the middle of South Africa's winter at which time peak electricity demands are experienced [11, 13, 14, 15]. The typical winter maximum load for the Western Cape is in the region of 4,250MW and 3,900MW in summer [10, 12] of which Koeberg contributes 1,800MW.

Figure 2-1 shows a simplified layout of the transmission network of the Western Cape (Note that in this figure only power sources of Eskom are shown and that the City of Cape Town's generation (i.e. Steenbras) is excluded). A total of 4,750MW generation capacity is available when all power plants in the Western Cape and the transmission lines from the north are fully operational. With the predicted load of 4,250MW a surplus of 500MW is normally experienced.

Note that the Western Cape electrical network is isolated, and consequently is a load constraint network and not a frequency or voltage constraint network [16].

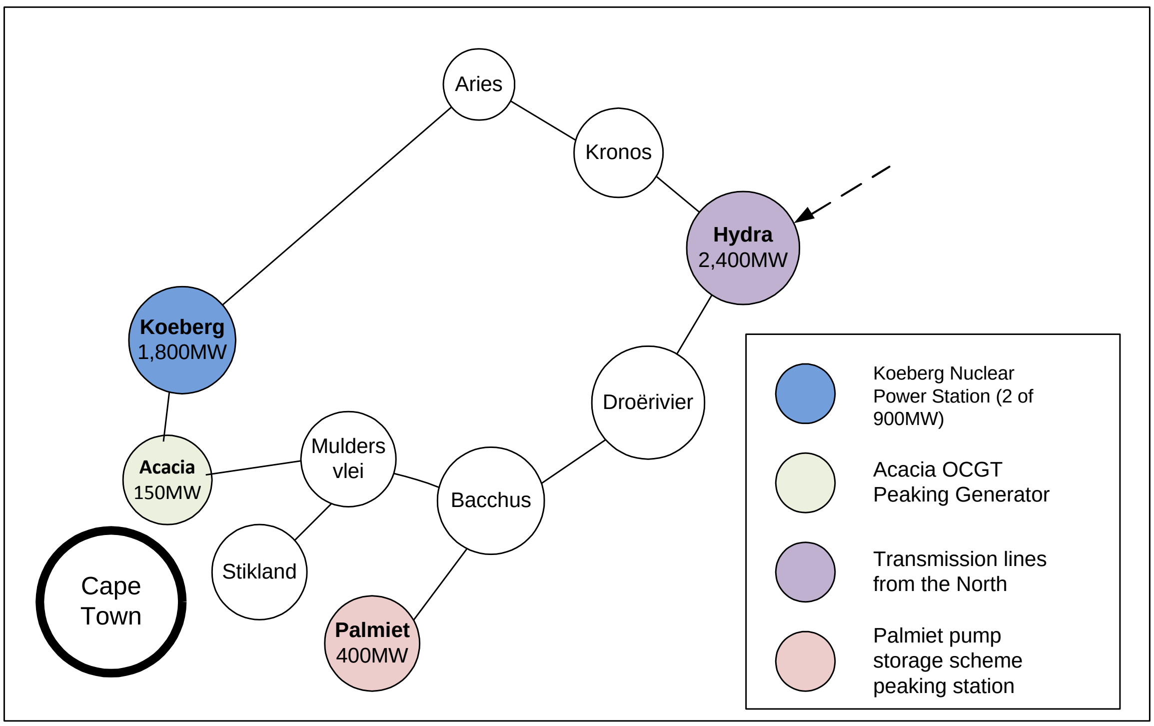

Figure 2-1: Simplified transmission network of the Western Cape

With one of the two Koeberg units not in operation, a shortfall of 400MW was expected in the winter of 2006 in the Western Cape. Two possibilities existed [17] to overcome this shortfall and widespread power interruptions, namely:

- Supply Side Management (SSM) – to build more power plants; or
- Demand Side Management (DSM) – reduce the demand.

In 2004 the South African government gave Eskom permission to construct new power plants [18]. Two new baseload power plants are currently under construction and they are due to come on line only from 2013 onwards [19]. Open cycle gas turbines (OCGT) can be built quickly, but even so, was only ready by winter 2007 [18, 20, 21]; a year too late. Supply Side Management was therefore not a viable solution to alleviate the Western Cape power crisis during the winter of 2006 and will consequently not be further discussed in this study.

DSM was therefore critical in the short-term due to the long lead times when building new power plants. In this specific power crisis, short-term meant less than six months, i.e. a DSM intervention should be proposed, investigated, approved, implemented, and operational in less than six months.

This chapter will further focus on what could be done in terms of DSM to help alleviate the Western Cape power crisis. It will also be investigated what time of day problems are expected and which sector (residential, industrial, or commercial) should be specifically addressed to alleviate the crisis. A detailed literature survey was conducted to determine what DSM technologies are available for the residential sector and also if they could be applied to the Western Cape power crisis. The chapter concludes with an area in which no previous research work was found. In ensuing chapters the potential impacts, development, implementation, operation and performance assessment of the new developed residential load management system are presented.

2.2. What is Demand Side Management?

One definition found for DSM is from Wikipedia, the free online encyclopaedia: *"Demand side management entails actions that influence the quantity or patterns of use of energy consumed by end-users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants."* [22]

It is also the view of Wilson [23] that utilities implement DSM programmes – including energy efficiency – to shape customers energy load profiles. He also mentions that many utilities use DSM as a resource option to meet projected demand in their integrated resource planning processes.

The aim of DSM therefore is to postpone the need for constructing new power plants by implementing energy efficiency and fuel switching (influencing the quantity) and/or implementing load shifting and load shedding projects (influencing the pattern).

This is also mentioned by Auffhammer [24] and he added that past programme evaluations and utility-reported data have indicated that these programmes are highly cost effective.

DSM can be roughly divided in two areas [25, 26]:

- Energy Efficiency (see Paragraph 2.2.1);
- Load Management comprising of valley filling, load shifting, and load shedding (see Paragraphs 2.2.2, 2.2.3, 2.2.4).

2.2.1 Energy Efficiency

Energy efficiency implies the usage of more efficient technologies. These technologies have a sustained reduction in electricity usage and include actions like converting inefficient lighting (incandescent lamps) to efficient lighting (CFLs). It has a reduction in energy consumption (MWh) without affecting the service level delivered by the technology.

Energy efficiency can be applied to all three major sectors – residential, commercial, and industrial.

2.2.2 Fuel Switching/Strategic Load Growth/Valley Filling

Fuel switching implies the conversion from one energy source to another. An example is switching from electricity to gas for space heating or water heating. Fuel switching can also be done in all three major sectors.

2.2.3 Load Shifting

Load shifting implies the redistribution of electricity demand from peak periods to lower demand periods without affecting the service level. Load shifting is limited to systems that have some or other form of storage albeit thermal (ice storage, hot water cylinders) or additional capacity (reservoirs).

An example is to physically switch off a hot water cylinder during peak periods while hot water is still available and only after peak periods allow the hot water cylinder to switch on to heat the stored water again.

2.2.4 Load Shedding

Load shedding is done when a customer is physically disconnected from the network and therefore is likely to reduce the service level. Load shedding is a measure that will influence the power supply to end-users and will have a negative impact on consumers albeit in terms of production or comfort. It is therefore always considered a last resort and is a measure used to sustain the network security and prevent the total network from becoming unstable. [27]

Knowing that four main DSM strategies are available, a solution had to be found most applicable to the Western Cape's power crisis. If this strategy was known one can apply the identified strategy on either the residential, commercial, or industrial sector.

It was the view of Saini [17] that the most common DSM techniques are energy conservation and efficiency programmes, and demand/load response programmes to shift and reschedule energy consumption. This implies that the most commonly implemented DSM techniques are energy efficiency and load shifting. Fuel switching and load shedding are not too frequently encountered.

2.3. Expected Load Constrained Periods

Considering Figure 2-1 again, it shows that a total generation capacity of 4,750MW was available. With one Koeberg unit not operational, the generation capacity reduced to 3,850MW. This generation capacity included the two peaking power plants Palmiet (400MW) and Acacia (150MW) - baseload generation capacity was therefore 3,300MW. Knowing that these two peaking power plants could only operate for relative short periods (Palmiet - because it is a pumping storage scheme and Acacia - due to costs related to operating an OCGT plant) and that a supply shortfall of 400MW was expected with a forecasted maximum load of 4,250MW, it was concluded that the power crisis in the Western Cape was related to peak periods.

Figure 2-2 shows an average weekday demand profile of the Western Cape for May 2006. It was seen that a load of approximately 3,300MW was experienced during the midday and during the evening peak (18:00 to 20:00) the demand increased by about 200MW to 3,500MW. This figure indicated that the expected 400MW shortfall and consequently the Western Cape power crisis was related to peak periods, and more specifically the evening peak.

This was an indication that the focus of DSM initiatives should be on load management during the evening peak to alleviate the Western Cape power crisis.

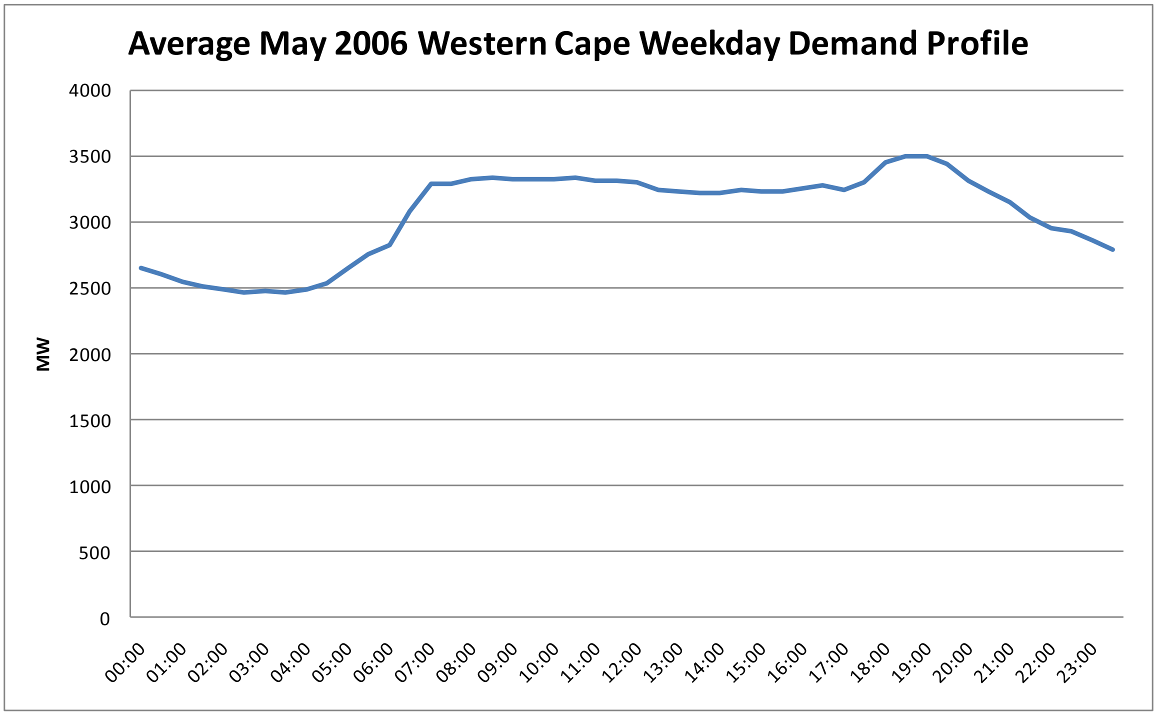

Figure 2-2: Average weekday demand profile of the Western Cape – May 2006

It was seen that the expected shortfall occurs during the evening peak and that the DSM efforts should focus on load management, but on which sector should the DSM initiatives focus; industrial, commercial, or residential?

According to Eskom [28], residential customers consume approximately 17.5% of the total electricity generated by Eskom, with an estimated demand for electricity during peak periods amounting to more than 30% of the total; which is approximately 1,275MW of the forecasted peak demand. The fact that residential demand during the evening peak period is almost double than for other periods of the day, was reason enough for any DSM activities to focus on the residential sector.

The time day, 18:00 to 20:00, when the evening peak occurs, was when most people were at home or arrive at home and consequently start using appliances, cooking food, and using hot water.

The time of the evening peak, as well as the routine of people, indicated that the DSM activities should focus on the residential sector to alleviate the power crisis.

The remainder of this study will consequently focus on residential Demand Side Management only and barriers for the implementation of these technologies in crisis situations, and ways to overcome the barriers.

2.4. Residential Demand Side Management Methodologies and Technologies

According to Atikol [29] the major factors that affect or drive electricity usage in the residential sector include the following:

- Building structure;
- Heating, Ventilation and air-conditioning;
- Water heating;
- Lighting;
- Appliances; and
- Swimming pools/spas.

If electricity consumption of a residence needs to be influenced, DSM measures have to be applied to the above-mentioned systems. The electricity consumers and electricity drivers in the residential sector, as well as DSM techniques found in the literature, are discussed in the paragraphs that follow.

Atikol goes further to mention various residential DSM measures for the above-mentioned energy drivers and consumers:

- Building structures
  - Insulation of walls and ceilings;
  - Radiant barriers;
  - Foundation insulation;
  - Windows (triple pane, low e-glazing, gas filled);
  - Storm windows;
  - Window treatments (movable insulation, solar control);
  - Weather stripping; and
  - Passive solar design.
- Heating, ventilation and air conditioning
  - Heat pumps;
  - Whole-house and ceiling fans;
  - Heat storage;
  - Zoned heating;
  - Energy-efficient air-conditioning;
  - AC cyclic control;
  - Duct thermal losses (duct leaks, duct insulation); and
  - Distributed photovoltaic-systems.
- Water heating
  - Water-heater blanket (insulation);
  - Thermal traps;
  - Pipe wrap (pipe insulation);
  - Low-flow shower head;
  - Heat pumps (water heaters);
  - Solar water heaters; and
  - Domestic hot water cycling control.

- Lighting
  - Incandescent alternatives (such as CFLs and light emitting diodes (LED)).
- Appliances
  - Energy efficient refrigerators and freezers;
  - Low-water clothes/dishwashers;
  - Moisture sensor clothes-dryers; and
  - Cooking equipment (improved cooking tops, induction cooking tops, and improved oven).
- Swimming pools/spas
  - Pool/spa pump control; and
  - Solar pool heaters/covers.

California also experienced power problems in 2000-2001 [30]. Vine [31] listed emerging technologies as a result of the California crisis which was promoted by California utilities in the building sector. Of these emerging technologies, only a few were applicable to the residential sector:

- Verified duct sealing;
- Energy efficient windows;
- Geothermal heat pumps;
- Lower luminance LEDs;
- Efficient dishwashers;
- High efficiency (gas) storage water heaters;
- Optimised air conditioners;
- Daylighting tools and controls;
- Residential pool pumps;
- Combined space/water heat (hydronic); and

- Combined space/water heat (forced air).

The California Energy Commission (CEC) was authorised to receive and administer at least $61.8-million for specified public interest energy research [31]. This research was done through the Public Interest Energy Research (PIER) programme. Some research work relevant to the residential sector listed, but not discussed, by Vine includes:

- Residential thermal distribution systems;
- Alternatives for compressor cooling;
- Development and demonstration of high-efficiency lighting torchieres;
- Building design advisor;
- Improve the cost-effectiveness of building commissioning using new techniques for measurement, verification and analysis;
- Energy efficient downlights for kitchens;
- Instrumented home energy rating and commissioning;
- Increased energy efficiency of refrigerators and air conditioners through use of advanced power electronics;
- A tool for comprehensive analysis of low-rise residential buildings;
- Building specification guidelines for energy efficiency; and
- Design refinement and demonstration of market-optimised residential heat pump water heater.

There exist various parallels between Atikol's work (emerging technologies as a result of California's Energy Crisis) and research work through the PIER programme. All were addressing electricity consumption related to the building envelope, water heating, lighting, HVAC, appliances, and pool pumps.

Bonneville [32] classified cost-effective DSM measures for both the residential and commercial sector from no-cost alternatives to investments with long payback periods.

To implement the most efficient and cost effective DSM actions, it is necessary to identify the largest energy consumers. DSM measures and energy and cost savings opportunities mentioned by him for the residential sector includes the following:

- No-cost actions
  - All unnecessary light bulbs and appliances should be turned off;
  - All standby powered equipment (e.g. TV sets) should be turned off;
  - Reduce temperature of hot water;
  - Keep lids on pots when cooking;
  - Do not leave fridge doors open for longer than necessary;
  - Use washing machines and tumble dryers at full load;
  - Close curtains at dusk to reduce heat transfer through windows; and
  - Reduce thermostat temperature by 1°C.
- Short payback period actions
  - Use daylight where possible to reduce electricity consumption for artificial lighting;
  - Programming the control of lights, air-conditioning, and heating through timeswitch thermostats all allows to match needs with particular comfort expectations; and
  - Insulation of hot water tanks and pipes.
- Medium payback period measures
  - Replace old incandescent light bulbs with efficient light bulbs such as CFLs;
  - Replace old appliances with new high efficiency units; and
  - Improve the insulation of opening mechanisms for windows.
- Long payback period measures
  - Outside and inside house insulation;

- Replace single-glazing and poorly insulated window frames with efficient windows – double, or even triple-glazing, low emissions; and
- Have a veranda to benefit from passive gains in winter. To prevent summer overheating, curtains must be installed on the outside of the veranda.

Bonneville also mention that awareness is needed. He gave the example of national campaigns in France (*Faison vite, ca chauffe*) that targets the public with TV-spots, press articles, and websites developing awareness of climate change issues. He concludes that DSM relies on a combination of technology and behaviour. Continuous information and education programmes are necessary for the development of an efficient system.

Strbac [33] reviewed major techniques that were put into practice:

- Night-time heating with load switching;
- Direct-load control;
- Load limiters;
- Frequency regulation;
- Time-of-Use pricing;
- Demand bidding; and
- Smart metering and appliances.

Dicorato [34] similarly listed energy efficiency improvements. The following were applicable to residential electricity users:

- Use of CFLs to replace incandescent lamps;
- Dual pane window installation in the place of single pan windows;
- Improvement of heat insulation of external walls and ceilings;
- Substitution of older appliances with high-efficiency electric household appliances;

- Installation of low-flow showerheads in the place of older ones;
- Aerated jet breaker for water raps instead of older ones;
- Installation of a heat pump to heat water; and
- Installation of solar thermal collectors.

This list of technologies of Dicorato also addresses most of the energy users and drivers listed by Atikol. Additional here is the influencing of water usage (low-flow showerheads and aerators on taps) that will have a knock-on effect on electricity usage (less hot water needs to be heated) as well as positive, although small, effects in the total water reticulation network of a city.

DSM measures applicable to the residential sector are discussed in the following paragraphs.

2.4.1 Building Envelope

In his study, Ouyang [35] has made changes to the building envelope to determine the feasibility of those changes on the heating and cooling loads. Changes done on a building included:

- Closing stairs by installing building doors and windows to separate the stairs from the outside air;
- Substituting old windows with plastic double windows;
- Applying unfixable curtains or blinds to reduce exterior windows shadow coefficient;
- Adding 40mm extruded polystyrene insulation onto the roof;
- Adding 10mm extruded polystyrene insulation to the exterior walls; and
- Applying light coloured paint to outside surfaces of the building envelop to alter the absorption coefficient.

Ouyang found that:

1. Although the measures realised savings, the viability of the options was hampered because of a) the measures were too expensive and b) electricity prices were too cheap. This would results in long payback periods.
2. There were variations between actual results and simulated results and that the revision process was essential.

He further concludes that other similar studies that were based on simulations only could be too optimistic in presenting savings for building envelope changes. Ouyang has not considered human behaviour and the effect on electricity consumption.

Wall [36] showed in her study that it was possible to build passive houses in a Scandinavian climate with very low energy use at the same cost than conventional construction techniques. Her village of 20 newly built houses included the following changes to the building envelope:

1. Insulation to the walls, roof, and ground floor;
2. Energy efficient windows including one or two low-emissivity coatings and a noble gas in the air gaps; and
3. Doors to minimise the infiltration rate of air into the building.

With these changes she found that the heating loads were considerably lower, but that the heating load (and consequently electricity consumption) was highly influenced by the behaviour of the occupants. The human behaviour was not addressed.

She goes further by stating one of the reasons for variations between her simulation results and actual measurements was that indoor temperature in the simulations was 20°C, but in reality occupants preferred it at 23°C. This was the single most influencing factor on the increased space heating demand. It could be concluded from her study that the behaviour component of occupants is crucial and should be addressed if residential DSM was to be successful.

Martinaitis [37] discussed energy efficiency measures that were considered during building renovations in a typical Lithuanian multi-family building. Most of the renovation measures included changes to the building envelope. The renovation measures consisted of:

- Insulation of external walls;
- Rehabilitation of the roof;
- Replacement of windows; and
- Replacement of external doors.

Lombard [38] found that in the South African residential sector the largest conservation potential exist through the following:

- Better envelop insulation; and
- Improved insulation for the hot water reticulation system.

Future work that he recommended was:

- Awareness campaigns to increase energy efficiency awareness focusing on improved insulation, general energy awareness, and free auditing and advice on request. On a national scale a peak load reduction of 76MW was expected. Regional impacts were not elaborated on.
- Additional to the point above, interest free loans for funding for installation of building envelope and hot water reticulation network insulation. On a national scale a peak load reduction of 262MW was expected.
- The study also suggested a minimum standard which prescribes installation of ceiling insulation for new houses as well as extra hot water cylinder insulation

which is enforced by law. On a national scale a peak load reduction of 547MW was expected.

Lombard concluded that in the residential sector technical issues alone cannot decide between various alternatives. The importance of behaviour of the customers was highlighted as a very important aspect.

In a study by Jakob [39] existing buildings were refurbished with the following energy efficient measures:

- Roof insulation;
- Wall insulation;
- Improved coatings, different gas fillings, and triple instead of double glazing on windows. Also plastic framed windows versus wooden framed windows; and
- An improved air renewal system with heat recovery.

He found that insulating buildings which were previously non-insulated is profitable, but that increases in energy prices should be taken into account during extended periods, as well as ancillary benefits. The ancillary benefits included were avoided external costs with regard to conventional air pollutants and greenhouse gas emissions.

Jaber [40] considered the effect of ceiling and wall insulation on the space heating load. He found that in Jordan the heating load could be reduced by about 50% if insulation was installed. He also made mention that where it was economically attractive, passive solar design and solar water heating should be considered.

Gieseler [41] presented quantitative results on the economics of different levels of thermal insulation for a building envelope in Germany. Defining the cost efficiency of an energy efficient building allowed one to identify solutions which were already economically viable as well as to determine specific costs of the investment in an advanced sustainable building. Gieseler found that there was a certain cut-off point where additional insulation would not be economically efficient, but would only contribute to additional thermal comfort and is an investment in saving of resources and reduction of CO_2 emissions.

Tommerup [42] mentioned that a large potential for energy savings exists in the Danish residential building stock due to the fact that 75% of the buildings were constructed before 1979. He focused on the renovation of existing buildings and considered insulation improvements of the building envelope, in heat distribution and producing systems, and heat recovery for mechanical ventilation systems. Actual retrofits have not been performed. He did mention that expected energy consumption for space heating in residential buildings be 82% lower by 2050 than in 2005.

Another innovative energy saving measure in residential buildings was worked on by Gugliermetti [43]. He presented the use of fully reversible windows. The windows consisted of two panes; an absorbing one and a clear one. The window could operate as closed windows in both normal and reversed positions. The absorbing pane influences the thermal behaviour. In summer the window is opened such that the filtering behaviour is used to reduce solar radiation thereby reducing the cooling requirement in the residence. In winter the window is reversed to benefit from solar heat gain thereby reducing the heating requirement for the residence.

Various energy savings measures in retrofitted dwellings were considered by Verbeeck [44]. He aimed to find economical ways and means to choose between insulation measures, better glazing, installation measures, and renewable systems such as solar collectors and Photovoltaic (PV) cells. He concluded by presenting a logical hierarchy of energy saving measures as follows:

- Insulation of the roof;

- Insulation of the floor;
- Thermal better performing glazing;
- A more energy efficient heating system; and
- Renewable energy system.

Due to the nature of the Western Cape Power Crisis it is not viable to consider changes to the building structure any further in this study due to implementation time and cost constraints even though there will be a reduction in electricity consumption because of changes to the building structure. The reason is that it was also found previously in this chapter that all DSM measures that need to be considered for implementation in the Western Cape residential sector should have a large load management component as expected impact. The focus therefore should be on actual electricity consuming devices and the management thereof. Time and money was also a major constraint in the Western Cape power crisis.

2.4.2 Direct Load Control of Domestic Hot Water Cylinders

Strbac [33] listed direct load control of hot water cylinders as a DSM technique because the cylinder can be turned off or cycled for relatively short periods of time. Direct load control requires a receiver installed on each device that is to be controlled. The utility would send a control signal to institute control. This signal could be relayed via a radio signal or even power-line communication. The utility then in effect can control load if it is needed and also by how much is needed. Direct load control can be applied to hot water cylinders, air conditioners, as well as pool pumps.

Nadel [45] listed some of the DSM programme types and some results. He listed various programmes of which the information, load management, and rebate programmes are relevant for this study. Nadel mentioned that hundreds of information programmes have been run by utilities, but data on programme results was rarely compiled or published. It was indicated by the limited data that were available that information programmes can have a positive impact, but that participation rates and savings are usually small. Nadel quoted Collins [46] who found net or gross energy savings of 0-2% among recipients of pamphlets, videos, and other energy-saving information services.

Furthermore Nadel also mentioned that load control programmes primarily involve direct utility control over residential air-conditioners and water heaters. It was found that savings per participant average nearly 1kW for air-conditioner programmes. Savings varied between 0.6 and 1kW for water heater programmes, with savings towards the upper end of this range in the winter. Nadel mentioned that the savings per customer vary with climate and cycling schedule. Savings increased as the length of the shutoff period increased, but the longer the shutoff period, the more likely customers were to complain of discomfort or lack of hot water. This programme, according to Nadel, is best applied in the low-income customers and other hard to reach customer segments or areas where substantial DSM savings are needed quickly.

Nadel also discussed rebate programmes and mentioned that they are best applied where DSM savings are needed quickly.

Nehrir [47] discussed the implementation of a customer-interactive multiple-block fuzzy logic-based electric water-heater DSM strategy for levelling the power demand profile of a distribution area. Results obtained from simulations showed that the proposed fuzzy DSM procedure could be effective in shifting the daily residential peak water-heater demand to off-peak hours. This will result in levelling distribution system power demand profile and consequently improving utility load factor.

2.4.3 Hot Water Cylinder and Ceiling Insulation

Weber [48] presented potential space heating and cooling energy savings and the reduction in hot water cylinder (geyser) standing losses with the application of thermal insulation to ceilings and geysers. In a previous study of Weber [49] it was found that a baseload reduction benefit of 26W/m^2 is possible through thermal insulation of ceilings. Weber reported an improvement of 21% for fibre insulation which is protected by both a water vapour barrier to the underside and a radiant barrier to the upper side. It was also concluded that the thermal conductivity of open fibre insulation installed in a ceiling could be downgraded by 20% because of the effects of dust, air movement and moisture. Accordingly insulation that has some form of barrier (similar to cladding on pipe lagging) will perform better than insulation without the barrier.

Harris [50] investigated the effects of hot water cylinder as well as pipe insulation in a laboratory. The whole geyser was insulated with fibre insulation and at least 1 meter inlet and 2 meter outlet pipes. Results quoted in the paper indicate that the standing losses of a hot water cylinder could be reduced by up to 27% if the cylinder is properly wrapped, as well as the 3 meters of piping as mentioned.

2.4.4 Solar Water Heating

Solar water heating (SWH) is a renewable energy method that harvests energy from the sun to heat water and could free electricity from the distribution network that would otherwise have been consumed to heat water the traditional way. An objective of this study was not to go through Residential DSM technologies in detail; it was merely to discuss technologies that exist.

Pillai [51] discussed a methodology for estimating the potential for solar water heating in a target area. He considered SWHs for his target area that consisted of residential, hospitals, nursing homes, and hotels in India. In his results he found the annual savings was 650kWh/m^2 of collector area and that this accounted for approximately 3% of the total electricity consumption of the selected target area.

Pillai did not include in his work the influence of human behaviour, but focussed on the economics. In the PhD dissertation of MacSleyne [52], mention is made that homeowners invest in energy efficiency (such as SWH) to improve comfort and decrease energy expenditures. MacSlayne has not addressed the barriers for investing in energy efficiency by households of which a crucial one was capital investment requirements.

SWHs were not well absorbed into the South African market because of the capital needed for investing in a SWH system and the relative low cost of electricity. A SWH system for a residence needed a capital investment of between R17,000 to R30,000 (some systems even more). A similar size hot water cylinder installation was in the region of R3,000. Assuming such SWH system (with no auxiliary power) replaced a 3kW geyser, this relates to between R5,700 and R10,000 per kW. Neither Eskom nor the average homeowner was prepared to make that kind of investment for a SWH installation. To put it into perspective, Eskom was prepared to fund replacements of 60W incandescent lamps with 14W CFL at a cost of roughly R15 per CFL. This relates to about R330/kW.

Additionally, a rough business case is as follows: Assume a good business case would yield a return within 3 years. It means that an installation of R30,000 needs to save R10,000 per annum (inflation and time value of money neglected). That is equivalent to R833 per month or 1,111kWh (at 75c/kWh) on the hot water system alone. Taking into account that in South Africa, the average home uses 1,100kWh per month [53]. These two figures (1,111kWh savings needed per month and total home electricity use of 1,100kWh) alone means that the payback of a solar water heating system is much longer than 3 years at the moment.

A slightly better estimate of the payback of a solar water heating system would be as follows: According to Eskom [53], a traditional hot water cylinder uses about 39% of the total household power. Of 1,100kWh that is 429kWh per month. Also according to Eskom [53] a SWH can reduce the electricity used to heat water by up to 70%. The total saving by installing a SWH could therefore be about 300kWh per month. Taking again the R30,000 installation cost system with no inflation, electricity cost of 75c/kWh and neglecting the time value of money, that means the system needs to save 40,000kWh just to break equal. With 300kWh savings per month that translates to 133 months, or 11 years. At the moment, SWHs are not a good investment looking from the residents or from Eskom's point of view.

Installation of a SWH does not make sense at the moment if one is looking at it from only an economical point of view. This probably contributes to the reluctance of Eskom and the homeowners to install SWH technologies. It also needs to be kept in mind that as electricity prices increase and SWH costs reduce, the business case will always change.

2.4.5 Heating, Ventilation and Air-conditioning

Shultis [54] demonstrated the impact of local control on reducing peak residential air-conditioning demand. A group of 104 test houses were selected and all fitted with the load control device. Of the test group, the device was disabled on 52 of the houses for evaluation purpose. The load control device was enabled on the remaining 52 houses. The impact caused by the air-conditioning load control device during peak conditions (14:00 to 18:00) was estimated to be about 0.36kW per house on weekdays. Shultis did not express the impact as a percentage of the air-conditioning load neither as a percentage of the total house load. He also did not address the human behaviour issue by investigating if the air-conditioners were really needed; i.e. was the houses occupied at that stage especially since impact was made between 14:00 and 18:00? It is the author's experience that those hours are normally office-hours. Were the air-conditioners left on by the homeowners so that the house was cool upon returning from work? Or were the air-conditioners only left operational for the experiment?

2.4.6 Lighting

Urge-Vorsatz [55] mentioned Hungary's remarkable market success with regards to implementation of CFLs. She mentioned that the penetration rate of CFLs in the residential sector were higher than that of many industrialised countries. Hungary was ranked in the top eight European countries with respect to CFL penetration. Her discussion was about the driving forces that contributed to the outstanding success of this programme. The two driving forces identified were:

- Fierce competition among CFL market participants, mainly manufacturers that led to broad marketing of the technology that resulted in increased awareness.
- Psychological shock of the drastic hikes in electricity tariffs. She mentioned that although prices rose mainly in nominal terms, they have generated a strong desire in the population to reduce energy bills.

The increased will of consumers to conserve energy, as well as the general lack of awareness on how to save energy, provided a fertile ground for CFL marketing campaigns. This statement in itself is critical for any programme to succeed. The consumer will react if the right message is communicated to the consumer at the right time.

Eiswerth [56] studied the residential electricity use and the potential impacts of energy efficiency options in Pakistan. He found that the most promising areas for DSM programme implementation in the residential sector include the following:

- Efficient lighting. Replacing incandescent light bulbs with lower wattage compact fluorescent bulbs;

- Efficient refrigerators. Encouraging the purchase of more energy efficient models by first time buyers and providing incentives for the replacement of existing stock with more energy efficient refrigerators; and
- Efficient cooling fans.

With regards to the lighting, Eiswerth made the reader aware that the impact due to light replacement will only occur during the early evening and early morning since the lighting contribution to the total load was statistically insignificant during the day.

Martinot [57] discussed his experience regarding energy efficient lighting programmes in eight countries – Poland, Thailand, Mexico, Jamaica, Peru, Brazil, Denmark, and the United Kingdom. He indicated that peak load reductions were significant and in Brazil, where a give-away programme was initiated, the peak load reduction was 1.8MW. Mention was also made to indirect impacts such as Greenhouse Gas (GHG) emission reductions. These impacts could not be quantified in many cases because of lack of baselines necessary for impact calculations.

Zia [58] discussed energy management in Lucknow city. He determined the availability of certain appliances in the city within all income groups. The most frequently found appliances were a cooler, followed by a television, fridge, and a stereo. In terms of energy efficiency opportunities identified in the residential sector, two were related to lighting; replacement of incandescent lamps with CFLs and replacement of TLD-fluorescent lamps (T8) with TL-fluorescent lamps (T5). Other opportunities included to replace ceiling fans with efficient fan motors, replace standard efficiency cooler with high-efficiency cooler, and introduce high-efficiency refrigerators.

Yang [59] assessed various DSM measures in Nepal. Most of the technologies considered were not relevant to the residential sectors such as power factor correction, electric vehicles, intelligent motor controllers, maintenance schedules, time of day tariffs, voluntary constraints, captive generation, and reduced voltage supply. The only DSM measure that was considered in the residential sector was efficient lighting. Lighting technologies focused on include the following:

- 100W incandescent lamps to 23W CFLs;
- 60W incandescent lamps to 18W CFLs; and
- T12 40W fluorescent lamps to T8 36W fluorescent lamps.

The Net Present Value (NPV) of the lighting retrofits was all greater than zero indicating that the programme was financially viable. It was expected that the peak demand impact because of lighting retrofits could be between 26MW and 130MW.

Mahlia [60] studied the project electricity savings, cost-benefits and emission reductions of lighting retrofits in the residential sector of Malaysia. He proposed that incandescent lamps be replaced by CFLs which consumes 80% less electricity than incandescent lamps. Substantial energy savings were presented with positive NPV values over four years. He concluded that consumers should be encouraged to use energy efficient lighting and to replace inefficient lighting in their households.

2.4.7 Appliances

Lu [61] discussed the potential energy savings and environmental impact made by implementing energy efficiency standards for refrigerators in China. Lu considered three different grades of refrigerators ranging from an efficiency of 55%, 65%, and 80%. He found that if the standard is implemented in 2003, the accumulated savings in 2023 for Grade 1 could be 1,293 TWh, 786 TWh for Grade 2, and 495 TWh for Grade 3. Lu concluded that it was, due to these savings and the consequently environmental impact (as China is the world's second biggest emitter of CO_2 emissions), very necessary to implement the energy efficiency standard for refrigerators in China.

2.4.8 Demand Response

Demand response is a mechanism in use by utilities to manage customer consumption in response to supply conditions. The load reduction response could be either due to critical times or due to market prices of electricity. [62]

The most common demand response strategies according to Sezgen [63] are the following:

- Load curtailment; also called load shedding. Through load shedding customers reduce discretionary their electricity demand because of a high price signal.
- Load displacement; also called load shifting. Through load shifting customers post-pone use of electricity during peak demand periods (high prices) to off-peak demand periods (lower prices).
- Fuel-substitution that includes distributed generation. Customers would use on-site generators for example and reduce their demand from the electricity network during peak periods this way.

These strategies are exactly the strategies of DSM as well, but there are some shortfalls with regards to Western Cape residential customers that are discussed further in this paragraph.

Kiliccote [64] discussed how advanced controls can support multiple modes of operations including both energy efficiency and demand response. Advanced controls for demand response and energy efficiency reduce the cost of implementing demand response, thus improving demand shedding potential. Studies referenced by Kiliccote indicated that there are important synergies between dynamic peak load reduction technologies and new energy efficiency equipment and advanced energy management and control systems.

2.4.9 Pricing

Faruqui [65] quantified the customer response to dynamic pricing in California. His findings were that all customers, including residential customers, conclusively reduced peak-period energy use in response to time-varying prices. He further concluded that the responsiveness varied with rate type, climate zone, season, air conditioning ownership, and some other customer characteristics. Faruqui also said that dynamic pricing requires the installation of digital interval meters and installation of such meter only makes economic sense if the benefits exceed the cost of the new metering infrastructure.

Strbac [33] listed Time-of-Use (TOU) pricing as a DSM technique. Time-of-Use pricing entails different prices for electricity during different times of the day. Rates are more expensive during peak periods and are lower during off-peak periods. Again, just as with dynamic pricing, TOU pricing requires digital interval meters which is a barrier for introducing this DSM measure in the residential sector in the Western Cape.

Saini [17] mentioned some tool for DSM and listed them as follows:

- Dynamic/Real time pricing;
- TOU rates;
- Automated/smart metering;
- Web-based/communication system; and
- Emergency demand response programmes.

Herter [66] summarised the results from an exploratory analysis of residential customer response to a critical peak pricing (CPP) experiment in California. Participating customers received a high price signal from the local electricity distribution company 15 times per year. The high prices were almost three times the on-peak price for the otherwise applicable time-of-use rate. Statistically significant load reduction for participants both with and without automated end-use control technologies was found. During five hour critical peak periods, participants without control technology used up to 13% less energy than they did during normal peak periods. Participants equipped with programmable communicating thermostats used 25% and 41% less for five and two hour critical events respectively. Herter concluded that the residential sector can provide substantial contributions to retail demand response.

These tools are viable solutions for load management, but only certain customers could participate because of the communication channels and the technology needed to enforce those tools.

Dynamic pricing or demand response in the residential sector of the Western Cape could not be implemented because of the following reasons:

- No residences were equipped with digital interval meters;
- Most residential customers bought electricity from a municipality and they charge (because of no interval meters) their consumers a c/kWh flat rate; and
- The long time-span for all the process (legal, proposal, approval, installation, commissioning, etc) was too long for installation of residential interval meters to make dynamic pricing a viable solution.

2.4.10 Fuel Switching

De Almeida [67] analysed 17 different technology options for fuel switching which were chosen to match the consumption behaviour of a typical Portuguese family in Portugal. He has shown that the use of an electric heat pump, both for space and water heating, combined with the use of a natural gas cooker, leads to the lowest energy consumption. If only the running cost were considered, this combination was 45% more economic than having a natural gas centralised heating system combined with a gas cooker and was 60% more economic than having an electric resistance space heater combined with an electric storage water heater and electric cooker which was the worst case. This worst case is probably the most frequently encountered case in South Africa.

2.4.11 Frequency Regulation

Strbac [33] listed frequency regulation as a DSM technique. Any electrical appliance that is time-flexible could be used and this could include air-conditioners, hot water cylinders, and refrigeration. Just as in the United Kingdom, South Africa's system frequency is also closely monitored and continuously maintained within a narrow band around 50Hz.

Binneman [68] explained the importance of frequency in the South African Power Distribution Network and also mentioned that when the frequency dropped below a certain value, load had to be shed in the network to prevent frequency decay.

Carolin [16] explained the different constraints of the different distribution areas in South Africa. The frequency is monitored and closely controlled. In the Western Cape the frequency is not the constraint; the actual demand [MW] is the constraint. Supply problems in the Western Cape would therefore not be detected by monitoring the frequency. As a result, Residential DSM techniques in the Western Cape based on frequency would not provide a viable solution.

2.4.12 Energy Consumption Management Systems

Papagiannis [69] investigated the economic and environment impacts that resulted from the implementation of an intelligent DSM system, called Energy Consumption Management System (ECMS) at the European level. The ECMS allows for individual control of electric devices and used Narrow-band Power Line Communication (NPLC) to communicate with electric devices. The ECMS technology was applied to space heating, domestic hot water systems, and lighting in an analysis performed by Papagiannis to determine the energy savings potential of the technology. An average saving of 50 € (300kWh) was obtained in the EU-15 (EU-15 includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom) which was too low to justify the installation of the technology at a cost of between 500 € and 800 €. Despite this low energy saving per house, energy savings of between 0.21% and 1.49% in the primary energy for the EU-15 could be realised purely because of the large number of dwellings. Total peak power reduction for the EU-15 was between 0.15% and 1.38%. On a single house scale, the technology does not look promising. If the technology is evaluated on a national scale, there were significant financial gains for both the end-users and the community. Papagiannis also mentioned that energy intensities for the residential sectors varied greatly with climatic conditions. The work of Papagiannis demonstrated that small savings add up to a lot on a larger scale. The human behaviour component was not addressed by Papagiannis as technology alone was applied to control the load.

2.4.13 Human Behaviour

Ueno [70] focused on the awareness of residents to energy conservation and the potential of reducing energy demand through energy-savings activities. An online interactive *energy consumption information system* was designed and installed in nine residential houses. The measurements were used to do measurement and verification of the savings. Major findings of Ueno included the following:

- Installation of the system led to a 9% reduction in power consumption.
- Comparisons of daily-load curves and load-duration curves for each appliance before and after installation of the system revealed various energy-saving behaviours of the household members.

- Energy conservation awareness affected not only the power consumption of the appliances explicitly shown on the system monitor, but also other household appliances.

Important from this work is that the display of information would create awareness under the households and have a positive impact on the power consumption.

Yamamoto [71] did a survey of consumers that showed that most have little awareness of the energy efficiency of appliances, the price of the services produced by electrical appliances, or electricity rates. He argued that these findings indicate that price does not function as a signal in electricity consumption through electrical appliance use. Rather, he found that consumer decision-making in electricity consumption is dependent on the characteristics of the particular electrical appliances they used. Yamamoto concluded that decision-making about electrical appliance use and electricity consumption in the home is not always rational and is affected by the particular characteristics of the appliances and the payment system for electricity consumption along with human psychology.

Sebitosi [72] tried to address the human behaviour aspect in South Africa through an interview with Eskom DSM department. Questions asked included:

- Are we drawing the attention of the South African consumer?
- Are we making any in-roads in reaching the South African consumer?
- Are we succeeding in convincing the consumer to act?
- If so, is the consumer’s reaction sustainable?
- Do we have an index by which to quantify our success (or lack thereof)?
- Do we have an effective energy services industry through which we can sustainably reach the consumer?

- If the answers are largely, no, how can we (the public, institutions) contribute to help?

No feedback was received from the specific department. It can only be concluded that the human behaviour aspect was not considered part of the solution by the department.

Lin [73] studied how local culture could have an impact on electricity consumption. It was thought that competition between different technologies would lead to better consumer choices, but it was found that it could also lead to changes in clothes-washing habits, from cold to hot water washing and therefore a much higher energy use. The work of Lin highlights the needs for technical standards as well as the needs for awareness creating of consumers regarding different technologies.

Carlsson-Kanyama [74] mentioned that very few efficiency programmes have addressed energy use behaviour of humans. Her studies have shown that energy saving of between 10 and 20% exist through behaviour changes. Her previous research focused on theoretical issues or on how home owners themselves think they would act if eventually asked to save energy and to do so by various policy instruments. She referenced some energy-efficiency campaigns in Sweden and found that data and information and the visibility thereof were important. In one of the programmes a goal was set for home owners to save 10% and most came close to their goal. The changes in behaviour and the long-term effects were not investigated. She concluded that most home-owners will, when confronted with the possibility to save money and at the same time given the technical equipment enabling them to do so, cooperate and establish new habits.

2.4.14 Conclusion on Residential Demand Side Management Technologies and Methodologies

Various residential DSM technologies and methodologies were discussed. The human behaviour aspect, apart from some awareness campaigns, was not well addressed as most of the researched papers focused on technologies for load management. The home owners, it appeared, was just a resident in his own home, a mere user that could never be requested to switch appliances off when asked.

Carlsson-Kanyama [74] showed the potential of 20% energy savings through behaviour changes exists. Except for dynamic pricing and demand response initiatives by utilities, the author could not find a single paper where the home owners in a whole region was actively involved in real-time and made responsible for managing the electricity consumption in his own home when the electricity utility was under pressure.

Gehring [75] also made mentioned that a major problem with load management programmes was a lack of communication with the customer. It was also the view of Govendor [76] that the best short-term solution to the energy crisis lay in the management of the demand through efficient energy management schemes.

No study or project was found that actively involved the home owner when it was really needed to assist with load management – switching off the right things in their homes at the right time to alleviate pressure on the electricity distribution network. A major gap was identified in informing the home owners in real-time on the status of the electricity network and requesting their assistance in alleviating the pressure on the network.

2.5. Barriers for Traditional Residential Demand Side Management in the Western Cape

In the previous paragraphs numerous residential DSM technologies, methodologies, and opportunities were discussed. Given the situation in the Western Cape where a 400MW reduction was required within six months, very little of these technologies, were considered viable because of implementation timeframes involved, economic consideration, and possible resistance from homeowners. The answer lies in the co-operation of the home owners; getting everybody on board and making everybody responsible for saving electricity. Ultimately, *who* will make the impact rather than *what* will make the impact.

It was also unrealistic to expect that home owners should always switch appliances off. The idea is really to do only what is necessary, given a certain problem. It was therefore important to understand what consumes electricity in the residential sector and consequently what should be targeted with a load management programme where the home owner participates.

2.6. Electricity Consumption in the Residential Sector

2.6.1 Electricity End-Use Load Disaggregation

Various studies from around the globe were evaluated to determine what the major electrical end-users in residences were.

Table 2-1 shows the studied material as well as to which city or region the study was applicable. Two studies were also conducted related to South Africa; one by Lane and one by Nortje.

Table 2-1: Studies referenced for residential end-use load disaggregation

Contributor	Reference	City	Country / Region
Shimoda	[77]	Osaka City	
IEA	[78]		IEA19
Atikol	[29]	Northern Cyprus	
Atanasiu	[79]		NMS & CC
Lane	[80]	Hartebeespoort	South Africa
Chedid	[81]		Lebanon
Almeida	[82]		Brazil
Ghisi	[83]		Brazil
Larsen	[84]		Norway
Tso	[85]		Hong Kong
Parker	[86]		Central Florida
Nortje	[87]		South Africa
Papagiannis	[69]		EU-15

Figure 2-3 shows the findings of each of the authors listed in Table 2-1. The bars are the specific results from the studies and the solid line is the average of all studies. It could be seen from the studies that appliances were the highest electricity user. Electricity usage due to water heating and lighting was also consistently high in all studies.

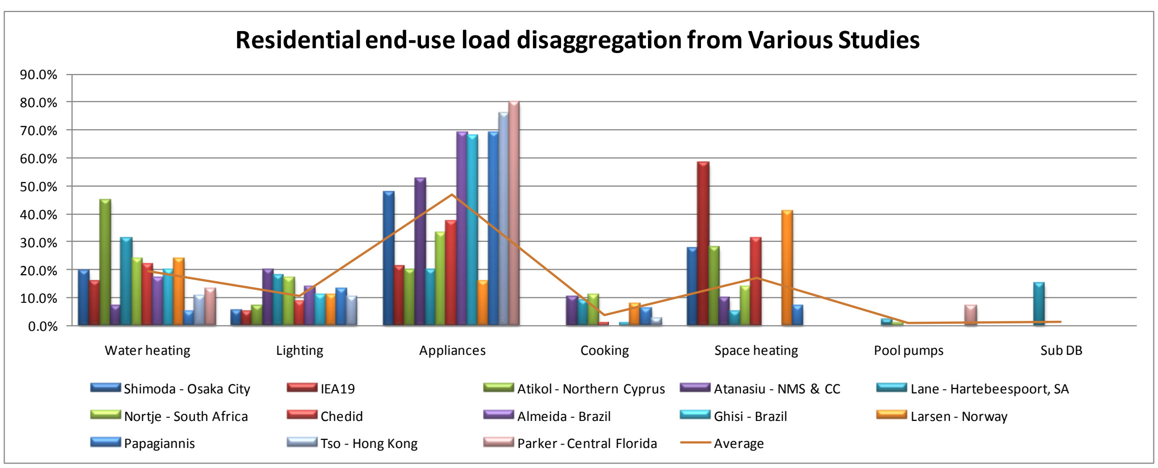

Figure 2-3: Residential electrical end use load disaggregation (all studies)

Figure 2-4 shows the load disaggregation of the average of all studies. It was seen that on average appliances were responsible for 46.9% of all electricity consumption in the residential sector followed by water heating (19.5%), space heating (17%), and lighting (10.8%).

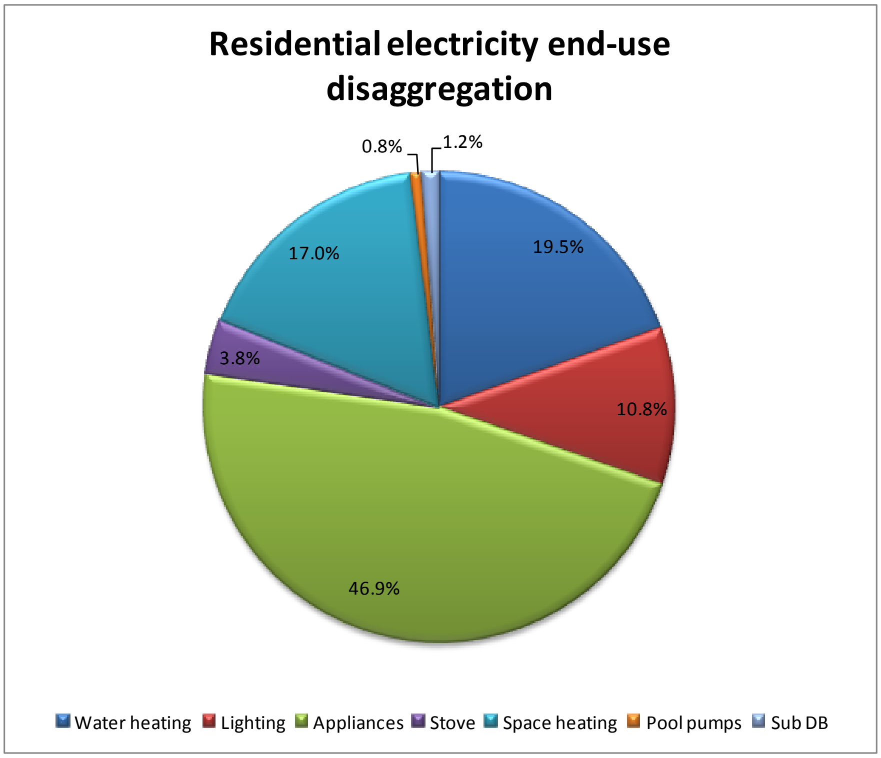

Figure 2-4: Residential electrical end-use load disaggregation (average)

Figure 2-5 shows the electrical end-use load disaggregation of the two South African studies. In the study by Lane it was seen that the major electricity user (31%) was the domestic hot water cylinder. Second largest contribution was from appliances (20%) followed by lighting (18%). The study of Nortje showed appliances (33%) to be the major electricity end-user followed by water heating (24%) and then lighting (17%).

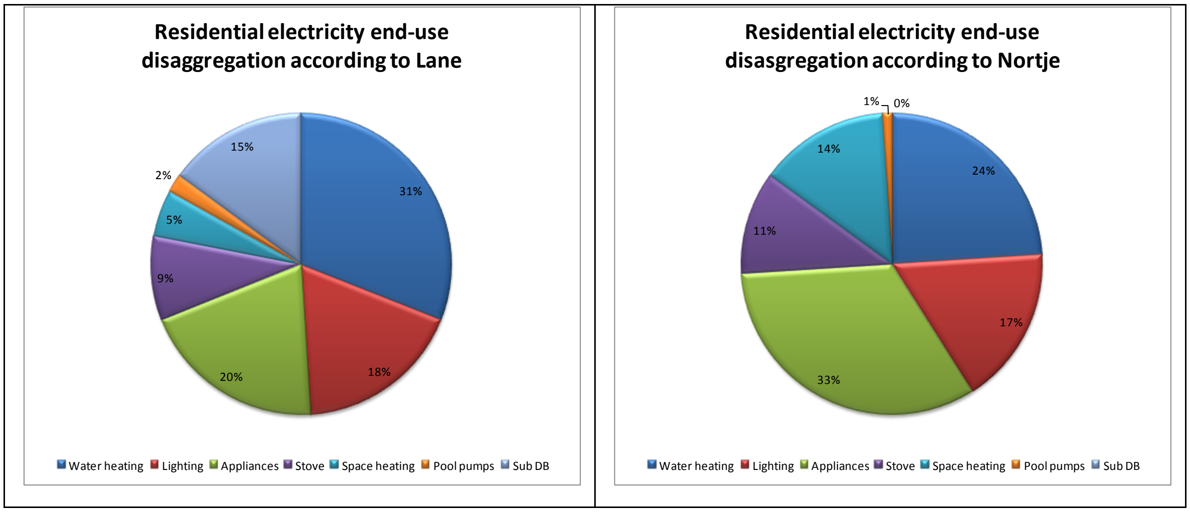

Figure 2-5: Residential electrical end-use load disaggregation of South African studies

From the results it was concluded that the largest impact of residential DSM could be achieved if the following end-users are targeted:

- Water heating;
- Lighting;
- Appliances;
- Stoves; and
- Space heating.

The next question to be answered was if the residents of the Western Cape owned the mentioned devices. For that the Living Standard Measure (LSM) in use by the South African Advertising Research Foundation (SAARF) was used.

2.6.2 Living Standard Measure – A Tool to Determine Who and What to Target

Households could be classified into different living standard groups according to a variety of aspects. Joyeux [88] made mention of the point that electricity consumption and income was not co-integrated. Given that, Joyeux concluded that LSM indexes that rely on income measures alone and do not directly include household-level energy consumption information will necessarily miss important indication of changes of standard of living. Therefore, LSM factors that rely only on income will not be useful in determining who has electricity consuming devices at home, thus missing the places where to focus efforts as well as getting messages wrong.

The SAARF's LSM is the most widely used marketing research tool in Southern Africa [89]. Household assets, access to services (water, electricity, sanitation, etc) and geographical location form the cornerstones of the SAARF's LSM model [90, 91].

LSM is therefore a valuable tool to assist in determining what electrical appliances are present in residences. Milne [91] gave an overview of the expected appliances to be found in different LSM houses:

- LSM 1: Minimal ownership of durables except radio sets. This group seldom have access to electricity.
- LSM 2: Minimal ownership of durables except radio sets and stoves. This group also seldom have access to electricity.
- LSM 3: Minimal ownership of durables except radio sets and stoves. This group have access to electricity.

- LSM 4: This group owns television sets, hi-fi/radio sets, electric hotplates, and fridges.
- LSM 5: This group owns television sets, hi-fi/radio sets, stoves, and fridges.
- LSM 6: This group owns a number of durables plus a cell phone.
- LSM 7: This group has an increased ownership of durables and also a motor vehicle.
- LSM 8: This group has full ownership of durables and including digital video disc (DVD) players, computers, and satellite dish.
- LSM 9: This group has full ownership of durables and including DVD-players, computers, and satellite dish.
- LSM 10: This group has full ownership of durables and including DVD-players, computers, and satellite dish.

According to Milne the majority of people in the Western Cape fall in a higher LSM group compared to the national figures. Approximately 8% of the Western Cape population falls into LSM groups 1-4, while 35% of the Western Cape populations fall in the LSM 7 group. The highest percentage of the population falls in that group. This indicated that people have more appliances in their houses and this contributes to electricity consumption. The target audience (and consequent messages to the public) would therefore be primarily the LSM 5 and higher groups.

One could therefore expect at least the following electricity consuming appliances in a Western Cape residence:

- Lights;
- Television;
- Geyser;
- Radio;

- Electric heater;
- Stove; and
- Fridge.

2.6.3 Conclusion on Residential Electricity End-use

Combining the results of the residential electricity end-use load disaggregation and the LSM study, any mass-media campaign that wants to reduce the residential electricity demand should therefore address the following:

- Non-essential appliances. Televisions and radios were also excluded as they are part of the communication channel;
- Lighting;
- Stoves;
- Geysers (hot water cylinders); and
- Heaters.

2.7. Conclusion

A power crisis was experienced in the Western Cape in the winter of 2006. A shortfall of 400MW was expected due to the unexpected failure of one of the crucial power stations. This shortfall was expected in the evening peak that indicated that the management of the residential evening (18:00 to 21:00) peak load could yield the best results to solve the power crisis. Due to the extremely short timeframe of six weeks before demand was expected to exceed supply, traditional DSM measures was for almost all practical reasons excluded. It was found that human behaviour changes could have a dramatic impact on electricity consumption. The solution therefore was to involve the residents of the Western Cape. Making them part of the solution to alleviate the power crisis.

The conducted load disaggregation and living standard measure analysis indicated that space and water heating, lighting, appliances, and stoves were the major appliances consuming electrical power in residences. Those consumers should therefore be targeted to assist alleviating the power crisis.

Power Alert was born to involve the Western Cape residents and make them part of the solution to alleviate the power crisis. Power Alert was designed as an early warning service that tracks increasing electricity use in the region by means of national television broadcasts. The level of strain on the network was communicated to the public. The public was given suggestions on how they could assist to reduce the strain and thereby help prevent load shedding.

The following chapters of this study will focus on the feasibility of residential load management in the Western Cape, the development of the Power Alert system, the performance assessment of Power Alert and top-down measurement and verification results of the complete DSM initiative in the Western Cape.

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CHAPTER 3

Feasibility of Power Alert as a Residential Load Management System

This chapter focuses on the expected peak demand reductions and how it was calculated.

The first step was to find the potential impact for residential load management in a single residence. That number was then extrapolated to find the potential impact of residential load management through Power Alert in the whole of the Western Cape by incorporating TV-viewer numbers combined with an expected participation percentage.

CHAPTER 3 FEASIBILITY OF A RESIDENTIAL LOAD MANAGEMENT SYSTEM

3.1. Introduction

Electricity use of residential housing is highly dependent and influenced by human behaviour and habits. It was therefore of primary importance to create awareness of the expected electricity shortfall of approximately 400MW during the peak periods for the winter months (June, July and August) in order to achieve electrical demand reductions in the Western Cape residential sector.

The only way to minimise the risk of load shedding would have been to involve the public by making use of continuous feedback regarding the status of the electrical distribution network and how they can participate.

The potential of residential load management were unknown because no detailed data for end-use of electricity consumption existed for the Western Cape. This chapter focuses on the feasibility study that was performed to determine the potential of such a residential load management system. Questions that were answered included:

- How much electricity do we expect to save in a single residence?
- When do we expect to save electricity?
- On what appliances do we expect to save electricity?
- How many houses are in the Western Cape?
- How many people watch the National broadcasters' television channels?
- How many people do we expect to participate?

Based on the answers to the above questions it could be determined how much electricity could be saved through residential load management in the Western Cape.

The residential load management system was commonly referred to as Power Alert.

3.2. Feasibility for Residential Load Management in the Western Cape

A crucial aspect in the development and implementation of a residential load management system was to determine the potential for load reduction in the Western Cape residential sector during peak times. No detailed data for end-use of electricity consumption existed for the Western Cape and it was also not the aim of this study to determine end-use energy profiles through metering or surveys in the area. Existing literature was sourced and the residential electricity consumption in the Western Cape was estimated from there.

Lane [1] provided data of a study done in a residential area to come up with an expected demand profile of a residence as well as detailed load disaggregation load profiles. This data was applied to the Western Cape to determine the feasibility of a residential load management system.

Consider Figure 3-1 that provides an electrical load profile for a typical residential house during a weekday. The results shown in Figure 3-1 were based on a study of numerous houses over a 12-month period in Hartebeespoort. The results provided the after-diversity maximum demand (ADMD) for the complete study. At the time of this writing no other study was conducted in South Africa to determine the ADMD factor for electrical loads found in households.

The individual contributing loads shown in Figure 3-1 were the following:

- Geyser load;
- Space heating load;
- Stove load;
- Plug loads;
- Pool pump loads;
- Lighting loads; and
- Sub distribution board loads.

The average after ADMD loads for these households during the evening peak period (18:00 to 20:00) was 2.33kW.

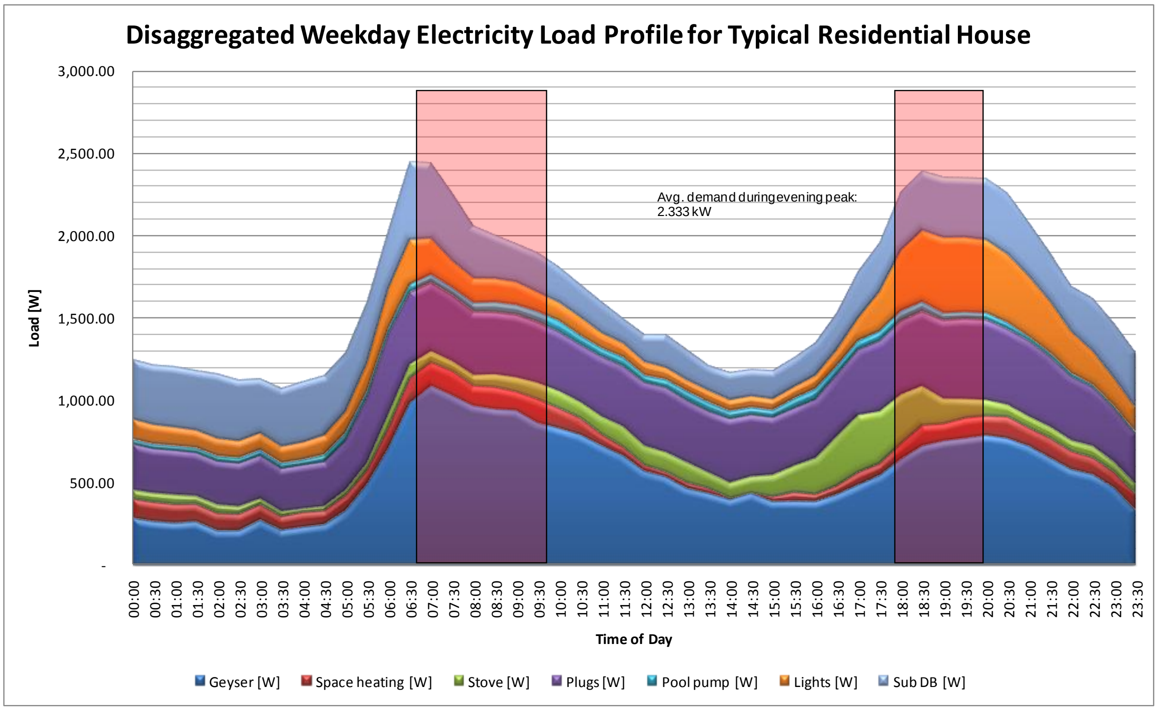


Figure 3-1: Disaggregated residential load profile for a weekday with peak times indicated

Table 3-1 provides a summary of the contributions that each load has on the total load profile during the evening peak periods. As an example, although a geyser is rated as 3kW its contribution to the load during evening peak times is only 719W. This contribution figure is known as the ADMD.

Table 3-1: ADMD loads for a typical residential house during winter months in terms of their contributions during evening peak periods

Description of Load	Evening Peak Period (18:00 – 20:00, Weekdays)			
	After-diversity maximum demand (during Winter) [W]	Percentage contribution to overall total [%]	Maximum viable % of load that can be switched off if necessary [%]	Potential after-diversity maximum demand impact [W]
Geyser	719	31%	100%	719
Space heating	110	5%	100%	110
Stove	204	9%	100%	204
Plugs	464	20%	50%	232
Pool pumps	50	2%	100%	50
Lights	426	18%	50%	213
Sub distribution board	361	15%	0%	0
Total residence	**2,333**	**100%**	N/A	1,528

A demand reduction of 1,528W or 1.53kW per household can be obtained if the following loads are switched off during the evening peak period (Figure 3-2):

- Geyser load: Switch off 100% of load
- Space heating load: Switch off 100% of load
- Stove load: Switch off 100% of load
- Pool pump load: Switch off 100% of load
- Plug loads: Switch off 50% of load
- Lighting load: Switch off 50% of load

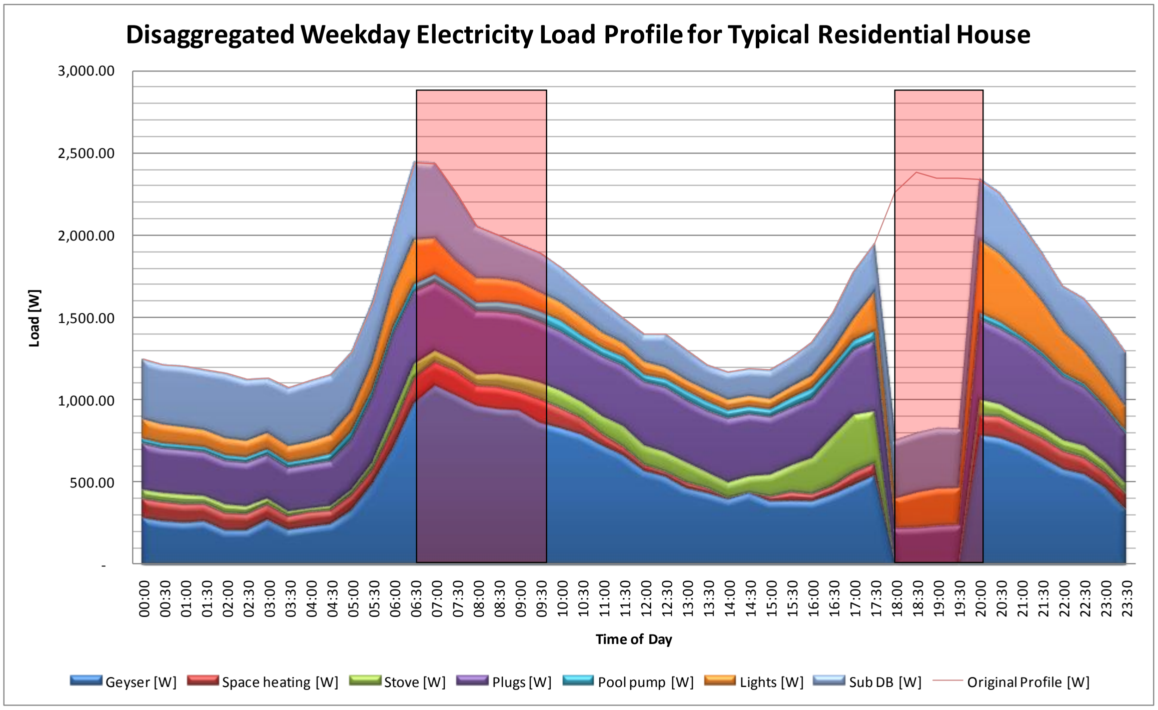


Figure 3-2: Disaggregated residential house load profile for a typical weekday with maximum load control during evening peak period

Not shown in the graph is the comeback load of electrical equipment such as the geyser as a result of thermal energy that needs to be recovered by the electrical element. Part of Power Alert was also to make sure that a new evening peak after 20:00 was not created due to comeback loads. For that purpose the Power Alert control centre (PACC) was operational from 18:00 to 21:00. Prior 20:00 was mainly to control the residential load by asking residents to switch off appliances. After 20:00 the centre informed residents that electricity consumption is under control and that appliances could be switched back on again.

Table 3-2 show the demand impact per house if a staged approach is followed in switching off the above mentioned loads.

Table 3-2: Expected demand impacts per household based on various action levels of residential load management

Load control:	Geyser (100%)	Geyser (100%) Space Heating (100%)	Geyser (100%) Space Heating (100%) Stove (100%)	Geyser (100%) Space Heating (100%) Stove (100%) Plugs (50%)	Geyser (100%) Space Heating (100%) Stove (100%) Plugs (50%) Pool pumps (100%)	Geyser (100%) Space Heating (100%) Stove (100%) Plugs (50%) Pool pumps (100%) Lights (50%)
Hour	Demand impact [W]	Demand impact [W]	Demand impact [W]	Demand impact [W]	Demand impact [W]	Demand impact [W]
00:00 – 5:30	-	-	-	-	-	-
06:00	-	-	-	-	-	-
06:30	-	-	-	-	-	-
07:00	-	-	-	-	-	-
07:30	-	-	-	-	-	-
08:00	-	-	-	-	-	-
08:30	-	-	-	-	-	-
09:00	-	-	-	-	-	-
09:30	-	-	-	-	-	-
10:00 – 17:30	-	-	-	-	-	-
18:00	640	732	1,032	1,255	1,315	1,497
18:30	721	844	1,084	1,310	1,367	1,584
19:00	750	852	1,007	1,244	1,287	1,515
19:30	766	887	1,006	1,248	1,288	1,514
20:00	-	-	-	-	-	-
20:30	-	-	-	-	-	-
21:00	-	-	-	-	-	-
21:30	-	-	-	-	-	-
22:00 – 23:30	-	-	-	-	-	-
Average impact during evening peak period.	**719W**	**829W**	**1,032W**	**1,264W**	**1,314W**	**1,528W**
Equivalent amperes shed	**3.27 A**	**3.77 A**	**4.69 A**	**5.75 A**	**5.97 A**	**6.95 A**

Table 3-2 provides the potential per household for Hartebeespoort. These results can be used to obtain an estimate of the potential impacts that can be obtained for the Western Cape.

The results achieved in the study mentioned above have been extrapolated to the Western Cape using the following information:

- There are approximately 625,000 residential households in the Western Cape [2].
- The peak-demand for the Western Cape during the winter evening peak periods is approximately 4,000MW to 4,250MW based on actual metered data and in literature [3]. To be conservative, 4,000MW would be used in calculations from here on forward.
- The residential sector is responsible for approximately 35% of the maximum demand during the evening peak periods [4].

From the above information it was calculated that the residential sector accounts for 1,400MW of the total 4,000MW forecasted for the evening peak periods. The ADMD per residential household was calculated as 2.24kW when dividing their contribution of 1,400MW by the total number of households (4,000,000kW / 625,000). The study of Lane found the ADMD to be 2.33kW. The results of that study was consequently adjusted downwards so that the load disaggregation figures mentioned in Table 3-1 adds up to 2.24kW. As an example, the Western Cape calculated ADMD was 96.1% of the value from the study of Lane. The contribution of the geyser for example was adjusted to 690W (719W x 0.961).

Table 3-3 provides the contributing load per household load for an average household in the Western Cape.

Table 3-3: Determined after-diversity maximum demand loads for a typical residential house during winter months in terms of contributions during evening peak periods in the Western Cape

Description of Load	Evening Peak Period (18:00 – 20:00, Weekdays)			
	Assumed percentage contribution to overall total (based on results of Hartebeespoort study) [%]	After-diversity maximum demand (during Winter) [W]	Maximum viable % of load that can be switched off if necessary [%]	Potential after-diversity maximum demand impact [W]
Geyser	31%	690	100%	690
Space heating	5%	105	100%	105
Stove	9%	196	100%	196
Plugs	20%	445	50%	223
Pool pumps	2%	48	100%	48
Lights	18%	409	50%	205
Sub distribution board	15%	346	0%	
Total residence	**100%**	2,240	N/A	1,466

Table 3-3 shows that the potential impact of 1.466kW per residence exists in the Western Cape if the listed loads could be switched off according to the following:

- Geyser load: Switch off 100% of load
- Space heating load: Switch off 100% of load
- Stove load: Switch off 100% of load
- Pool pump load: Switch off 100% of load
- Plug loads: Switch off 50% of load
- Lighting load: Switch off 50% of load

3.3. Viewers of the Different Television Channels

Figure 3-3 shows the average adult viewers in the Western Cape of the National Broadcaster television channels (SABC 1, 2, 3) per day between 18:00 and 21:00. SABC 2 has the most viewers, followed by SABC 1, and then SABC 3.

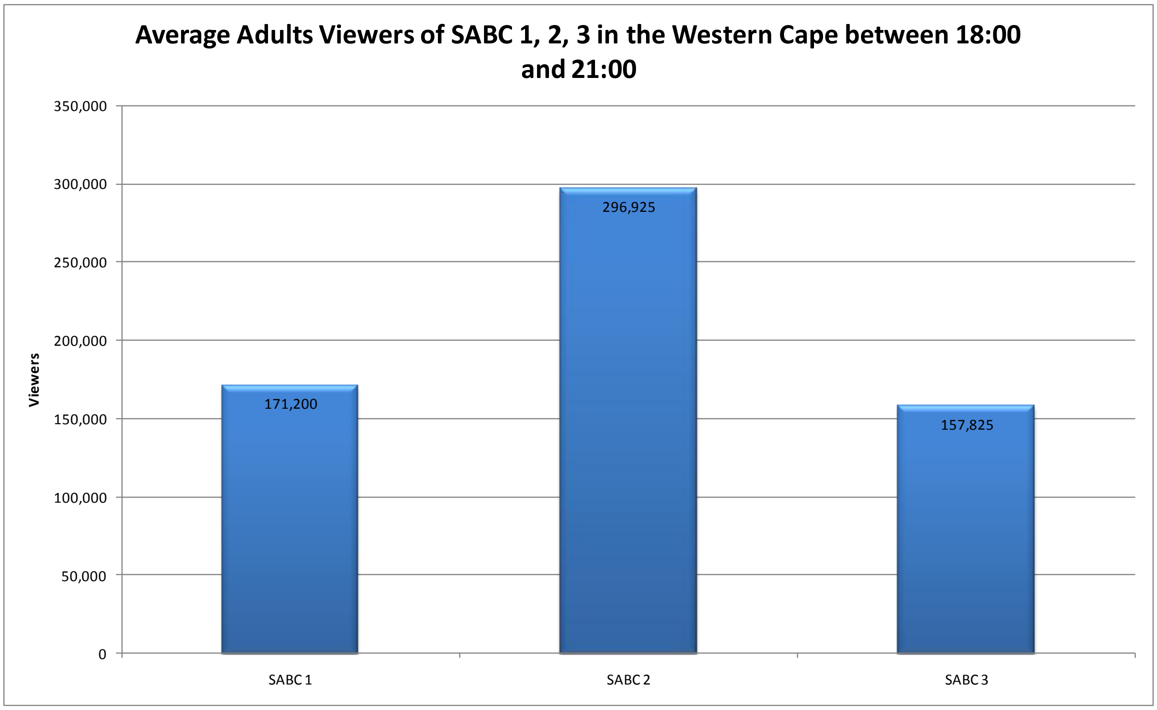


Figure 3-3: Average adult viewers in Western Cape per day between 18:00 and 21:00 per channel

Assuming that there are 1.5 adults on average per household, the number of households reached by each broadcaster can be calculated. If only 20% of these households respond to the Power Alert flightings, the impact that can be obtained is 122MW. These results are summarised in Table 3-4.

Table 3-4: Potential demand impacts in evening peak per broadcaster for various levels of residential participation in the Western Cape with an assumed average of 1.5 adult per household

	Individual and combined broadcasters			
Broadcaster	**SABC 1**	**SABC 2**	**SABC 3**	**SABC 1, 2, 3 Total**
Viewership (18:00 to 21:00)	171,200	296,925	157,825	625,950
Total households reached (1.5 adults/household)	114,133	197,950	105,217	417,300
Potential impact per household [kW]	1.47kW	1.47kW	1.47kW	1.47kW
Percentage households participating in WC	MW (SABC 1)	MW (SABC 2)	MW (SABC 3)	MW (All SABC)
10%	17	29	15	61
20%	33	58	31	**122**
30%	50	87	46	183
40%	67	116	62	245
50%	84	145	77	306
60%	100	174	93	367
70%	117	203	108	428
80%	134	232	123	489
90%	151	261	139	551
100%	167	290	154	611

The impact of 122MW could be obtained by switching certain loads off based on the status level generated and broadcasted by Power Alert. Table 3-5 provides a list of typical loads commonly found in residential households together with the status level in which they should be switched off. It was proposed that geysers are switched off only when prompted by the red status level. The reason for this was to avoid comeback loads as far as possible after the equipment was switched back on.

Table 3-5: Residential household loads as prioritised according to switching priority

Switching priority	Description	Watt Rating [W]
Yellow - 1st	Dishwasher: Heater and motor	2700
Yellow - 1st	Freezer (chest)	230
Yellow - 1st	Freezer (upright)	330
Yellow - 1st	Refrigerator with freezer	550
Yellow - 1st	Pool pump	1000
Orange - 2nd	Electric stove front large plate	2000
Orange - 2nd	Electric stove front small plate	1500
Orange - 2nd	Electric stove back large plate	1500
Orange - 2nd	Electric stove back small plate	1000
Orange - 2nd	Electric oven grill element	2200
Orange - 2nd	Electric oven bake element	1900
Orange - 2nd	Electric two plate stove (Hotplate)	2000
Orange - 2nd	Kettle	2400
Orange - 2nd	Microwave oven (Medium)	1300
Orange - 2nd	Slow cooker	250
Orange - 2nd	Air conditioner	2500
Orange - 2nd	Heater (2 bars)	1300
Orange - 2nd	Heater (3 bars)	2000
Orange - 2nd	Heater fan	2000
Orange - 2nd	Heater oil	2000
Red – 3rd	Compact disk player (CD)	10
Red – 3rd	Hi-fi with 30 watt speakers	180
Red – 3rd	Tape deck (double)	20
Red – 3rd	Computer	120
Red – 3rd	Video recorder	35
Red – 3rd	DVD player	14
Red – 3rd	Geyser	2000
Switch off all unnecessary lighting during the yellow, orange and red switching priorities	Lighting: single bulb (60w)	60
	Lighting: single bulb (100w)	100
	Lighting: ceiling fixture 3 x 60w bulb	180
	Lighting: fluorescent 2 tube (1 metre)	100
	Lighting: energy saving lamp (cfl)	20
	Lighting: energy saving lamp (cfl)	11
This equipment does not need to be switched off.	M-net decoder	28
	Radio: portable with cassette	18
	Radio: portable without cassette player	6
	Television 37 cm colour	50
	Television 51 cm colour	80
	Television 70 cm colour	100

3.4. Conclusion

A crucial aspect in the development and implementation of a residential load management system was to determine the potential for load reduction in the Western Cape residential sector during peak times. No detailed data for end-use of electricity consumption exists for the Western Cape. Existing literature and other studies was sourced and the residential electricity consumption in the Western Cape was estimated from that.

The potential of load management in the evening peak period (18:00 to 20:00) by managing the appliances most likely found in a Western Cape residence was found to be 1.466kW. To get to that figure appliances such as the geyser, heaters, stoves, pool pumps, lights, and some plug loads needed to be controlled.

This figure was extrapolated to obtain a potential impact for the Western Cape by combining it with the number of people that watches the SABC channels in the Western Cape. It was accepted that not all viewers would participate and a 20% participation rate was assumed. This brought the expected evening peak impact of load management in the residential sector in the Western Cape to 122MW. It was found viable to manage this load. The next chapter discusses the development, implementation and actual operation of the residential load management system called Power Alert.

3.5. References

1 Lane, I.E. 2005. Measurements taken for a research project. Prof. Ian Lane provided the data to the author. Many thanks.

2 Eskom. May 2006. http://www.eskom.co.za/live/loadshed.php?Item_ID=1385 Date of access: May 2007.

3 Nersa. Investigation into the electricity outages in the Western Cape for the period November 2005 to March 2006. Published Date: Unknown.

4 Anon. May 2006. Residential Load Management FAQs. http://www.eskomdsm.co.za/?q=Residential_FAQs Date of access: Sep 2008.

This chapter focuses on the development, implementation and operation of Power Alert. This includes all the processes of Power Alert, from data acquiring, data processing, forecasting, determining strain levels, right up to submitting the correct strain levels and messages to the national broadcaster in almost real-time.

CHAPTER 4

The Development, Implementation and Operation of Power Alert

CHAPTER 4 THE DEVELOPMENT, IMPLEMENTATION AND OPERATION OF POWER ALERT

4.1. Introduction

It was identified from the feasibility study that the potential of Power Alert was in the region of 122MW. These savings were expected if specific appliances could be switched off at specific times, but it should also be avoided to always ask for everything to be switched off. The required savings should therefore be a function of the strain on the electricity distribution network. I.e. if there was a high strain on the network, more appliances should be switched off. Also, if the strain on the network was low, fewer appliances could to be switched off. A requirement therefore was for an interactive link between the power supply utility and the power using public with specific messages based on the strain on the electricity distribution network.

No system existed that could provide real-time information on the strain of the electricity supply network and at the same time send a request to the 625,000 Western Cape households to switch off specific appliances at once. Power Alert was therefore developed and was in direct real-time communication with the power utility, able to interpret the data, calculate the strain on the network, forecast the strain on the network, generate a message, and communicate the correct messages in real-time to the national broadcaster for broadcasting to the Western Cape public.

This chapter focuses on the development, implementation and the actual operation of Power Alert.

4.2. Development of Power Alert

Power Alert was designed as an early warning system that tracks increasing electricity use and strain in the Western Cape. Power Alert makes use of real-time electrical load data obtained from Eskom's national control centre to identify and forecast periods when the electrical supply would be under strain. The level of strain is then communicated to the general public in an easy to understand manner on national television. Figure 4-1 shows the interactive link between the power supply utility and the power users. It is seen that when load is reduced, the utility would experience a reduction in demand and consequently an increase in available capacity. This would reduce the strain on the network. The reduction is also monitored by Power Alert. This data is processed and new messages are sent to the broadcasters to complete the interactive loop. The process is also true for load increases which would increase the strain on the network and consequent message changes.

Figure 4-2 shows the data flow from National Control (Eskom) to the Power Alert Control Centre and from there to national broadcaster. Data is obtained from Eskom and stored in a repository system within the PACC. Data could also be manually entered should data be missing from the live sources and obtained through email or other means. From here, data is subjected to data cleaning and is then stored. The stored data is used to developed load and strain forecasts and messages are generated. Both the actual load and forecasted data is visualised in the centre to ease monitoring and tracking. With the messages generated it goes through a final review, approval, and change (if necessary) stage before it is relayed to the national broadcaster.

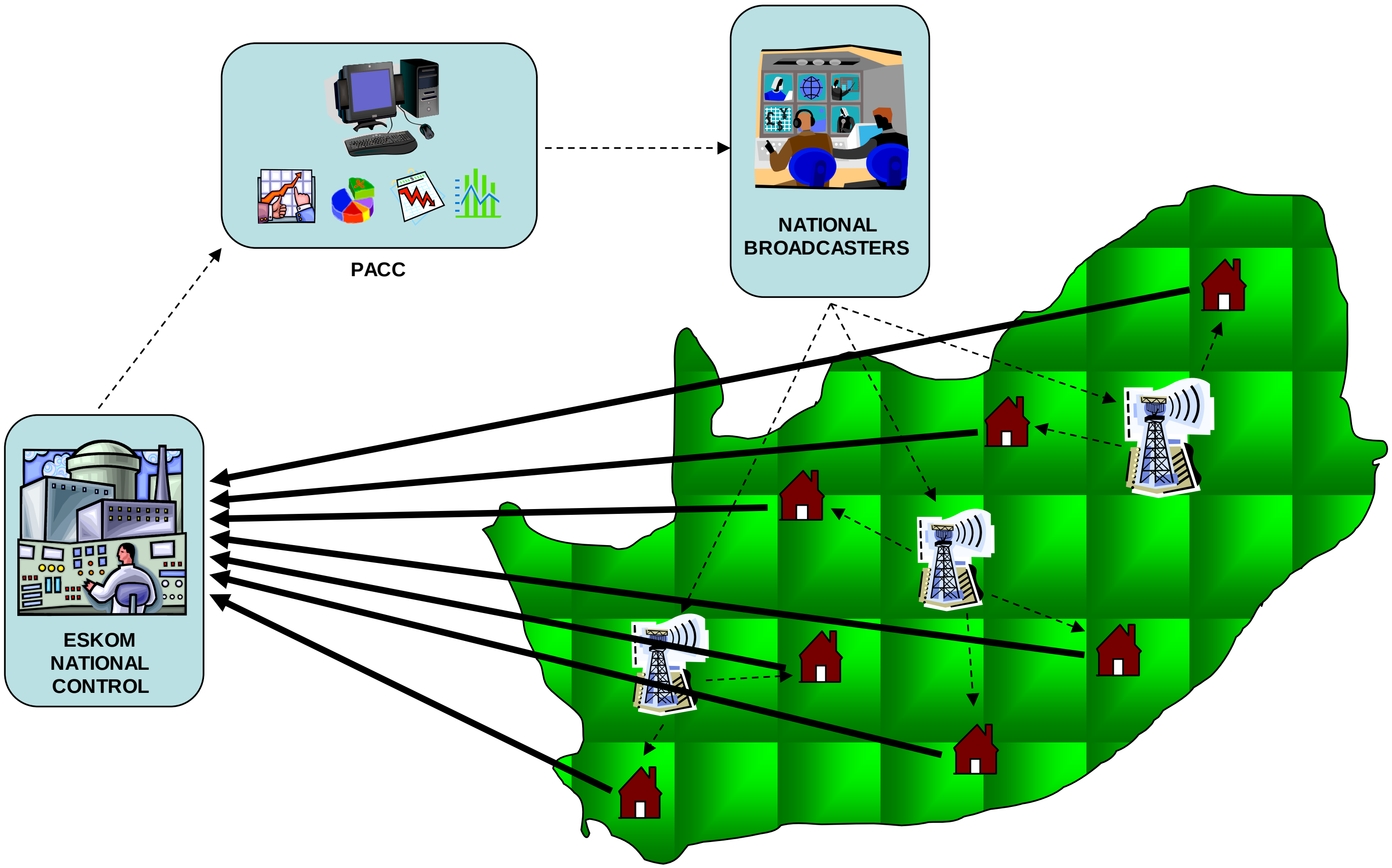


Figure 4-1: Link of Power Alert with Residents, Eskom, and the national broadcaster (National shown)

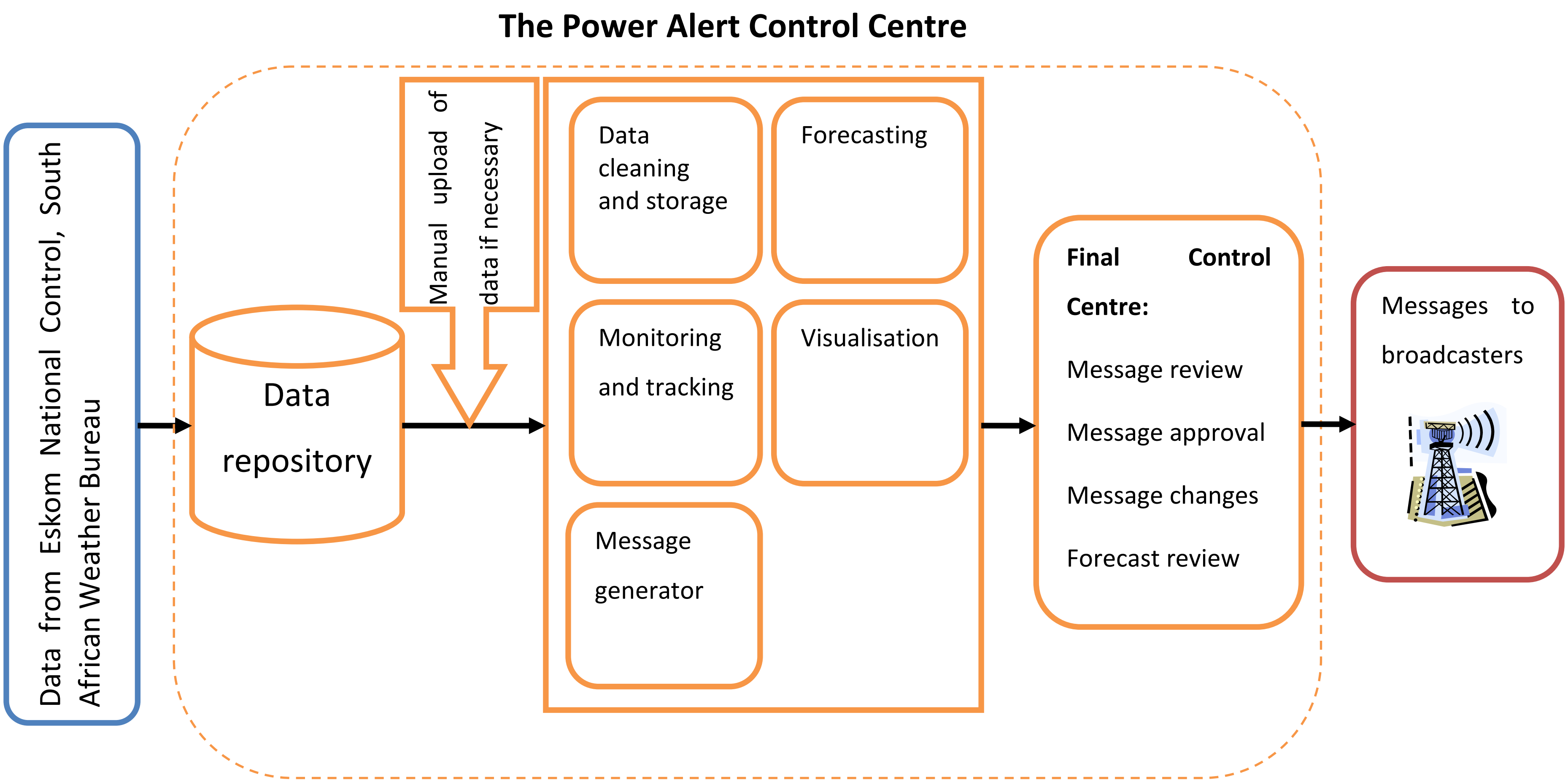


Figure 4-2: Data from National Control and Weather Bureau, analysed in the PACC, and relayed to SABC for broadcasting

4.3. Strain levels of Power Alert

The strain levels were communicated as follows:

- **Green –** Indication that there was no strain on the electrical supply of the Western Cape, demand was under control and that all generation sources were intact.
- **Orange** – Indication that there was strain on the electrical supply and/or probably due to the operating Koeberg unit being offline.
- **Red -** Indication that there was increasing strain on the electrical supply and that load shedding was imminent and/or that there was contingency on the transmission lines.
- **Brown -** Indication that there was significant strain on the electrical supply and that load shedding was in progress and that it was possible that Koeberg, as well as Palmiet, had problems with some contingencies on the transmission lines.

An additional three directions were used under each of the prior-mentioned four strain levels:

- **Up.** Indicated that the demand (and strain) was increasing.
- **Down.** Indicated that the demand (and strain) was decreasing.
- **Stable.** Indicated that the demand (and strain) was stable.

Based on the level of strain, the public was given suggestions on how they could assist to reduce the strain and thereby help prevent load shedding.

The objective of Power Alert was to achieve a reduction of 122MW when there was a high level of strain on the electricity supply network between 18:00 and 21:00 on weekdays. Power Alert signals were broadcasted on SABC 1, SABC 2, and SABC 3. Red signals were broadcasted under high-strain conditions.

Achieving the intended load reduction/response depended on the participation of the TV audience. This participation was driven by, amongst other things, the frequency of the Power Alert broadcasts, and the general levels of awareness of the public. These levels of awareness were in turn influenced by “awareness advertising” or “awareness campaigns” as well as the frequency and severity of power interruptions.

4.4. Expected Influence of Power Alert on the Western Cape Demand Profile

Figure 4-3 shows an idealistic demand profile as well as a demand profile influenced by the reaction to Power Alert.

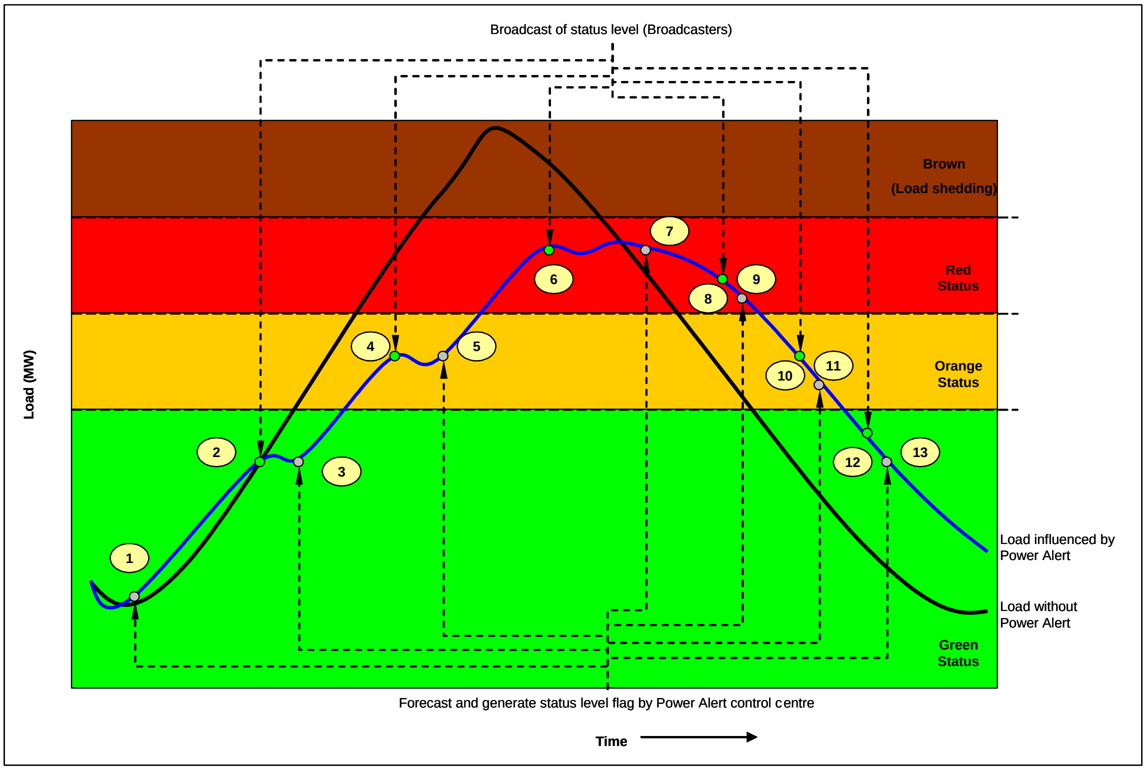


Figure 4-3: Expected demand profile due to Power Alert influences

At Point 1 Power Alert forecasts that the load will have a green status and communicate it through to the broadcaster for the timeslot before the occurrence. The broadcasters then air the green status flag at Point 2. The load is influenced, but at Point 3 Power Alert forecasts that the load will continue to increase and then it will have an orange status level. The broadcaster then air an orange status level (Point 4) which influences the load. At Point 5 the load again gradually increases and Power Alert forecast shows when the load will be in the red zone. The broadcasters then air a red status level at Point 6 on instructions from Power Alert. The forecasts (Point 7) then show that the load will be in the red zone and at Point 8 in time a red status level is again broadcasted.

The next forecast (Point 9) shows that the demand is decreasing and instructs the broadcasters to air a red flag in the next timeslot. At Point 10 the orange status level is aired. Residential consumers can then start to switch some of their loads on again. This process of relaxation continues (through Points 11 and 12) until a green status level is broadcasted and after the forecast at Point 13 indicates the fact.

4.5. Power Alert Creative Screen Layout

Figure 4-4 shows the screen layout template. All the variable fields are indicated. In this one screen residences were informed on the status of the electricity supply network in a certain area and also informed on how they could assist to alleviate any strain on the electricity supply network.

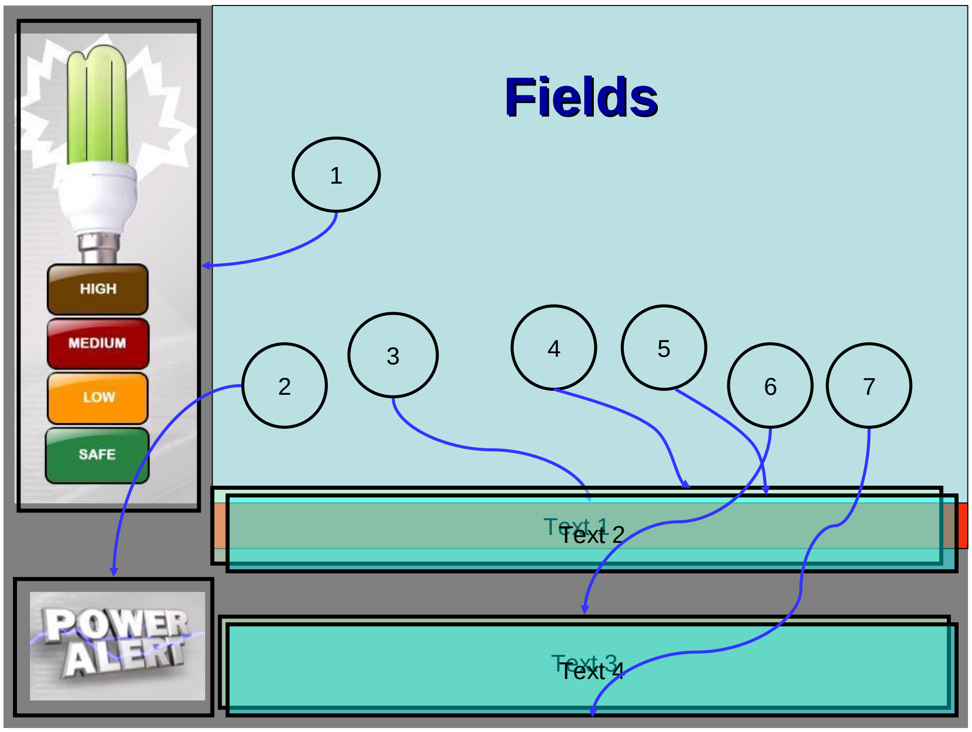


Figure 4-4: Power Alert graphics as seen on National TV and text fields

Table 4-1: Description of Fields as shown in Figure 4-4

	Activity	Description
1	State / Barometer	The state of the network. The colour (Green, Orange, Red, or Brown) as well as the direction of demand (increasing, decreasing, or stable)
2	Region	The region (Provinces as well as National) for which the Alert is given.
3	Colour bar	The colour associated with the specific strain of the network
4	Text 1	Any text that needs to be broadcasted in Text Field 1. Text in Field 1 and 2 alternate between different sets of text.
5	Text 2	Any text that needs to be broadcasted in Text Field 2.
6	Text 3	Any text that needs to be broadcasted in Text Field 3. Text in Field 3 and 4 alternate between different sets of text.
7	Text 4	Any text that needs to be broadcasted in Text Field 4.

Different messages were broadcasted when different strain levels were experienced. Combining the strain level (Brown, Red, Orange, and Green) as well as the direction (Up, Down, and Stable) resulted in a total of twelve messages that could be flighted based on the current status of the electricity supply network. Table 4-2 shows the messages that were used during Power Alert flightings.

Table 4-2: Messages broadcasted under different levels of strain

Colour & Arrow	Electricity usage	Message
Green Level – Arrow up	Electricity use in the Cape is increasing	Please switch off non-essential appliances and lights
Green Level – Arrow Down	Power use in the Cape has stabilized	Normal use of appliances can continue
Green Level – Stable	Electricity in the Cape is under control	Please use electricity wisely
Orange Level – Arrow up	Electricity use in the Cape is rising sharply	Switch off geysers, non-essential appliances and unnecessary lights
Orange Level – Arrow down	Thank you. Power use in the Cape is reducing	You may now switch on some appliances. Keep geysers, stoves and heaters off.
Orange Level – Stable	Electricity use in the Cape is stabilizing	You may switch on some lights, but please keep other appliances switched off.
Red Level – Arrow up	Power failures around the Cape are imminent	Switch off all appliances - heaters & stoves except the TV and essential lights.
Red Level – Arrow down	Power use in the Cape is stabilizing	Thank you. You may switch on some lights.
Red Level – Arrow level (stable)	Electricity use in the Cape is stabilizing	Please keep all appliances off incl. heaters & stoves, except the TV and essential lights.
Brown Level – Arrow up	Power interruptions are affecting certain areas	Help avoid more interruptions. Switch off all appliances except the TV and room light.
Brown Level – Arrow down	Power interruptions are affecting certain areas	Keep all appliances switched off.
Brown Level – Arrow level (stable)	Power interruptions are affecting certain areas	Help avoid more interruptions. Switch off all appliances except the TV and room light.

4.6. Inside the Power Alert Control Centre

The paragraphs that follow describe the operation of Power Alert during 2006. Key aspects to the operation of the centre are discussed as follows:

- Data source and requirements of the PACC (Paragraph 4.6.1).
- Data handling and predictive load modelling done by the PACC (Paragraph 4.6.2).
- Power Alert barometer level calculations and approval (Paragraph 4.7).
- Relaying the Power Alert messages to the SABC ready for broadcasting (Paragraph 4.8).

4.6.1 Data Requirements of Power Alert

The Power Alert Control Centre made use of real-time total electrical load data obtained from Eskom's National Control Centre to identify when the electrical supply was under strain. Predictive modelling was used to determine the total electrical demand for the Western Cape based on real-time data, historical data, predicted weather conditions, and available power sources.

4.6.1.1. Evening Peak Load Predictions

A crucial component for successful operation of Power Alert was to predict the load during the evening peak. These load predictions made use of various historical and current data. The data required by the control centre included the following:

- Historical energy (kW) data;
- Historical temperature (°C) data;
- Current energy (kW) data;
- Forecasted minimum and maximum temperatures (°C); and

- Supply limits (kW) and DMP (kW) availability.

Relations were developed between the historical energy and temperature data. These relations were used together with the forecasted temperatures to predict an expected profile. The expected profile was used together with the current energy data to track the current status of electricity supply to the Western Cape region. Power Alert barometer levels were generated using the current energy data, the supply limits to the region as well as available demand market participation (similar to *demand response* as referred in some countries). All data, except for the current energy data, was collected manually.

4.6.1.2. Collecting of Current Energy Data

A file transfer protocol (FTP) site in direct communication with the National Control Centre was established to gather all data required by the PACC. Data were received in 5-minute intervals for the following power sources:

- Acacia 1, 2 & 3 gas turbines;
- Palmiet 1 & 2;
- Koeberg 1 & 2;
- 3 Hydra TX-lines; and
- 1 Droërivier TX-line.

Additional data that was obtained from National Control included the supply limits on the TX-lines to the Western Cape.

4.6.2 Western Cape Demand Predictive Modelling

Figure 4-5 shows a layout of when what data was required while determining the level of the Power Alert barometer. In the following paragraphs the required data is discussed as well as how it was used during the predictive modelling phase in the PACC.

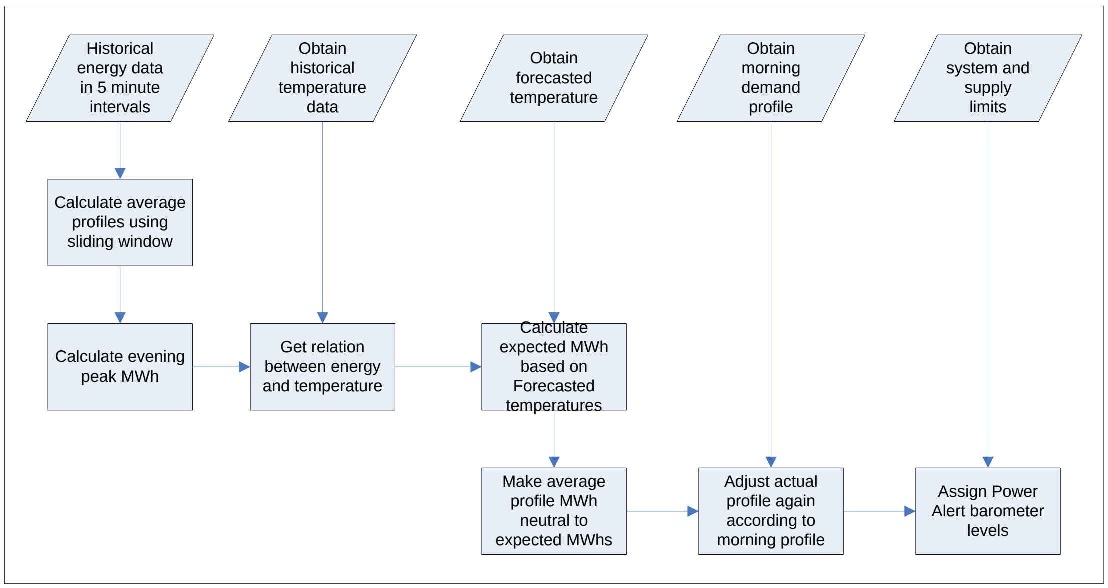


Figure 4-5: Visualisation of data flow in the PACC

4.6.2.1. Historical Energy Data for Predictive Modelling

(a) Average Profiles

Energy data of the Western Cape was obtained from National Control shortly before the start of Power Alert messages being broadcasted on television in May 2006. Any growth adjustments that might have been required from previous years were eliminated by using such recent data. The data was processed in the PACC to obtain an average profile for weekdays and weekends in 5-minute intervals. Figure 4-6 shows an example of an average weekday demand profile. This average demand profile formed the backbone of the predictive modelling component of the Power Alert Control Centre.

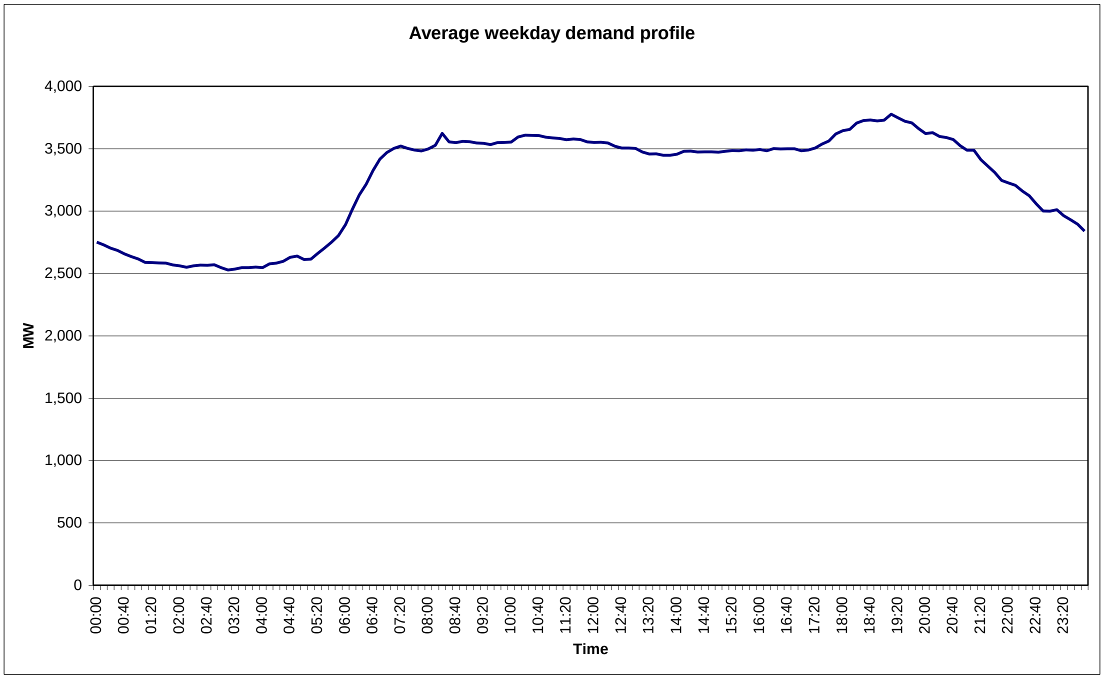


Figure 4-6: Average weekday demand profile

The average demand profile as shown in Figure 4-6 was not kept constant throughout the campaign. The average profile was recalculated daily on a rolling window principal because the demand profile of the previous day will have a greater influence on today's profile than the profile of two weeks ago would have had. The reason is mainly because human behaviour is more influenced by recent events than events in the past. Figure 4-7 shows how a rolling-window concept was followed to remove too old demand profiles from the average demand profile calculations.

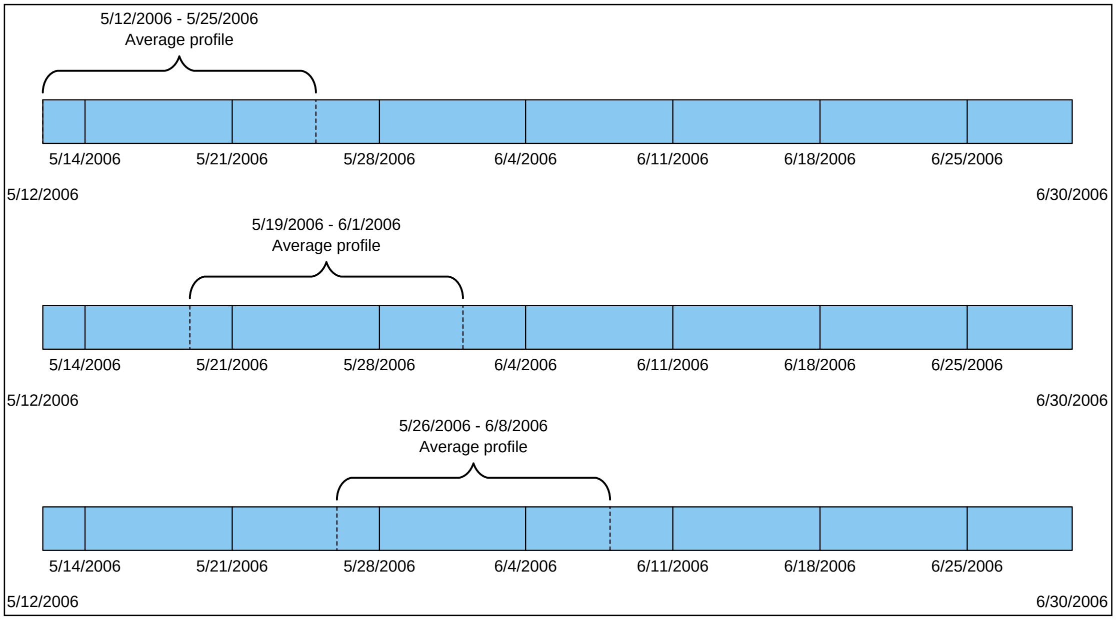


Figure 4-7: Moving timeframe to determine average weekday demand profile

(b) Relation Between Energy and Temperature

As was mentioned previously a relation was found between historical energy consumption data and historical temperature data. Figure 4-8 shows a typical relation between temperature (on the x-axis) and the evening peak energy consumption (on the y-axis).

The temperature was the average temperature recorded between 18:00 and 21:00 while the energy was the total electricity consumed (MWh) between 18:00 and 21:00. The obtained relation was then used on a daily basis to calculate the expected evening peak energy consumption for the specific day.

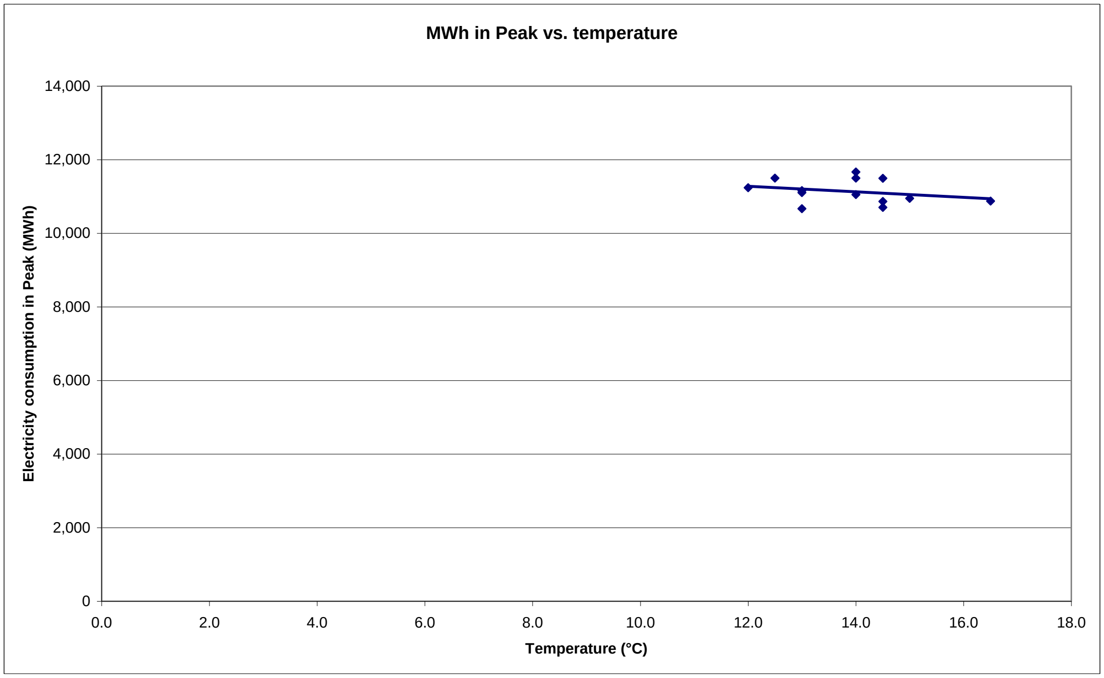


Figure 4-8: Relation between energy consumption and temperature

Based on the current forecasted temperature data the determined relation was used to calculate the expected evening peak energy consumption. The average profile as shown in Figure 4-6 was then adjusted either upwards or downwards so that the evening peak energy consumption of the average profile was exactly that of the predicted evening peak energy consumption.

4.6.2.2. Current Energy Data Used for Predictive Modelling

The second adjustment to the average profile used the morning data of the specific day for which the forecast was needed. The total energy consumption between 6:00 and 8:30 for the specific day was determined. The average profile that has been temperature adjusted was then adjusted again so that the morning energy consumption of the average profile was equal to the morning energy consumption of the actual profile.

4.6.2.3. Forecasted Minimum and Maximum Temperatures Used in Predictive Modelling

The forecasted minimum and maximum temperatures were required to temperature adjust the baseline. The data was obtained from the South African Weather Service on a daily basis.

4.6.2.4. Supply Limits and DMP Availability for Power Alert Barometer Assigning

The power station capacities and limits of the TX lines were essential to determine the bandwidths to which colour codes for the Power Alert barometer was assigned. The supply limits for all the generation sources as mentioned in Paragraph 4.6.1.2 was obtained on a daily basis from National Control.

4.7. Operation of the PACC

The strain on the electricity distribution network could change in a very short time; demand could suddenly rise or a power source could trip out. It was a requirement therefore that Power Alert could detect such changes and respond to any change in strain in a short time. As a result, the PACC operated in three modes:

- Normal operation;
- Tracking and evaluation; and
- Emergency operation.

4.7.1 Normal Operation of the PACC

Figure 4-9 shows the data flow in the PACC under normal operation conditions. Table 4-3 describes the activities shown in the figure during normal operation condition.

The flighting codes broadcasted were not based on the modelling done by the PACC operator alone. Inputs were obtained from the Network Optimisation Chief Engineer of the Western Region. The Power Alert codes had to be accepted and signed off by the engineer before it was submitted to the SABC because there could be other non-measurable influences on the strain of the network.

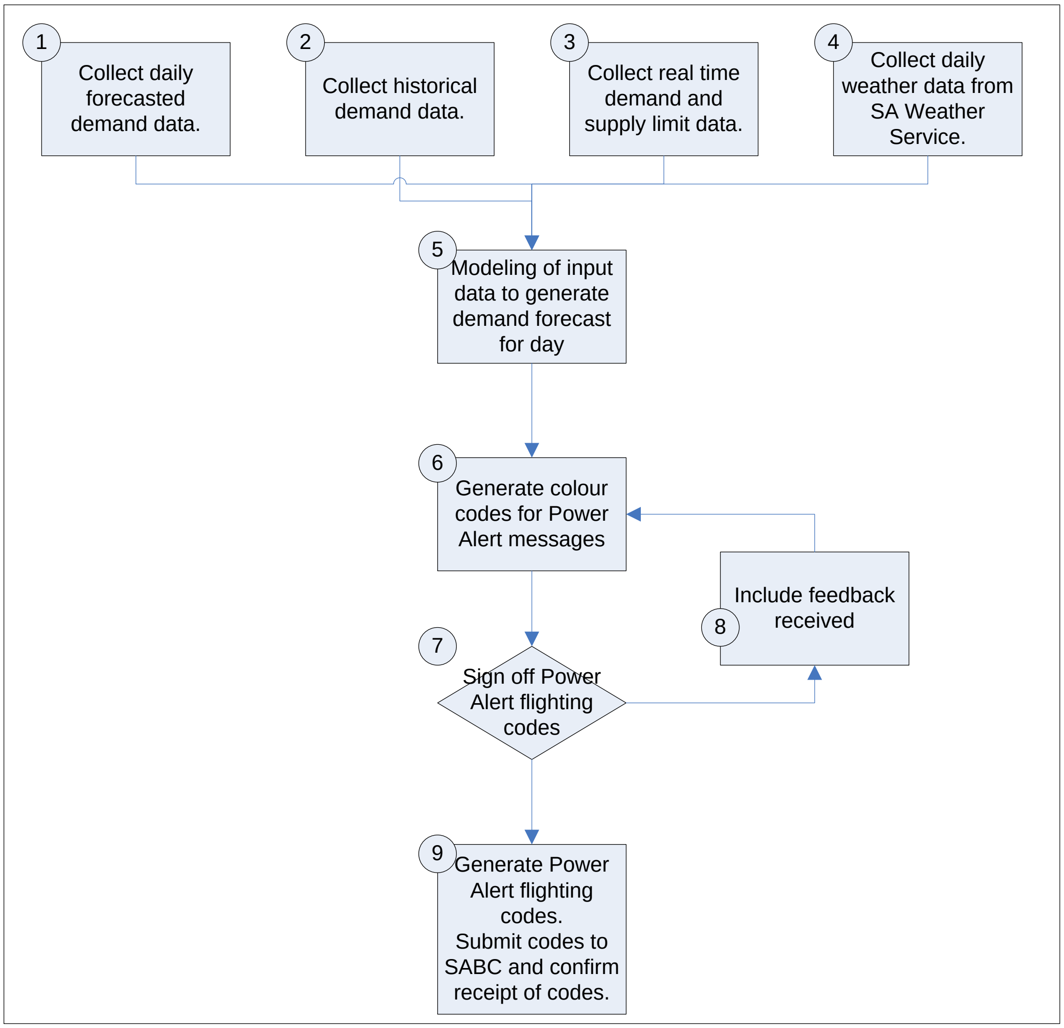


Figure 4-9: Normal operation of the PACC

Table 4-3: Description of activities during Normal Operation of the PACC

	Activity	Description
1	Collect forecasted demand data	Obtain the official Western Cape forecast from the Eskom Forecasters.
2	Collect historical demand data	Obtain historical demand data for the Western Cape to be used in modelling.
3	Collect demand data updated every 5 minutes	Obtain demand data for the Western Cape update every 5 minutes.
4	Collect weather data	Obtain the seven day forecasted minimum and maximum temperatures for Cape Town.
5	Modelling to generate forecast for the day	Use the obtained data and generate a load forecast for the Western Cape. Discussed in Paragraph 4.1.
6	Generate Power Alert colour codes	Generate Power Alert colour codes based on the two forecasts.
7	Sign off Power Alert codes	Submit the Power Alert colour codes to Bellville Regional Control Centre for acceptance and sign off.
8	Include feedback received	If codes have not been accepted, work additional information into model, re-generated codes and re-submit for acceptance and sign-off.
9	Generate flighting codes and submit to SABC, and confirm receipt.	Once the Power Alert colour codes have been accepted, generate Power Alert flighting codes, submit to the SABC and confirm receipt of the codes.

4.7.2 Tracking and Evaluation Operation of the PACC

Tracking and Evaluation (T&E) was a critical component of the PACC. The aim of the T&E component of the PACC was to monitor the real time data received, to evaluate it and to identify a problem as soon as it happens on the network. Figure 4-10 shows a typical example of the T&E facility of the PACC.

When the difference between the forecasted load and the actual load became too large, alarms were raised. The Network Optimization Chief Engineer was contacted to get confirmation if there was a problem. Once a problem was confirmed, and depending on the time of the day, either the Normal Operation Procedure would be re-done or the Emergency Operation Procedure, which is discussed in the following paragraph, would be followed so that the relevant Power Alert codes were submitted to the SABC to be broadcasted.

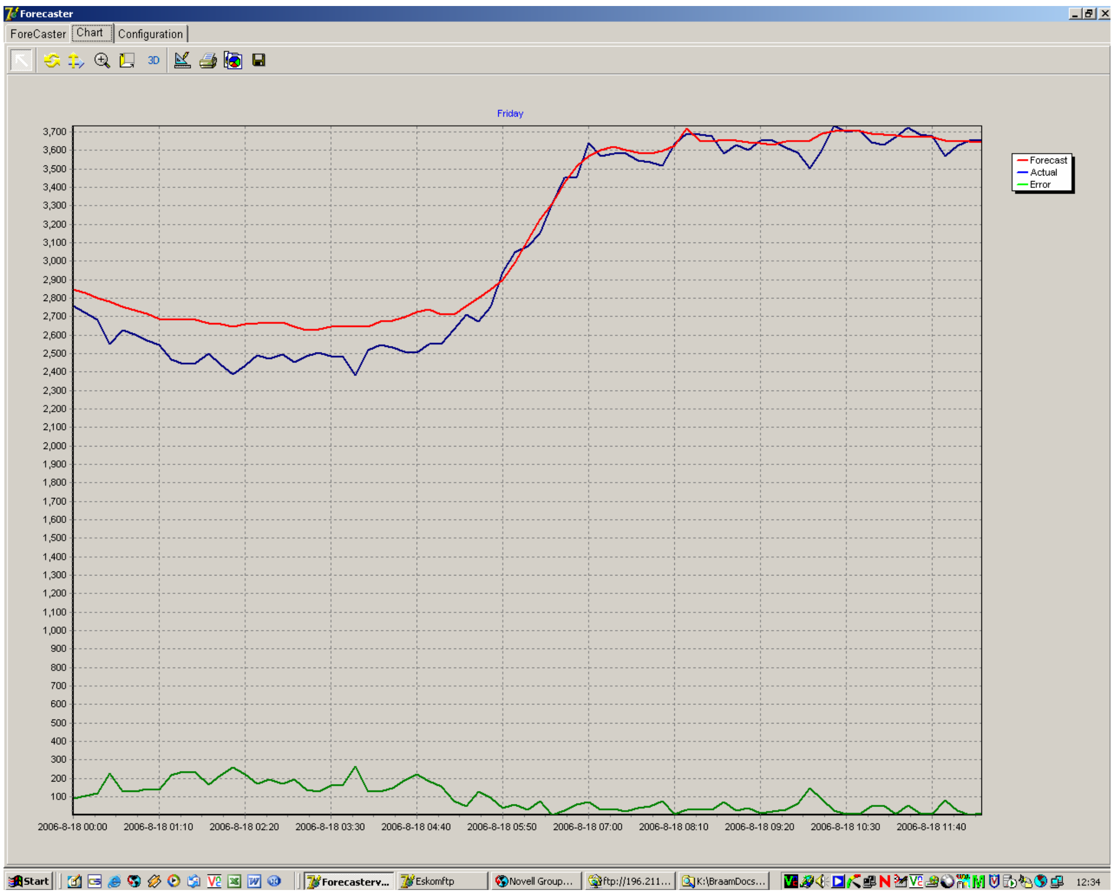


Figure 4-10: Tracking and evaluation of the Western Cape power demand

4.7.3 Emergency Operation of the PACC

The emergency procedure was followed in cases where Eskom experienced any unforeseen problems with the supply of electricity to the Western Cape and load shedding was necessary. The PACC was either informed by Eskom or it was seen from the T&E operations that there was a loss of any Power Station or TX-line. Brown up Power Alert flighting codes were broadcasted in an emergency condition by default indicating to the public that load shedding affected some regions in the Western Cape.

Figure 4-11 and Table 4-4 describes the process that was followed during emergency operation of the PACC.

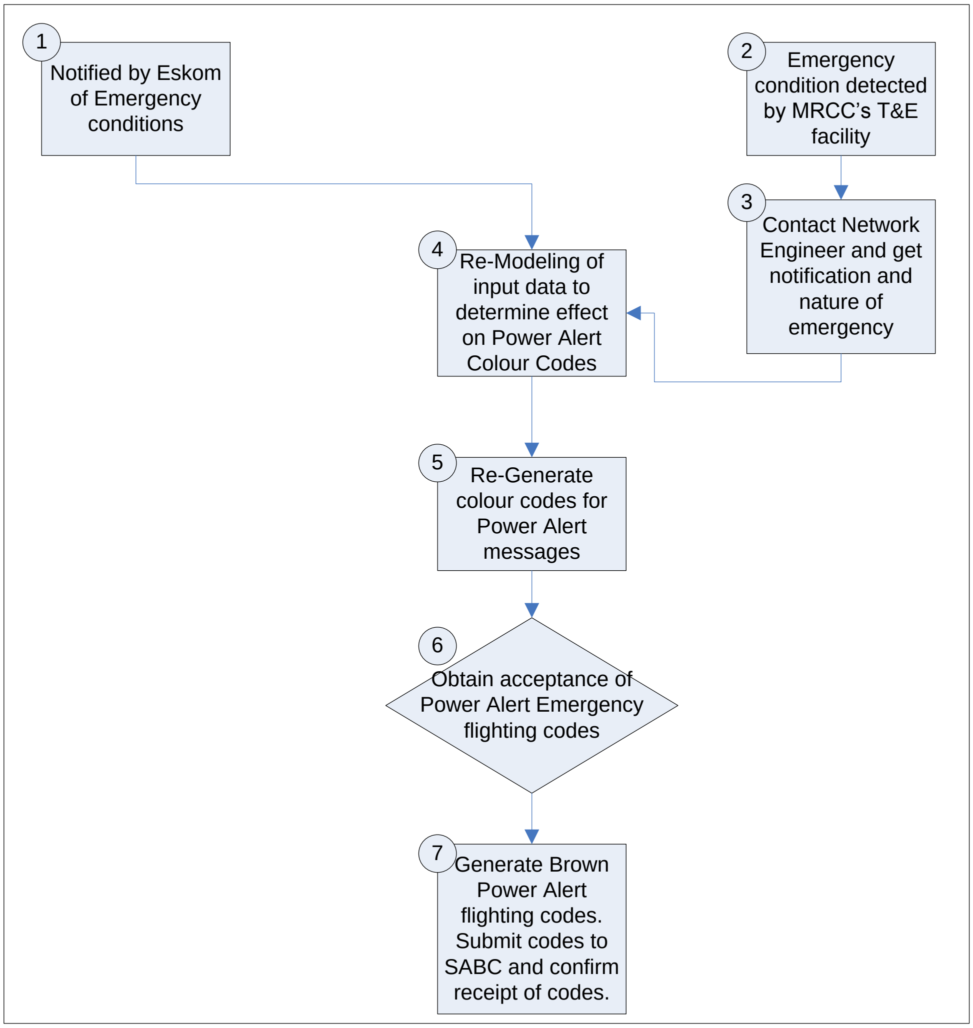


Figure 4-11: Emergency operation of the PACC

Table 4-4: Description of activities during emergency operation of the PACC

	Activity	Description
1	Notified by Eskom of emergency	An Eskom representative would contact the PACC and inform of the emergency
2	Emergency detected by PACC	The T&E facility of the PACC would detect a problem in supply
3	Contact network engineer	Personnel of the PACC would contact the Network Engineer and obtain notification and nature of emergency before proceeding
4	Re-Modelling of Power Alert codes	In the case of no load shedding the PACC remodelled the day with the new system constraints
5	Regenerate	In the case of no load shedding the Power Alert were re-generated with the new system constraints In the case of load shedding, all codes Brown Up
6	Obtain acceptance	In the case of no load shedding, submit the new codes for approval. In the case of load shedding, notify network engineer that Brown flighting codes would be broadcasted
7	Submit to SABC	Submit the new Power Alert flighting codes to the SABC

4.8. Getting the Message to the National Broadcaster, the SABC

On a daily basis the profile was forecasted and barometer values assigned in 10-minute intervals. This was preloaded in the PACC and served as the default for the day (Figure 4-12). These preloaded codes were also accepted by the network engineer on a daily basis and sent to the SABC. If no problems occurred during the day, these codes were broadcasted by the SABC.

The actual demand profile was continuously tracked by the PACC (Figure 4-10). In cases when major variations were detected, the right-leg process in Figure 4-11 was followed. Messages could then be altered in real-time and sent to the SABC via a uniform resource locater (URL) (Figure 4-13). The text fields in Figure 4-4 were then updated according to what was published on the URL of the PACC and broadcasted by the SABC. Any message could therefore be changed or removed in less than ten minutes.

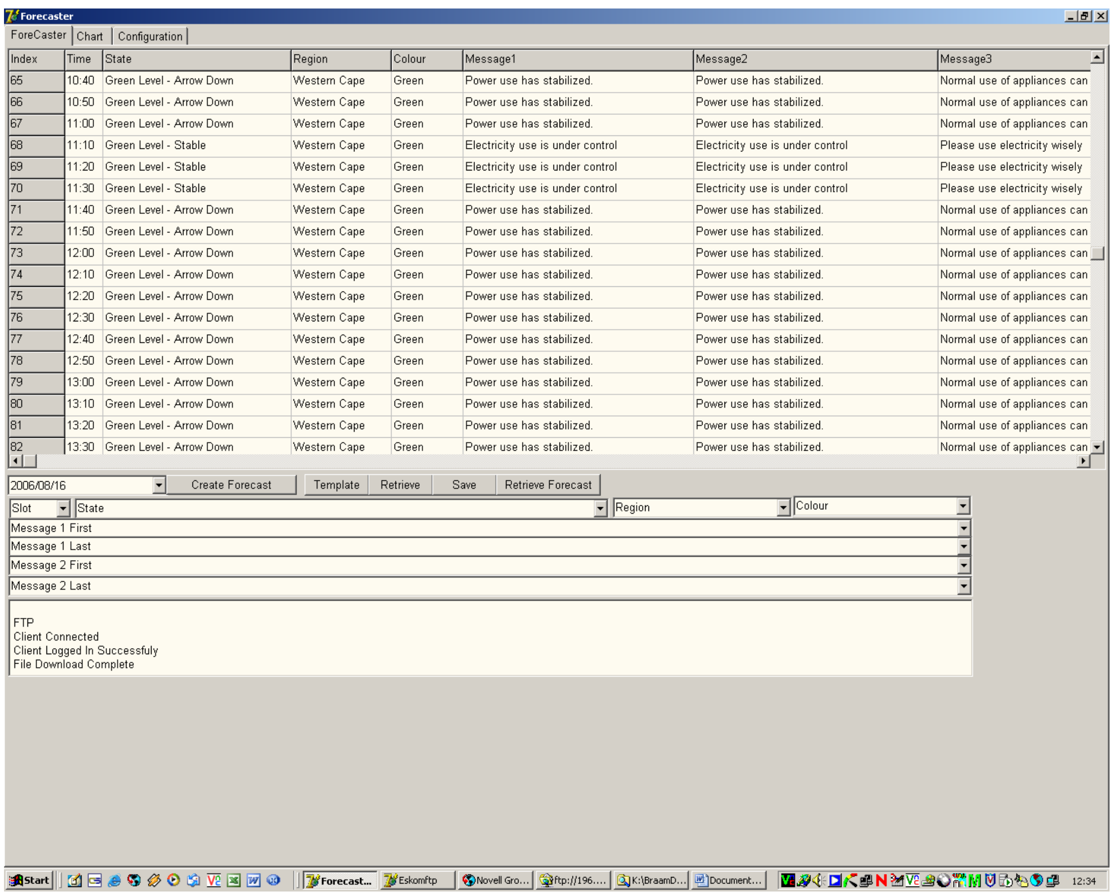


Figure 4-12: Screen capture of messages sent to the SABC in 10-minute intervals

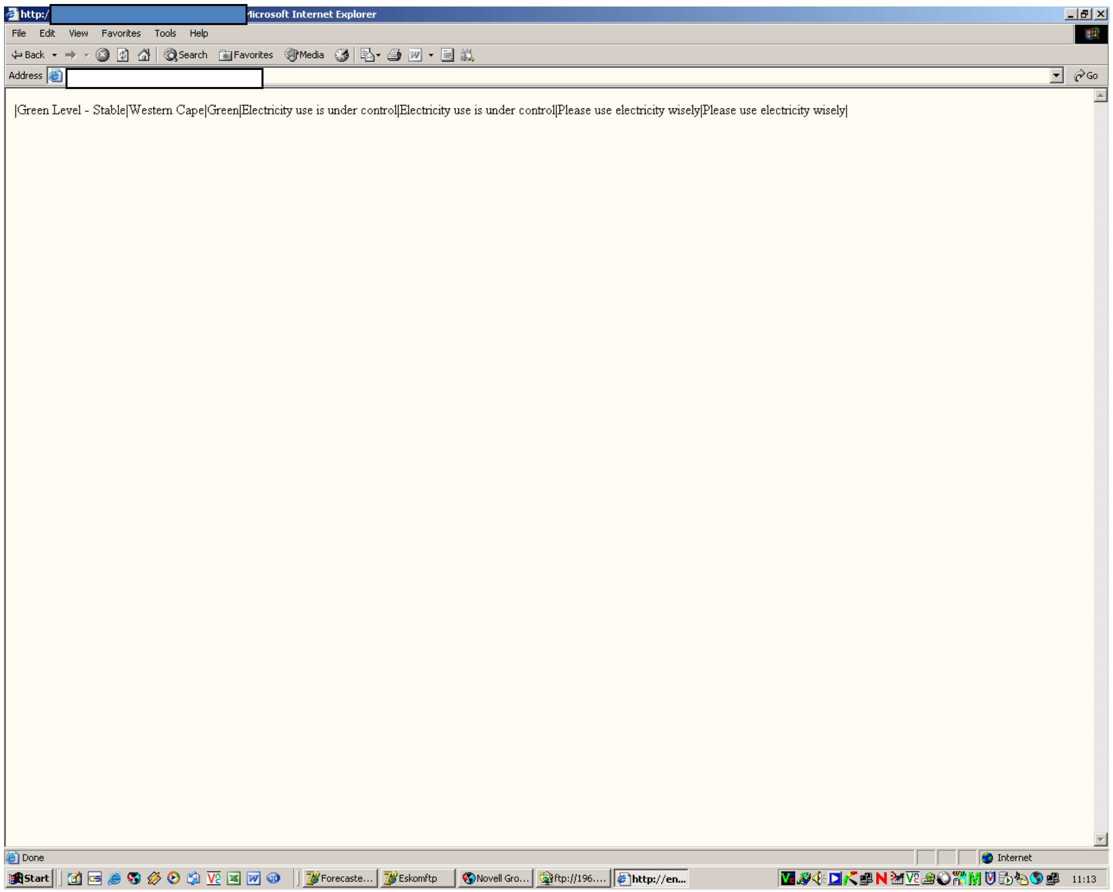


Figure 4-13: Power Alert messages as published to the SABC through an URL

The broadcaster developed an application that could interpret the information sent and using this information to broadcast the correct strain level, demand direction, as well as messages.

Figure 4-14 shows a screen capture of Power Alert flighted on National Television. The figure shows that the strain on the electricity supply network is an Orange Stable level; the area is National, and also the request to the public on how they could assist alleviating the strain on the network.

Figure 4-14: Screen capture of Power Alert flighted on National Television

4.9. Implication of this Technological Achievement

Many technological challenges had to be overcome during the establishment of Power Alert. Most of these challenges were information technology (IT) related; getting relevant data from Eskom, processing the data and publishing the final message for broadcasting to the SABC. Probably the most impressive achievement in the flow of data was establishing an IT link with the SABC.

Despite the load (MW) impacts achieved by Power Alert (discussed in Chapter 6) another major achievement was to establish a direct link between the PACC and the SABC so that Power Alert messages could be altered in 10 minute intervals. A message could be altered at any given time to any message targeted for any region in South

Africa. The altered message is available for broadcasting as soon as the time slot for that message appears. I.e. a message for 10:30 will not be broadcasted at 10:20; it will be broadcasted at the correct time. Messages could therefore be either pre-loaded at the PACC ready for publishing and broadcasting by the SABC or changed in real time.

4.10. Conclusion

In the previous chapter it was shown to be viable to implement a residential load management system – Power Alert. This chapter discussed the implementation and operation of Power Alert.

Power Alert was designed as an early warning system that tracks increasing electricity use and strain in the Western Cape. Power Alert makes use of real-time electrical load data obtained from Eskom's national control centre to identify and forecast periods when the electrical supply would be under strain. The level of strain was then communicated to the general public in an easy to understand manner on national television.

Power Alert was designed such that any message on the system could be changed within 10-minutes. This ensured that the system was so flexible that in case of a sudden loss of a generator, the public could immediately be warned that the strain on the network has changed. You could even wish the president happy birthday through Power Alert.

In the previous chapter it was mentioned that 122MW were expected from Power Alert. With the system implemented and operational it was possible to determine the impacts made due to Power Alert. The next chapter evaluates the performance in terms of load management impacts of Power Alert.

4.11. References

1 Eskom. May 2006. http://www.eskom.co.za/live/loadshed.php?Item_ID=1385 Date of access: May 2007.

CHAPTER 5

Top-Down Measurement and Verification of the Western Cape Accelerated DSM Programme

The stakeholders wanted to know whether their DSM actions had true impacts and also, how much. This is what M&V aims to do: Show how much energy has been saved.

A top-down M&V methodology was developed and followed because various DSM measures were implemented over the whole area and baselines (and data) were not available for the individual sites. Isolation of the impacts of the different measures would be impossible due to the number of projects in the Western Cape and also because some of the measures involved behaviour changes in the area which are impossible to quantify.

CHAPTER 5 TOP-DOWN MEASUREMENT AND VERIFICATION OF THE WESTERN CAPE ACCELERATED DSM PROGRAMME

5.1. Introduction

Demand-side Management broadly refers to activities and interventions implemented specifically to influence the time, pattern and amount of electricity used. The integrated recovery plan implemented in the Western Cape included various energy efficiency, load shifting, and load shedding initiatives.

The aim of energy efficiency interventions is to influence the demand profile throughout the day. Load shifting and load shedding activities aim to influence the demand profile during peak and high strain periods which normally jeopardise the security of the distribution network.

Already mentioned in Chapter 1 was a summarised plan for the accelerated Demand Side Management programme implemented in the Western Cape. Eskom identified potential areas of efficiency and peak shifting to categorise electricity users as being residential, commercial or industrial. On the industrial and commercial side efforts were focused on customer self-generation, energy efficiency, and load shedding. In the residential sector, most efforts were focused on energy efficiency such as distribution of CFLs, fuel switching as well as extensive energy efficiency campaigns. After Koeberg was returned to service and the energy crisis was temporarily veered off, the stakeholders wanted to know whether their actions had true impacts and also, how much. This is what Measurement and Verification (M&V) aims to do: Show how much energy has been saved.

The purpose of M&V was to show to stakeholders the impacts due to the DSM interventions implemented in the Western Cape. The expected short-fall was 400MW and DSM projects were implemented to avoid the short-fall and consequent load shedding. M&V aimed to show that the 400MW was indeed achieved.

A top-down M&V methodology was developed because various DSM measures, programmes, and interventions were implemented over the whole area and baselines (and data) were not available for the individual sites. Isolation of the impacts of the different measures would be impossible due to the number of projects and also because some of the measures involved behaviour changes which are impossible to quantify. Traditional M&V methodologies whereby the M&V boundaries are drawn close to the specific DSM interventions could therefore not be used.

This chapter focuses on the development of the top down M&V methodology. The methodology is applied to the case of the Western Cape and the consequent results are also presented in this chapter.

5.2. Top-down M&V methodology

Figure 5-1 illustrates in concept the developed top-down M&V methodology. The total DSM impact was determined as follows:

- Baseline models were developed for the Western Cape to predict what the electricity demand would have been without DSM. These models were developed using 2005 data, growth and temperature data.
- The total demand profile for the Western Cape was measured and is illustrated by the blue line in Figure 5-1. This was done from 1 May 2006.
- The differences between the total baseline and actual demand for the Western Cape will give the total impact of all the DSM initiatives. The impact is illustrated by the red line in Figure 5-1.

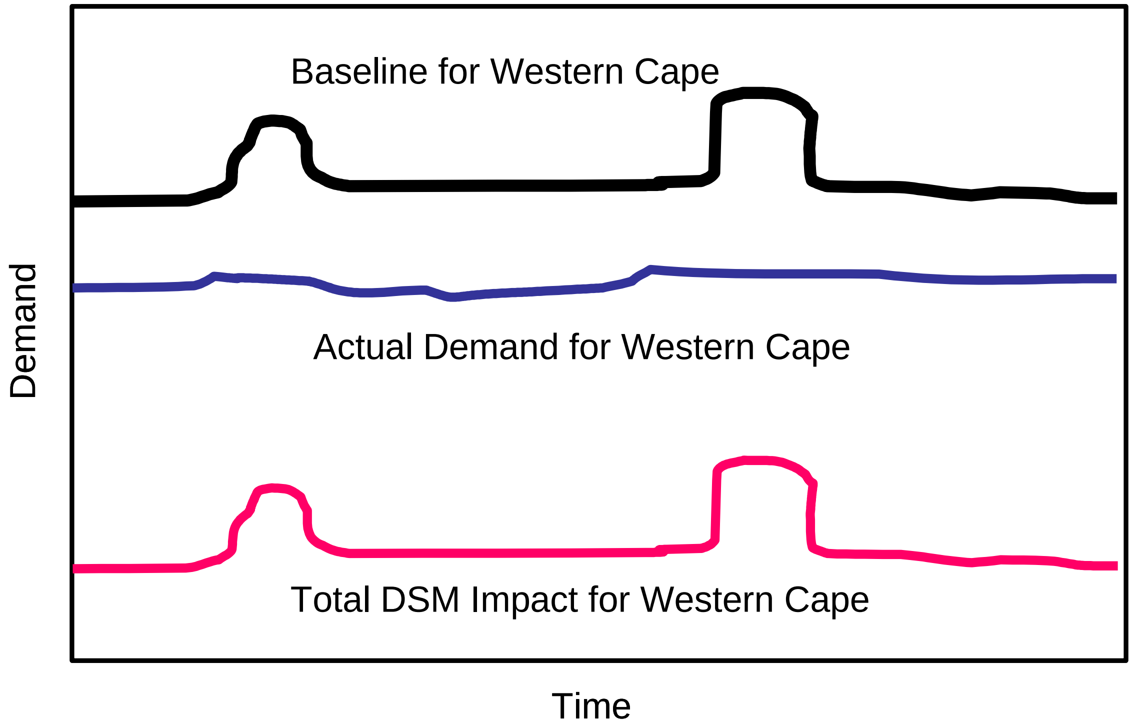


Figure 5-1: Method to determine Total DSM Impact

5.3. Baseline Development

The baseline is a prediction of what the electricity consumption would have been in the Western Cape without any DSM intervention. The baseline was used to do impact calculations according to the following formula:

Impact = Baseline – Actual ± Adjustments 5-1

The developed baseline consisted of the following components:

- Scatter plots relating electricity consumption and temperature; and
- Average Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday demand profiles.

Adjustments made to the developed baseline included the following:

- Temperature adjustments;
- Electricity sales growth;
- Demand Market Participation (DMP);
- Koeberg supply losses;
- Municipality Curtailment;
- Load shedding;
- Leased generation;
- Fuel switching; and
- NamPower power usage (Electricity exported to Namibia).

Development of the baseline is discussed in Paragraph 5.3.1 and 5.3.2. Adjustments of the baseline are discussed in Paragraph 5.4.

5.3.1 Scatter Plots

The scatter plots show relations between electrical load (MW) and ambient temperature for every 30 minutes for Weekdays, Saturdays, and Sundays. For each day type (Weekdays, Saturdays, and Sundays) there are 48 scatter plots; a total of 144 scatter plots per month.

The scatter plots were developed for each month of the period May to August using 2005 data. Figure 5-2 shows a typical scatter plot of an average weekday at a specific time stamp. For the M&V campaign between May and August a total of 576 scatter plots were developed.

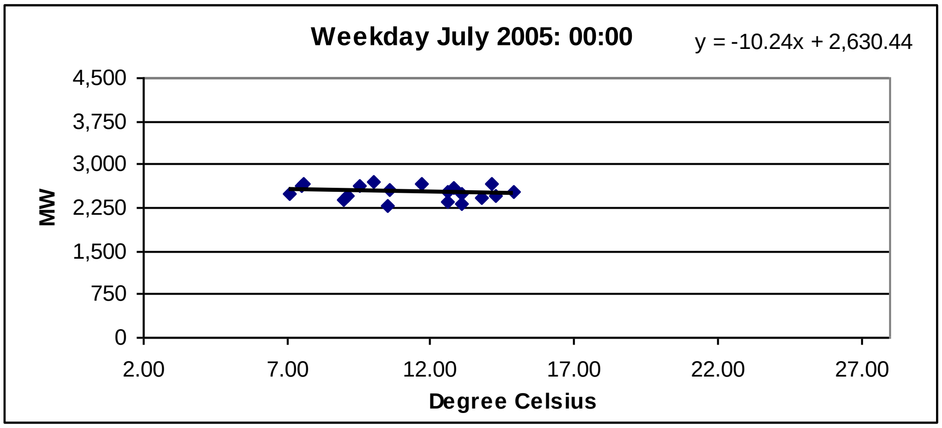


Figure 5-2: Scatter plot for an average weekday at 00:00

Linear relations were calculated between load (MW) and temperature from the scatter plots. From these relations the M_{value} (the slope) were obtained. The M_{value} shows the relation between energy and temperature for that 30-minue interval. It is also an indication of how temperature sensitive the energy consumption during a 30-minute period is. Hourly temperature data of Cape Town weather station was obtained from the South African Weather Service (WeatherSA). Ten minutely energy data was obtained from Bellville control centre. The data received contained the following:

- Palmiet unit 1 and 2;
- Koeberg unit 1 and 2;
- Droërivier Hydra line 1, 2 and 3;
- Aries Kronos line; and
- Acacia Power Station Generator 1, 2 and 3.

5.3.2 Average Profiles

Average Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday 30-minute demand profiles were developed from 2005 data. These profiles were developed relating to the average temperature measured during the specific month. Figure 5-3 shows a demand profile of an average Monday in July.

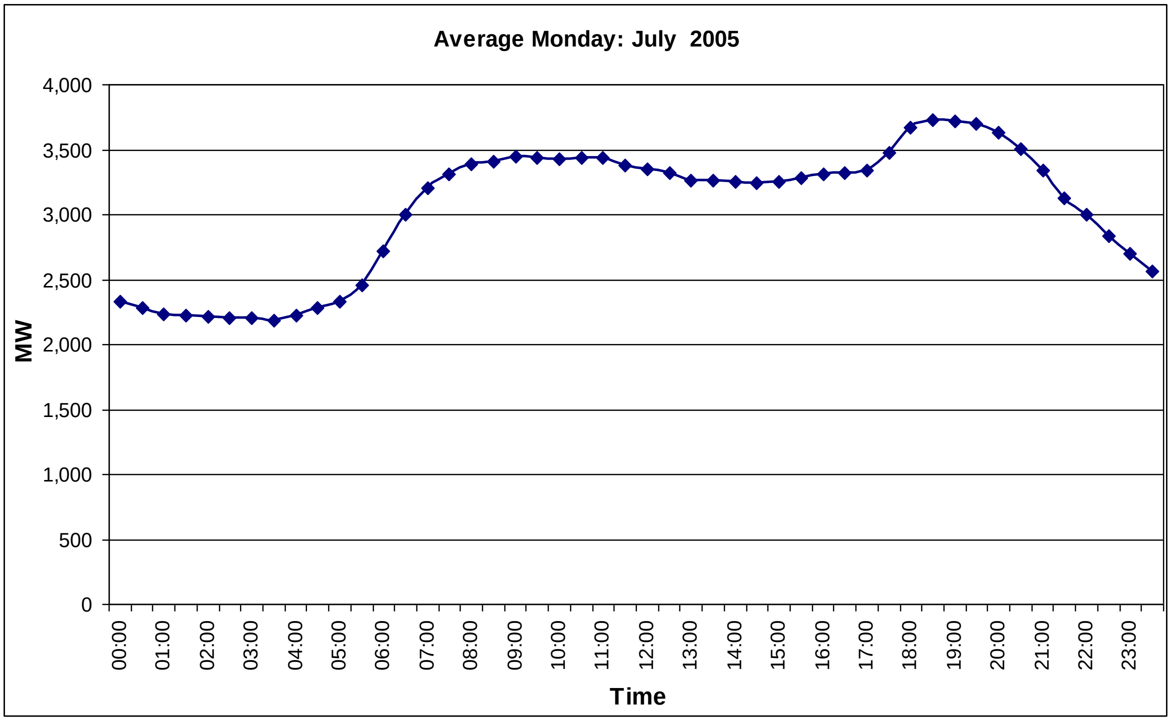


Figure 5-3: Demand profile of an average Monday in July 2005

5.4. Baseline Adjustments

A baseline is broadly a prediction of what the electricity consumption would have been without DSM under the same conditions. Baseline adjustments are needed to adjust the baseline electricity consumption using the same conditions as experienced during the time the impacts were made.

5.4.1 Temperature Adjustments

Since the temperature and growth differs from year to year, the baselines had to be adjusted to reflect an accurate approximation of the expected demand for 2006. This adjustment was done through the M_{value}. The M_{value} was calculated from the scatter plots for every 30-minute period of a specific month for Weekdays, Saturdays, and Sundays.

The actual temperatures of July 2006 were retrieved from WeatherSA and the average temperature for that specific day type (Monday, Tuesday, Wednesday, etc) was calculated from July 2005 data. Having these values the Delta Temperature between the actual 2006 measured value and the average temperature value for that specific day type was calculated. The temperature differences between 2005 and 2006 were then related to an increase in demand (MW) by using the established M_{value}. Equation 5-2 was used to do this adjustment.

$$Delta_{MW} = (M_{value}) \times Delta_T \qquad 5\text{-}2$$

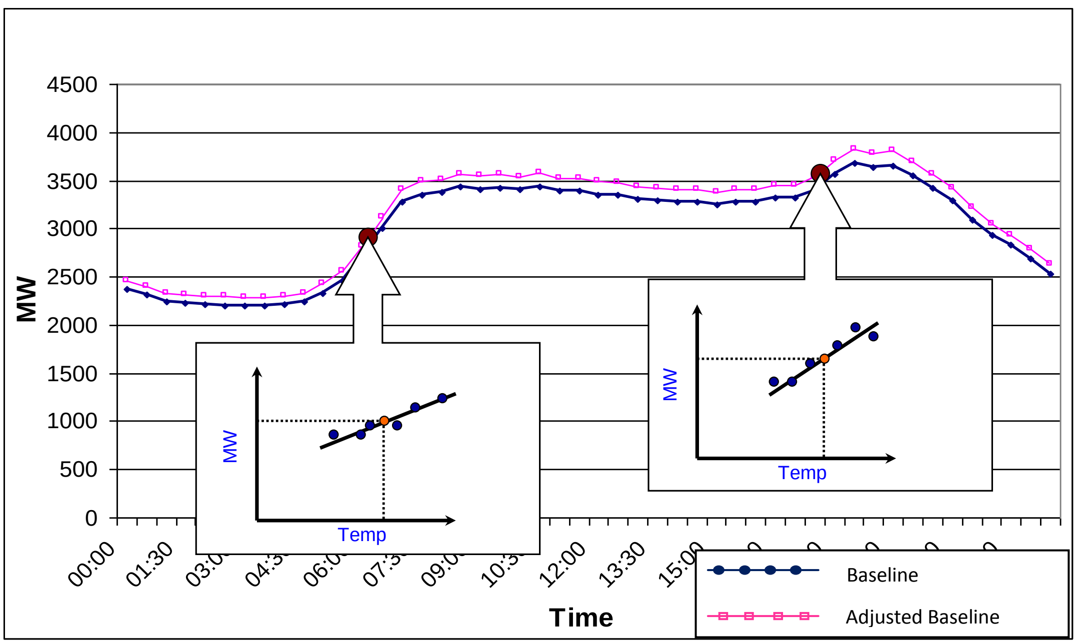


Figure 5-4: Baseline temperature adjustment using the scatter plots

This increase (or decrease) in demand was finally taken into account to adjust the average profiles developed from 2005 data to produce a temperature adjusted baseline as shown in Figure 5-4.

Table 5-1 gives the average weekday temperature differences between the different months for May to August for 2005 and 2006. The top part of Table 5-1 shows the difference in each month between 2005 and 2006. In May 2006 it was, on average, 0.46 °C colder than May 2005. This resulted in an average weekday increase of 0.71MW on the baseline as can be seen in the middle part of Table 5-1. June 2006 was, on average, 1.86 °C warmer than June 2005 and therefore, on average, 44.29MW was subtracted from the baseline.

The bottom part of Table 5-1 indicates the difference in temperature between the individual months within a certain year. When comparing June 2005 and May 2005 it was observed that, on average, June was 2.58 °C colder than May.

Table 5-1: Average weekday temperature adjustments

May	T (˚C)	June	T (˚C)	July	T (˚C)	Aug	T (˚C)
2005	14.53	2005	11.96	2005	13.38	**2005**	11.51
2006	14.07	2006	13.81	2006	12.55	**2006**	12.96
Temp Diff	-0.46	***Temp Diff***	1.86	***Temp Diff***	-0.84	***Temp Diff***	1.45
Baseline	0.71	***Baseline***	-44.29	***Baseline***	17.23	***Baseline***	-15.88
Adjustment	(MW)	***Adjustment***	(MW)	***Adjustment***	(MW)	***Adjustment***	(MW)
Temp Diff 2005 (˚C)				**Temp Diff 2006 (˚C)**			
June - May	-2.58			June - May	-0.26		
July - June	1.43			July - June	-1.27		
Aug - July	-1.87			Aug - July	0.41		

5.4.2 Electricity Sales Growth

Figure 5-5 shows the growth adjusted baseline. According to the sales data of Table 5-2 there was a year to year sales growth in May of 4.6 %. The growth percentage for each month was also fixed on 4.6 % for the June to August baselines. In May there was already some DSM projects operating and it was assumed that the new connections in May would be the same for June to July. 4.6 % might be a conservative growth figure to use since the figure takes into consideration new connections (increases in electricity consumption) as well as energy efficiency (decreases in energy consumption).

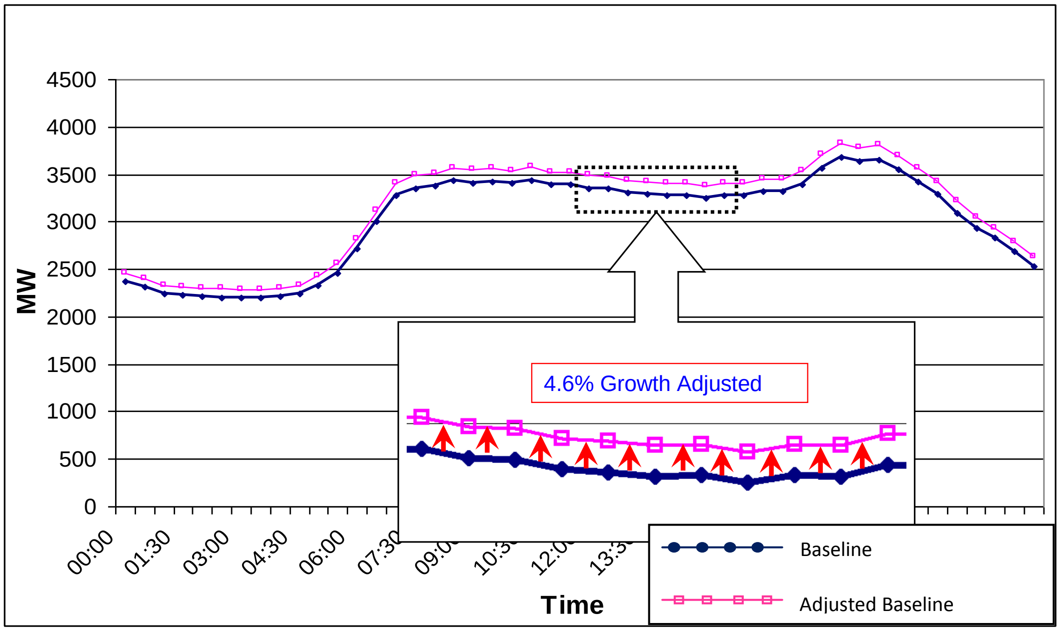


Figure 5-5: Growth adjusted baseline

Table 5-2: Monthly electricity sales

Total Tariffs				
		SACS July Projections 2006	CM Actual 2005	Percentage Growth
March	SAP Total Consumption (kWh)	1,581,570,943	1,554,331,331	1.72%
April	SAP Total Consumption (kWh)	1,573,638,000	1,507,907,539	4.18%
May	SAP Total Consumption (kWh)	1,626,755,083	1,551,860,277	4.60%
June	SAP Total Consumption (kWh)	1,583,049,854	1,599,282,312	-1.03%
July	SAP Total Consumption (kWh)	1,650,259,074	1,577,406,623	4.41%

Table 5-3 gives the average weekday baseline growth adjustment of each month for May to August.

Table 5-3: May to August baseline growth contribution

May	June	July	Aug
MW	*MW*	*MW*	*MW*
133.78	141.73	140.93	146.69

5.4.3 Demand Market Participation

Called and Billed DMP data was obtained by the M&V team. Called DMP data included requests from Eskom to a client to reduce load. It does not mean that the client actually reduced the load by the requested MW or for the requested time. Billed DMP data includes data that was used to bill the clients for their actual load reduction.

5.4.4 Supply Losses With One Koeberg Operating

Eskom indicated that there were more supply losses with one Koeberg unit operating instead of two Koeberg units. According to Eskom personnel the supply losses with one unit running is 100MW. These losses were taken into account by adjusting the baseline. The Western Cape should have saved 100MW for those losses to be overcome.

5.4.5 Municipality Curtailing

According to the Eskom, Western Cape Recovery plan distributors were allocated monthly demand limits which were proportional to their energy consumption, recorded in the corresponding period in 2005. Monthly demand limits were adjusted for:

- Load growth;
- System losses;
- Safety margins; and
- Critical/strategic loads.

When the demand limits were about to be exceeded the municipality was responsible to employ measures to prevent the limits being exceeded. As a very last resort, the municipality did load shedding which is referred to municipal curtailing. During the period May to August 2006 only two Municipality curtailing events took place. The load shed by the municipality is given in Table 5-4.

Table 5-4: Municipality curtailing events

Date	Curtailed	Municipality
8 June	54MW	Not specified
22 June	81MW	City of Cape Town, Drakenstein, Breederivier, George

5.4.6 Load Shedding

The proposed mitigating actions of the Eskom Western Cape recovery plan were intended to minimize the impact on customers. The benefits of those mitigating actions did not totally alleviate the requirement for load shedding. Principles to manage planned and emergency load shedding was agreed on by key stakeholders. The extent of load shedding required depended on the power supply levels as well as the forecasted level of demand and any unexpected increases in demand for electricity. Table 5-5 shows the load shedding events that took place between May and August 2006.

Table 5-5: May to August load shedding events

Date	Start Time	End Time	Load Shed		Reason
22-May	17:52	19:26	100.5	MW	Demand to high
01-Jun	18:31	18:44	54	MW	Petro SA could not sync with network
08-Jun	18:00	18:41	422	MW	Koeberg tripped
09-Jun	06:58	17:48	1585	MW	Koeberg tripped
22-Jun	09:15	12:22	312	MW	TX-line tripped

5.4.7 Leased Generation

Various generation sources are owned and managed by the City of Cape Town. These sources were also included in the baseline adjustments. The generators included the following:

- PetroSA;
- Roggerbaai;
- Steenbras; and
- Acacia Power Station (APS).

5.4.8 Fuel Switching

Fuel switching refers to the DSM activity of being able to use other sources of energy rather than electricity for processes where energy is required. An example is to use coal in a coal fired boiler to generate steam rather than electricity in an electrical boiler. The only fuel switching contributor was EB Steam. Exactly what they did to participate as a fuel switching participant was not made known.

5.4.9 NamPower

The electricity exported to Namibia in 2005 was used to form an average weekday baseline for each of the four months. The impact of 2006 compared to the NamPower baseline was taken into account for this baseline adjustment.

It was observed that for the periods 1 to 10 June, 10 to 14 July and 19 and 21 July 2006, NamPower was importing much less from Eskom compared to what was imported in 2005. Figure 5-6 shows the average electricity imported by NamPower for July 2005 and 2006. It was seen that they did import less electricity when requested to do so.

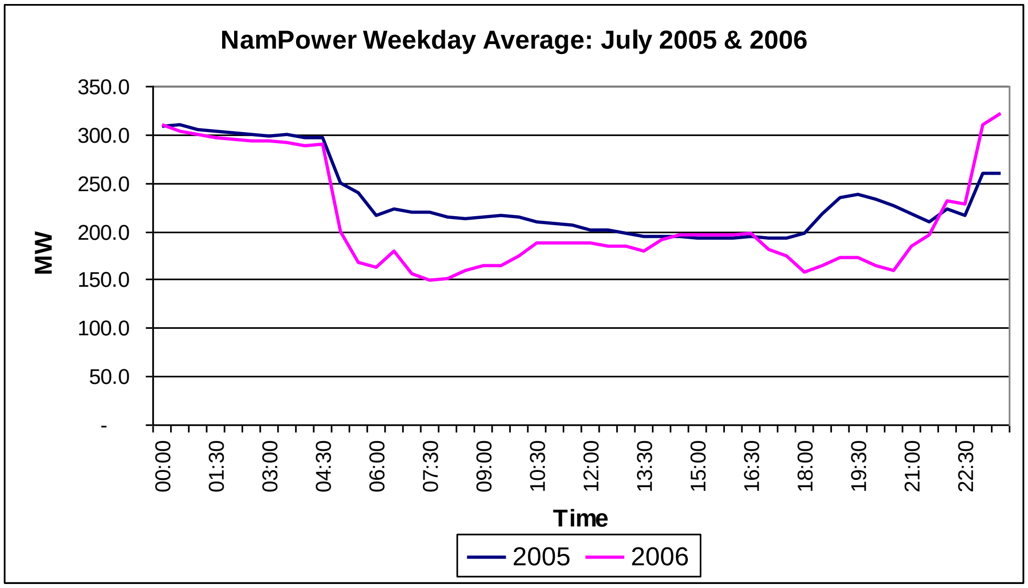


Figure 5-6: July 2005 & 2006 NamPower Weekday Average

5.5. Adjusted Baseline

All the adjustments discussed in the previous paragraphs were taken into account to obtain the final baseline. Figure 5-7 shows the final baseline for June 2006 as well as all the different components used in the baseline adjustment.

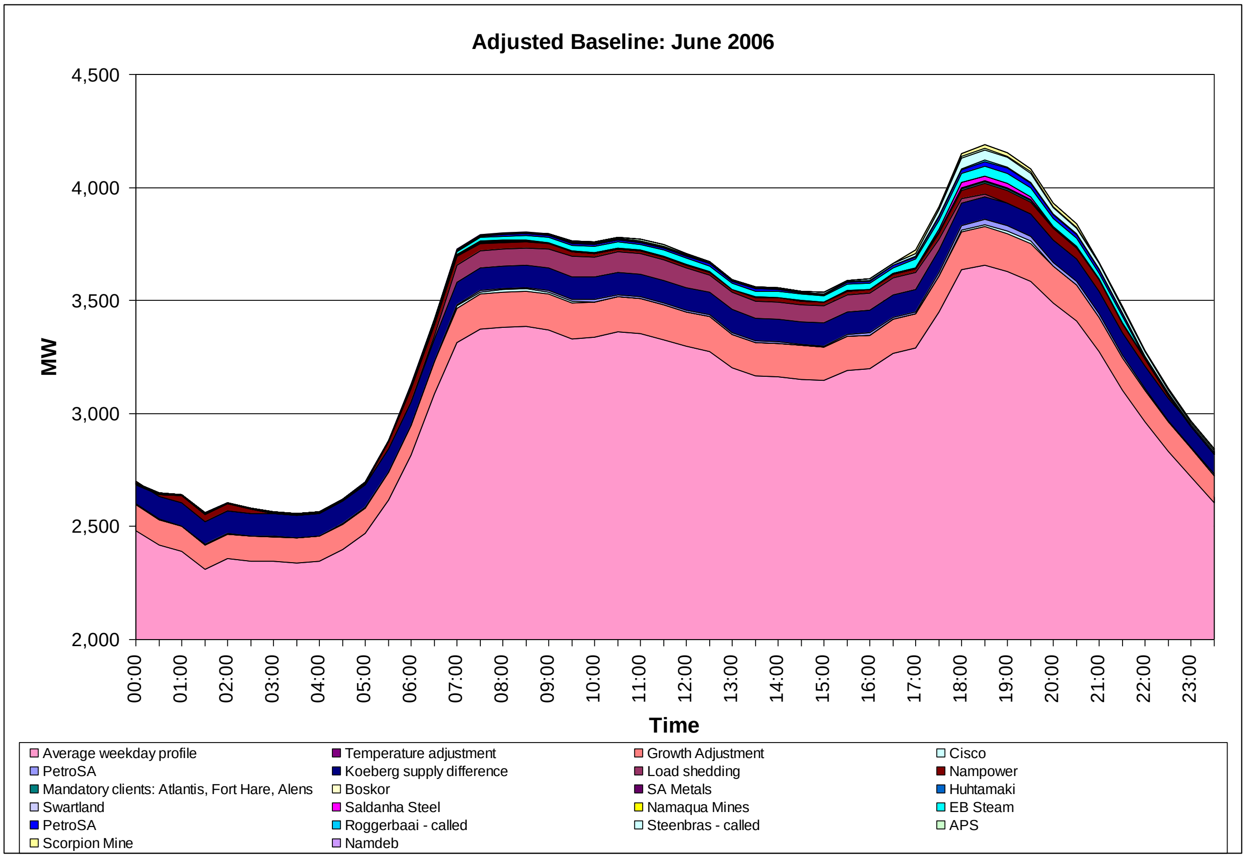


Figure 5-7: The adjusted baseline of June 2006

5.6. Baseline Verification

The developed baselines were calibrated according to the international performance measurement and verification protocol (IPMVP) [1, 2]. Firstly the mean bias error (MBE) was calculated by subtracting the actual half hourly data of July 2005 from the adjusted baseline. The differences are summed and divided with the sum of the actual values of the whole month. The MBE is expressed as:

$$MBE(\%) = \frac{\sum_{month}(S - M)_{30\min}}{\sum_{month} M_{30\min}} \times 100 \tag{6-3}$$

S indicates the kWh baseline and M the actual measured kWh values.

The MBE indicates how well the demand profile is predicted by the baseline when compared by actual data. It is subjected to cancellation errors, where the combination of positive and negative values for (Baseline - Actual) serves to reduce MBE. To account for cancellation errors, the CV(RMSE) was also needed.

$$RMSE_{month} \sqrt{\frac{\sum_{month}(S - M)^2_{30\min}}{N_{30\min}}} \times 100 \tag{6-4}$$

$$CV(RMSE_{month}) = \frac{RMSE_{month}}{Average_{month}} \times 100 \tag{6-5}$$

The CV(RMSE) is a normalized measure of variability between two sets of data. For calibrated simulation purposes, it is obtained by squaring the difference between paired hourly data points, summing the squared differences over the month, and then dividing by the number of points, which yields the mean squared error.

The square root of this quantity yields the root mean squared error. The CV(RMSE) is obtained by dividing the RMSE by the mean of the measured data for the month. The combination of MBE and CV(RMSE) represents how well a model fits the data: the closer to zero, the better the calibration.

The baselines were verified by the using the actual demand and temperature values of the relevant month in 2005 to test the baselines developed from the same data. Each of the three different baselines (Weekday, Saturday, and Sunday) was verified and the calibrated values of each month are given in the Table 5-6.

Table 5-6: Baseline Verification

Month	Index	Acceptable tolerances for data calibration	Calculated Baselines					
			Weekdays	Calibrated	Saturdays	Calibrated	Sundays	Calibrated
May	MBE	+/- 10%	4.74%	Yes	0.21%	Yes	-3.59%	Yes
	CV(RMSE)	+/- 25%	3.48%	Yes	4.10%	Yes	7.54%	Yes
June	MBE	+/- 10%	-0.05%	Yes	0.00%	Yes	0.00%	Yes
	CV(RMSE)	+/- 25%	3.59%	Yes	2.40%	Yes	2.45%	Yes
July	MBE	+/- 10%	-0.12%	Yes	-0.56%	Yes	-0.15%	Yes
	CV(RMSE)	+/- 25%	2.27%	Yes	2.48%	Yes	2.77%	Yes
Aug	MBE	+/- 10%	0.00%	Yes	0.00%	Yes	0.00%	Yes
	CV(RMSE)	+/- 25%	2.44%	Yes	2.16%	Yes	2.21%	Yes

5.7. Monthly Impacts

The average monthly impacts achieved during weekdays were calculated by using the adjusted baselines. Paragraphs 5.7.1 to 5.7.4 summarise the achieved impacts of each of the months May to August respectively. Table 5-7 to Table 5-10 show the following components averaged over the time-of-use periods:

- **Total Impact**: Adjusted baseline – actual. This impact includes all measures such as self generation, leased in generation, DMP, and DSM.
- **DSM impact:** This represents the total impact of all the DSM projects implemented in the Western Cape. The DSM impact was calculated by subtracting the average actual weekday demand from the temperature and growth adjusted baseline. Koeberg and NamPower (since the net import was important) were added to DSM impacts.

Each of the monthly impacts was also graphically represented by two different graphs. The first gives the weekday average baseline together with the actual demand of the month. The second illustrates the average weekday total impact and the total average weekday DSM impact of the Western Cape.

5.7.1 May Impact

Figure 5-8 shows the average weekday demand of May as well as the developed baseline.

Table 5-7 shows the total and DSM impacts in the different TOU periods. The total average weekday evening impact achieved in May was 370MW. DSM contributed 317MW to the total impact. Figure 5-9 shows the average total and DSM impact achieved in May.

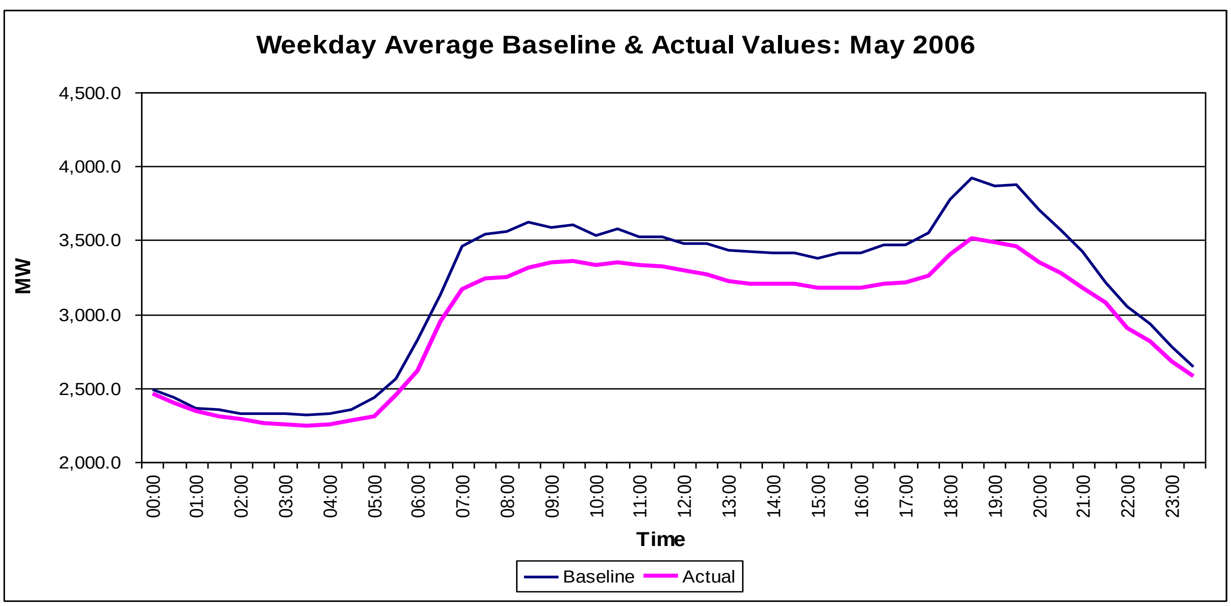


Figure 5-8: Baseline and actual demand of May 2006

Table 5-7: May weekday time-of-use impacts

Weekdays TOU Impacts: May 2006	Morning OffPeak	Morning Standard	Morning Peak	Midday Standard	Evening Peak	Evening Standard	Evening OffPeak
	00:00-06:00	06:00-07:00	07:00-10:00	10:00-18:00	18:00-21:00	21:00-22:00	22:00-00:00
Average WD Total Impact	62.04	198.38	281.07	221.50	370.14	189.04	108.17
Average WD DSM Impact	58.97	188.14	236.43	215.20	317.27	185.25	105.11

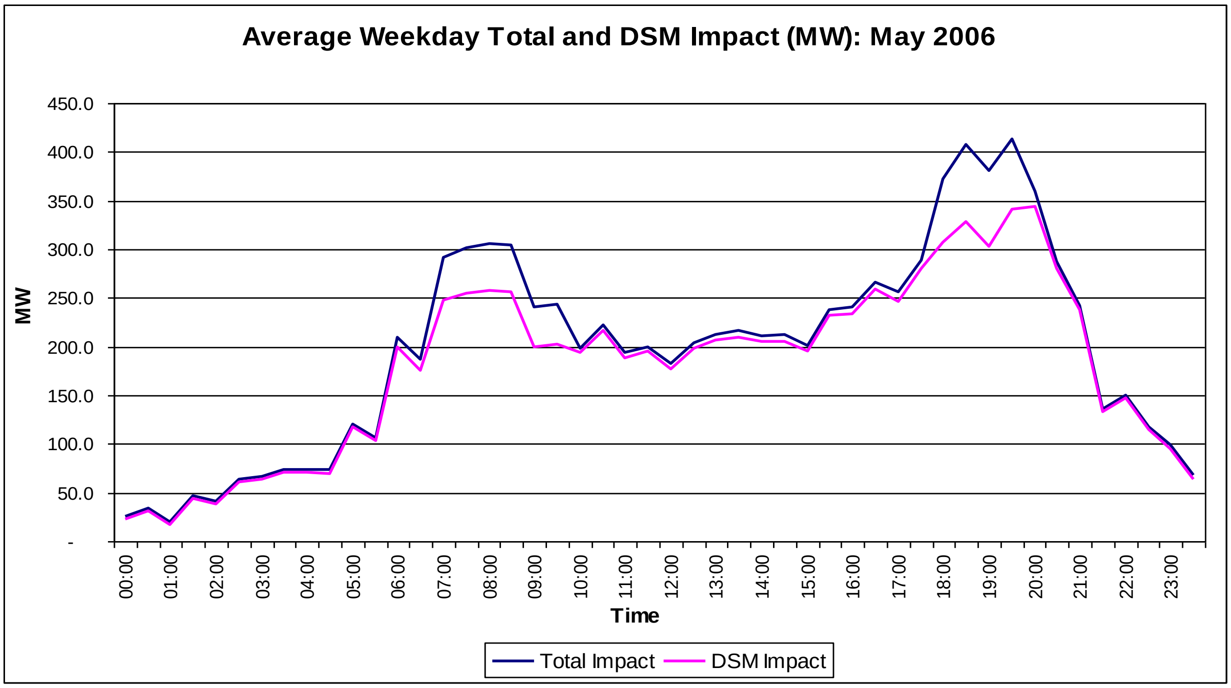


Figure 5-9: Average weekday total and DSM impact of May 2006

5.7.2 June Impact

Figure 5-10 shows the average weekday demand of June as well as the developed baseline. Table 5-8 shows the total and DSM impacts in the different TOU periods. The total average weekday evening impact achieved in June was 650MW. DSM contributed 497MW to the total impact. Figure 5-11 shows the average total and DSM impact achieved in June. The average total impact increased from May to June with 280MW while the average DSM impact increased with 180MW.

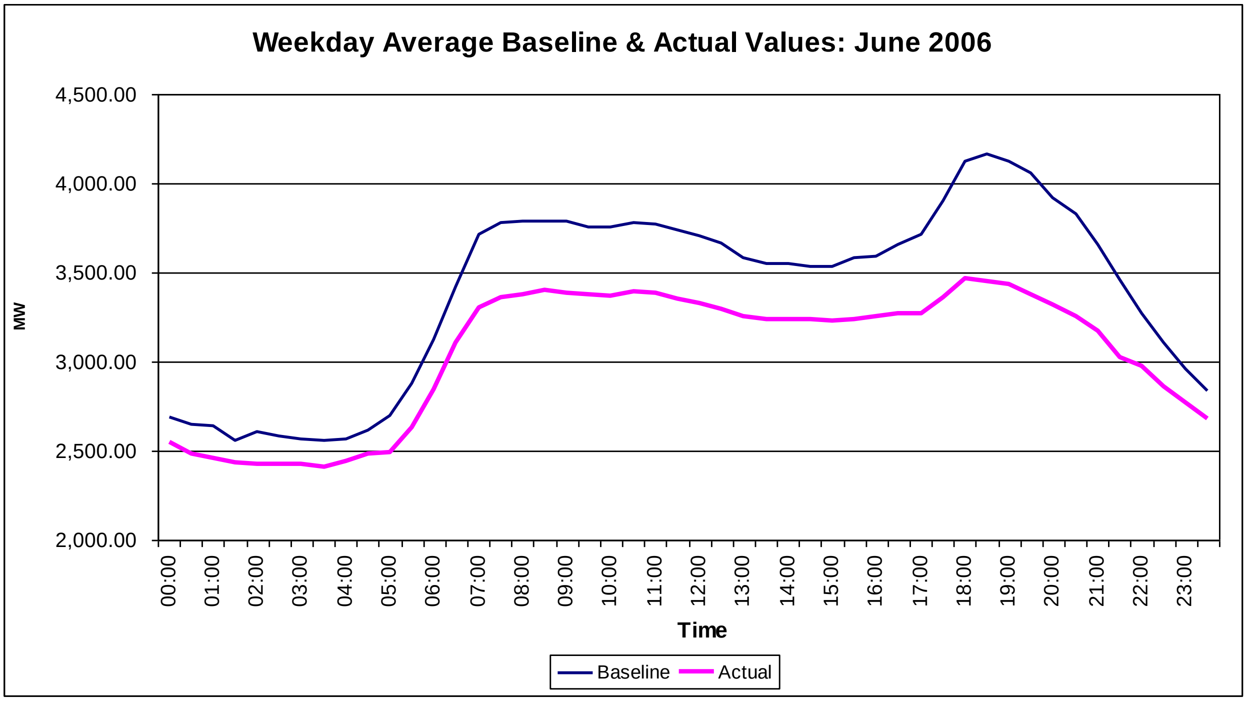


Figure 5-10: Baseline and actual demand of June 2006

Table 5-8: June weekday time-of-use impacts

Weekdays TOU Impacts: June 2006	Morning OffPeak	Morning Standard	Morning Peak	Midday Standard	Evening Peak	Evening Standard	Evening OffPeak
	00:00-06:00	06:00-07:00	07:00-10:00	10:00-18:00	18:00-21:00	21:00-22:00	22:00-00:00
Average WD Total Impact	160.15	293.99	399.66	368.58	649.85	462.63	221.57
Average WD DSM Impact	154.22	267.37	275.93	234.37	496.86	387.26	192.74

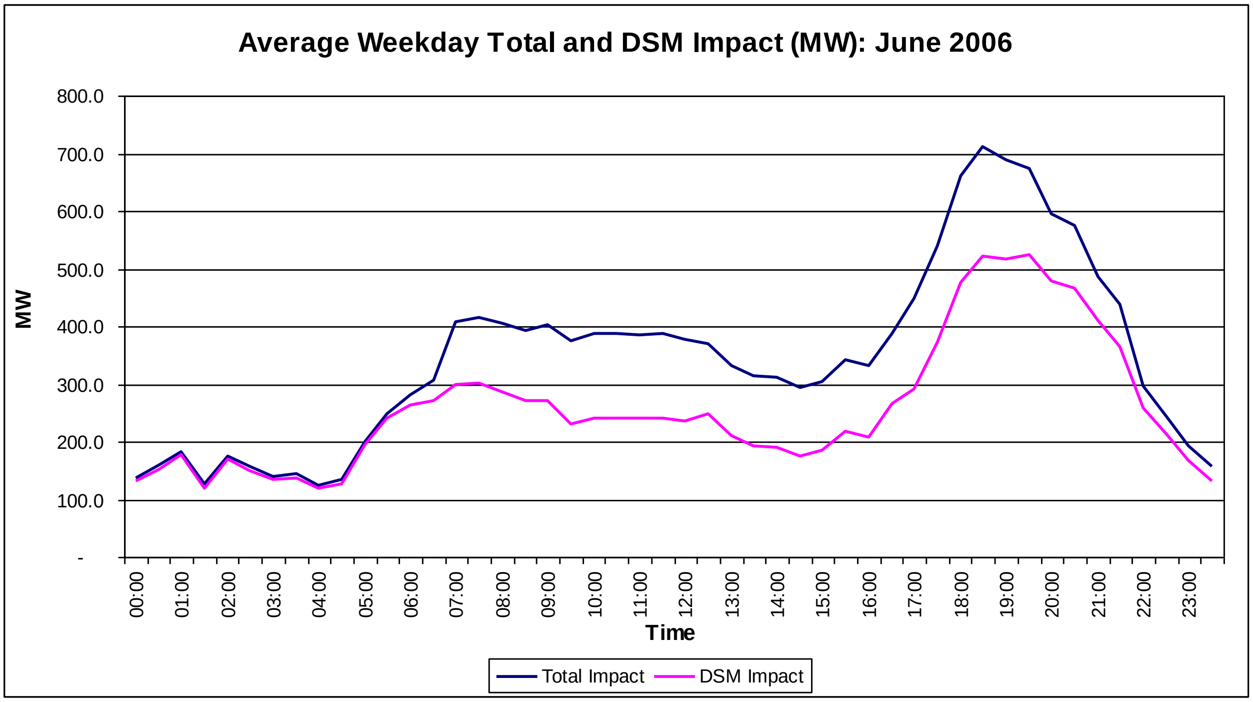


Figure 5-11: Average weekday total and DSM impact of June 2006

5.7.3 July Impact

Figure 5-12 shows the average weekday demand of July as well as the developed baseline. Table 5-9 shows the total and DSM impacts in the different TOU periods. The total average weekday evening impact achieved in July was 523MW. DSM contributed 389MW to the total impact. Figure 5-13 shows the average total and DSM impact achieved in July. The average total impact decreased from June to July with 127MW while the average DSM impact decreased with 108MW.

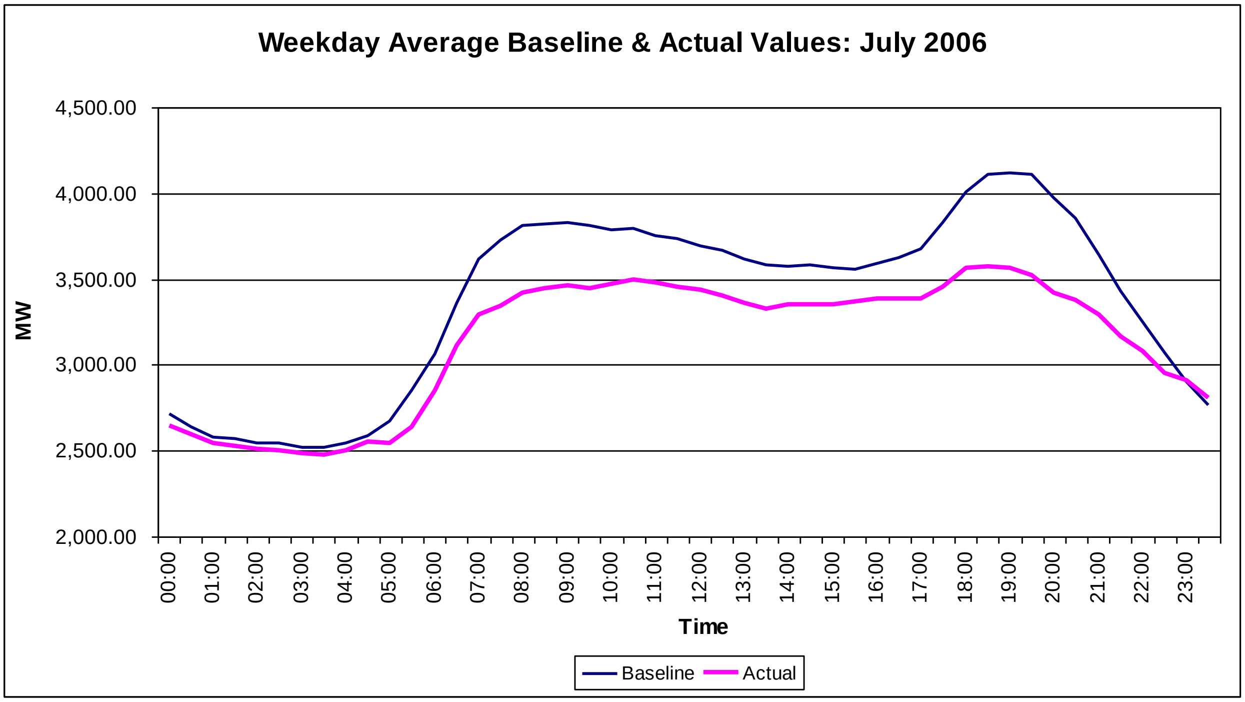


Figure 5-12: Baseline and actual demand of July 2006

Table 5-9: July weekday time-of-use impacts

Weekdays TOU Impacts: July 2006	Morning OffPeak	Morning Standard	Morning Peak	Midday Standard	Evening Peak	Evening Standard	Evening OffPeak
	00:00-06:00	06:00-07:00	07:00-10:00	10:00-18:00	18:00-21:00	21:00-22:00	22:00-00:00
Average WD Total Impact	62.82	229.94	367.55	260.94	522.92	308.38	59.23
Average WD DSM Impact	58.93	210.51	306.04	191.03	388.78	233.26	25.95

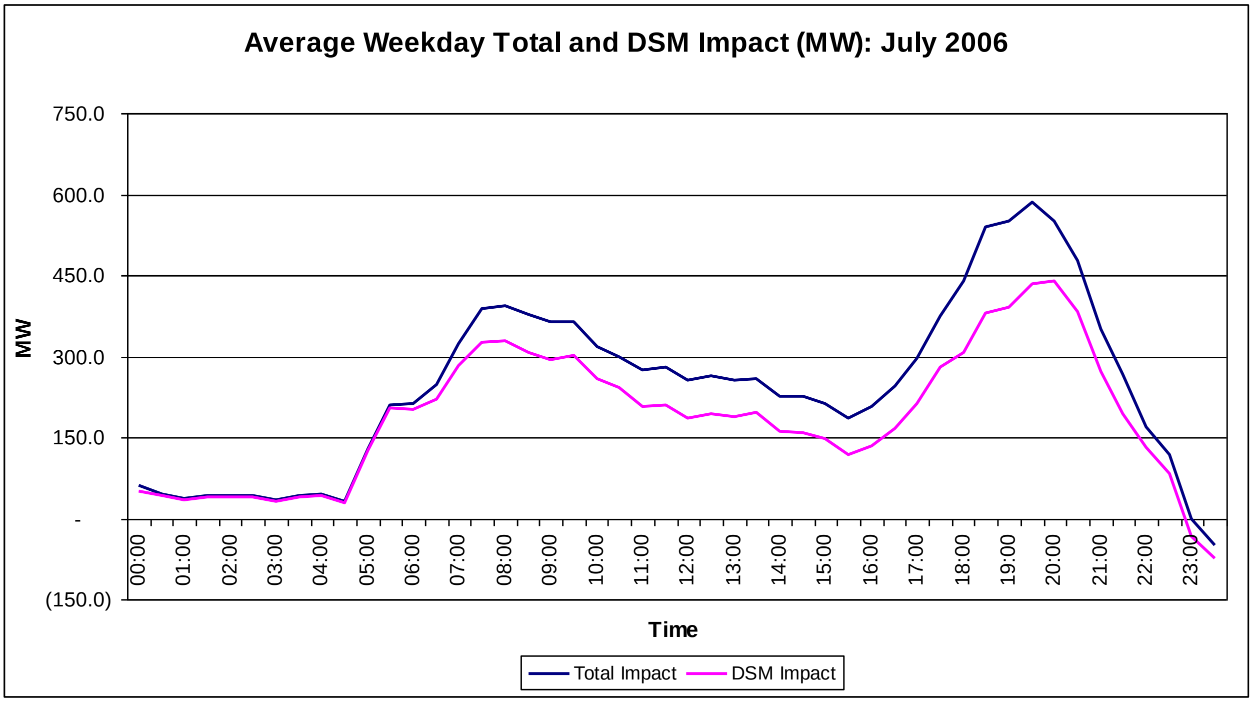


Figure 5-13: Average weekday total and DSM impact of July 2006

5.7.4 August Impact

Figure 5-14 shows the average weekday demand of August as well as the developed baseline. Table 5-10 shows the total and DSM impacts in the different TOU periods. The total average weekday evening impact achieved in August was 354MW. The total and DSM impact of August is equal as seen in Table 5-10. The reasons are that all DMP contracts expired on 31 July and both Koeberg units were operating again. The average total impact decreased from July to August with 169MW while the average DSM impact decreased with 35MW.

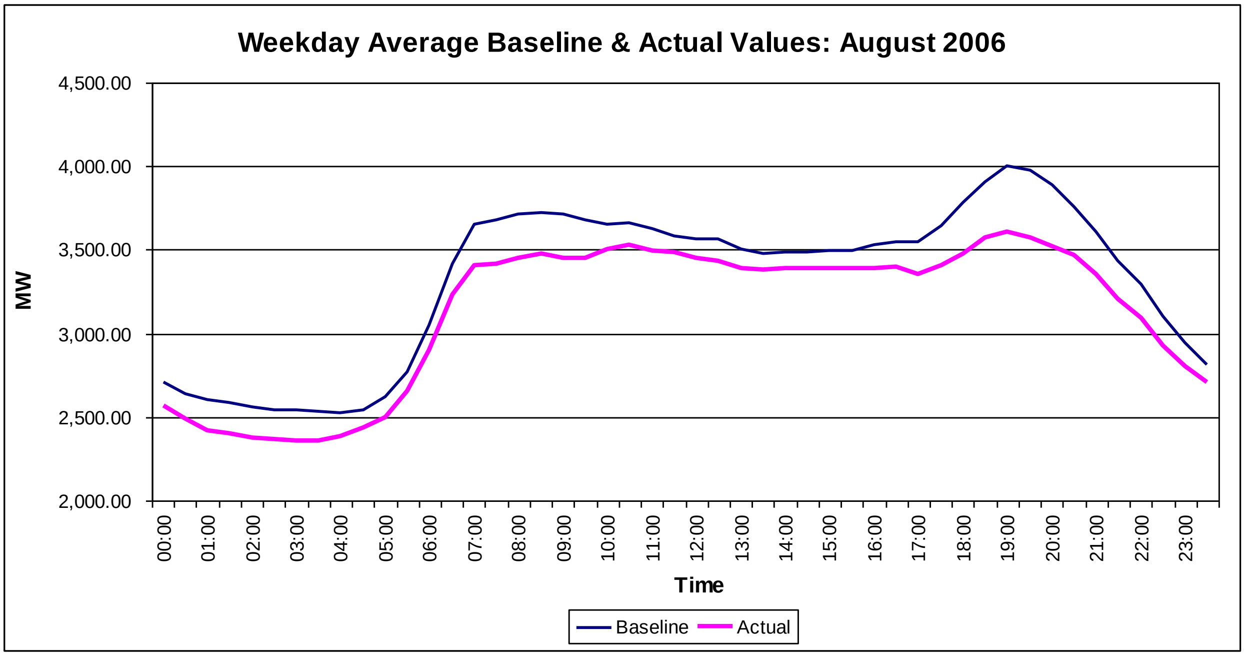


Figure 5-14: Baseline and actual demand of August 2006

Table 5-10: August weekday time-of-use impacts

Weekdays TOU Impacts: August 2006	Morning OffPeak	Morning Standard	Morning Peak	Midday Standard	Evening Peak	Evening Standard	Evening OffPeak
	00:00-06:00	06:00-07:00	07:00-10:00	10:00-18:00	18:00-21:00	21:00-22:00	22:00-00:00
Average WD Total Impact	151.30	187.45	260.59	153.83	353.75	276.45	149.97
Average WD DSM Impact	151.30	187.45	260.59	153.83	353.75	276.45	149.97

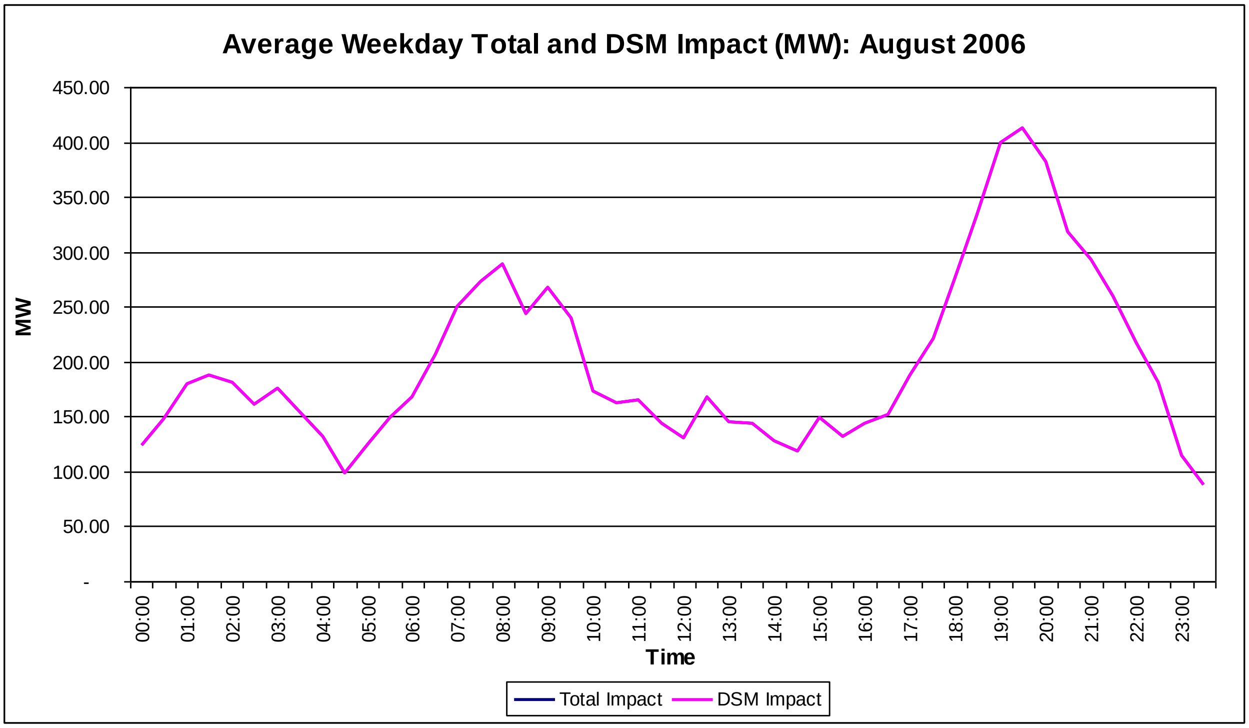


Figure 5-15: Average weekday total and DSM impact of August 2006

5.8. Summary of Results

Figure 5-17 shows the average DSM impact in the different time-of-use period for May to August 2006.

In May the average weekday evening peak DSM impact was 317MW. The DSM impact increased to 497MW in June. The DSM impact for July reduced by 108MW to 389MW; still 72MW higher than May. An average weekday evening peak of 513MW was seen in the first two weeks of July (1 to 15 July) while the last two weeks (16 to 31 July) revealed an impact of 278MW. The decline was a result of the Koeberg unit being back in service from 24 July and certain DSM projects not operating as aggressive from 24 July 2006. Figure 16 show a summary of the weekday average DSM impacts of May to August.

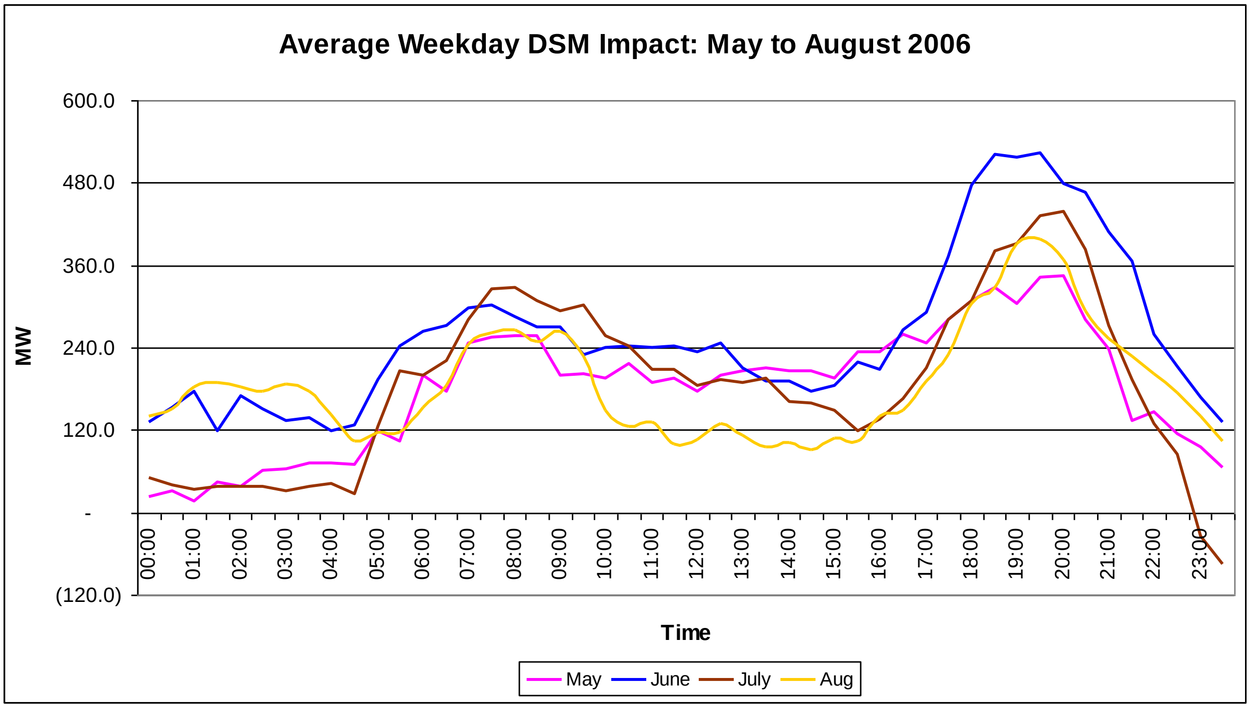


Figure 5-16: Average weekday DSM impact May to August 2006

In August it was seen that the average weekday DSM evening peak impact was 354MW. Figure 5-17 illustrates that the evening peak DSM impact of August is lower than July. It seems that the DSM impact decreased to similar impacts achieved in May.

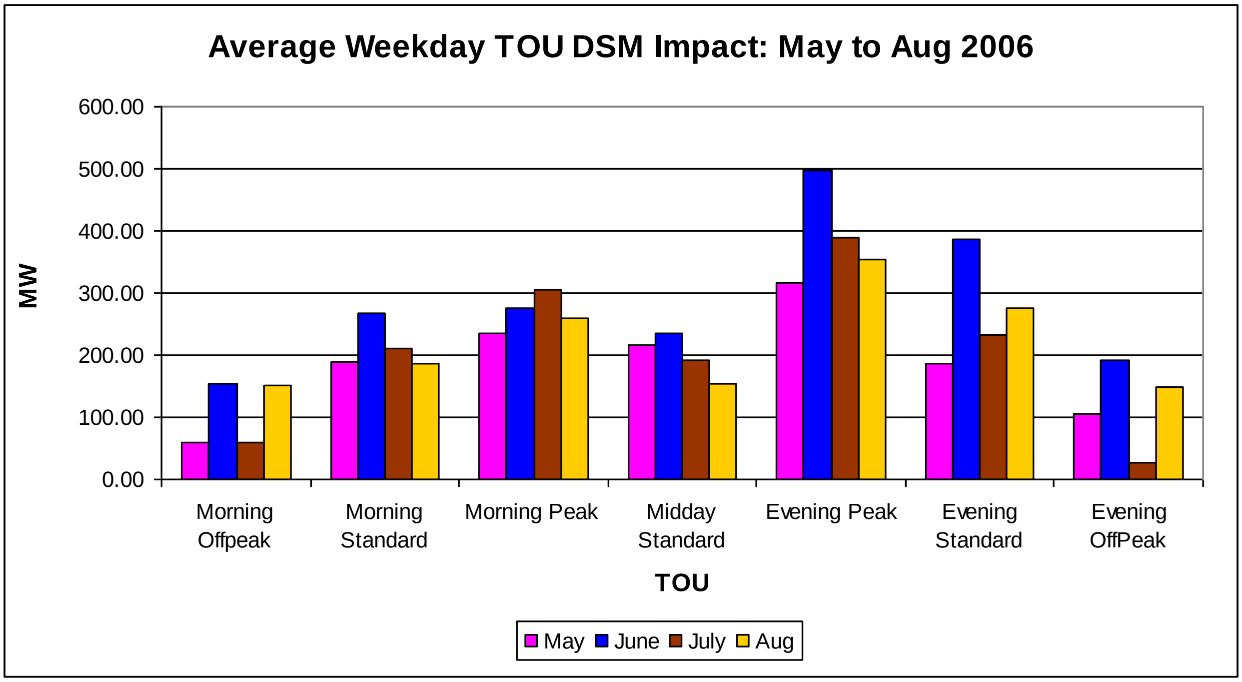


Figure 5-17: Weekday average time-of-use periods

The average DSM impact from May to August was not constant during the evening peak period. There was an 180MW increase in average evening peak DSM impact from May to June and a 108MW decline from June to July.

5.9. Conclusion

The purpose of M&V was to show to stakeholders the impacts due to the DSM interventions implemented in the Western Cape. The expected short-fall was 400MW and DSM projects were implemented to avoid the short-fall and consequent load shedding. The M&V campaign aimed to show that the 400MW was indeed achieved.

A top-down M&V methodology was followed because various DSM measures were implemented in the Western Cape and baselines (and data) were not available for the individual sites. Isolation of the impacts of the different measures would be impossible due to the number of projects in the Western Cape and also because some of the measures involved behaviour changes in the area which are impossible to quantify.

Baselines were developed that correlated the electrical load with temperature on 30-minute intervals for different day types. Other adjustments (such as growth, DMP, load shedding, etc) were also taken into account to compensate for them as they did not happen in the period where baseline data were taken from.

It was found that in May the average weekday evening peak DSM impact was 317MW. The DSM impact over the same period increased to 497MW in June. The DSM impact for July reduced by 108MW to 389MW; still 72MW higher than May.

An average weekday evening peak of 513MW was seen in the first two weeks of July (1 to 15 July) while the last two weeks (16 to 31 July) revealed an impact of 278MW. The decline was a result of the Koeberg unit being back in service from 24 July and certain DSM projects not operating as aggressive from 24 July 2006.

From these results it could be concluded that the DSM interventions were indeed successful as during peak times even more than 400MW load reduction was obtained. The results were confirmed by the low number of load shedding events that took place. Those events also only took place when a generator or other load supply was lost.

5.10. References

1 Efficiency Valuation Organization. International Performance Measurement and Verification Protocol – Concepts and Options for determining energy and water savings. Volume 1. April 2007. http://www.evo-world.org

2 ANON. 2000. California’s 2000 large non-residential standard performance contract programme, Procedures Manual Version 1.0, May 2, 2000. http://www.scespc.com

CHAPTER 6

Performance Assessment of Power Alert

This chapter focuses on the impacts achieved by Power Alert. The broadcasted Power Alert messages, the frequency of the broadcasts, and the load reduction that was obtained are specific subjects in this chapter. Two different impact calculation methodologies were developed. The methodologies as well as the impacts calculated from these methodologies are presented. The chapter concludes by presenting achievements as a result of the Power Alert initiative. It also provides lessons learnt from this study.

CHAPTER 6 PERFORMANCE ASSESSMENT OF POWER ALERT

"It is only wise that you and your kids follow TV messages from Eskom because while your geyser is on, somebody in ICU is in need of that power". [1]

6.1. Introduction

Establishing the Power Alert Control Centre in the short period of time, as it has been done, posed a number of challenges that had to be overcome in order for the centre to be successful. Not only has Power Alert achieved substantial load reduction during the campaign, but there were also major technological achievements. This chapter focuses on the calculation of the load reduction achievements of Power Alert.

6.2. The Power Alert Impact Calculation Problem

Power Alert was not the only load reduction measure implemented during the Western Cape Integrated Recovery Plan. Other measures included:

- Efficient lighting retrofits;
- Self-generation by customers;
- Commercial and Industrial energy efficiency;
- Efficient appliance subsidies;
- Extensive conservation drives;
- Switching of load to liquefied petroleum (LP) gas; and
- Demand market participation.

It was impossible to establish a clear impact calculation boundary for Power Alert. As with the top-down M&V, it was also impossible to draw clear and definite boundaries around the exact point of impacts caused by Power Alert. A new impact calculation methodology therefore was needed to determine the impacts of residential load management programmes such as Power Alert.

One major uncertainty in this specific case was for example the issue of the size of the expected impact in relation to the total load. An impact of 122MW was expected in relation to a total maximum demand of 4,250MW. It was tried to quantify an impact that is in the region of 2.9% of the total load. In this case, even a small variation in load could drastically influence the calculated impact.

In cases like these the uncertainty of impacts could be a matter of endless debate. One could easily be caught up in a debate of the exact value of the impact rather than to accept that an impact was made and also accept the uncertainty associated with the specific problem.

This chapter focuses on the development of two new methodologies to calculate the impact of residential load management programmes over a wide area. The two methodologies are an attempt to eliminate the reality of actual load variations on the value of impact. The two methodologies are then applied to actual data and the impacts achieved are calculated and presented.

The first methodology took the results from the top-down M&V (discussed in Chapter 5) as an input. That M&V methodology determined the impact of all DSM measures implemented. At the start of Power Alert (end of May 2006) no more DSM projects were implemented. The consequent increase in impacts of the months after May could be attributed to Power Alert.

The second methodology used the official Western Cape load forecast which was adjusted using actual data just before the start of Power Alert and determined the difference between the adjusted forecast and the actual load.

The research team went even further and calculated the average of the two methodologies and present those values as the ultimate impact of Power Alert.

6.3. Power Alert Flightings

The Power Alert barometer level, as well as the time the message was broadcasted, is presented in this paragraph.

Figure 6-1 and Figure 6-2 shows that in June a total of 150 Power Alert message were broadcasted of which 69 (46%) were green, 71 (47%) were orange, 3 (2%) were red, and 7 (5%) were brown. Figure 6-3 shows at which times during the evening peak the codes were broadcasted during June 2006.

Figure 6-4 and Figure 6-5 shows that in July a total of 140 Power Alert messages were broadcasted of which 83 (60%) were green, 42 (30%) were orange, and 15 (10%) were red. Figure 6-6 shows when the codes were broadcasted during the evening peak in July 2006.

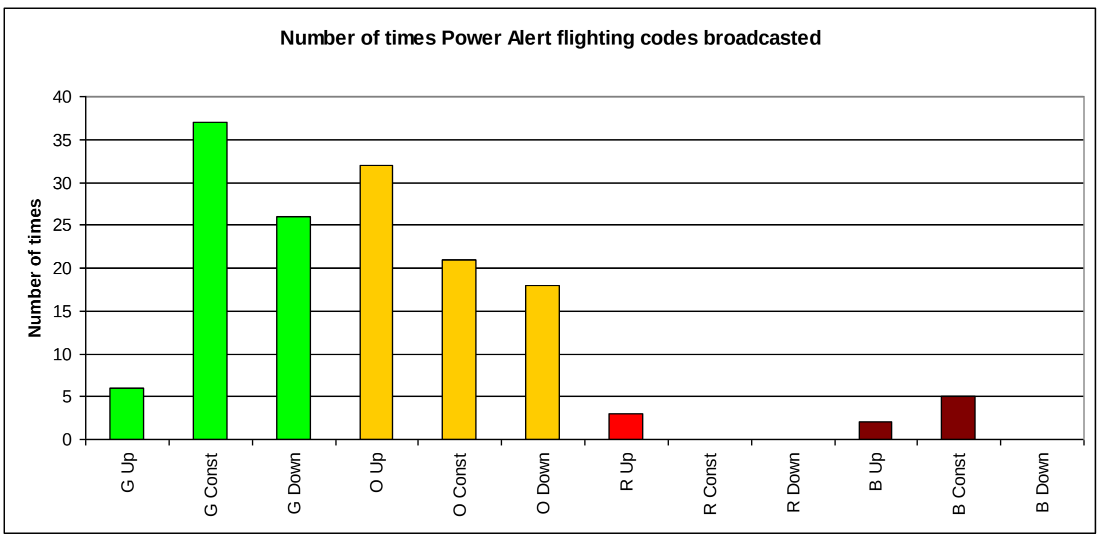


Figure 6-1: Number of times different specific Power Alert messages was flighted during June 2006

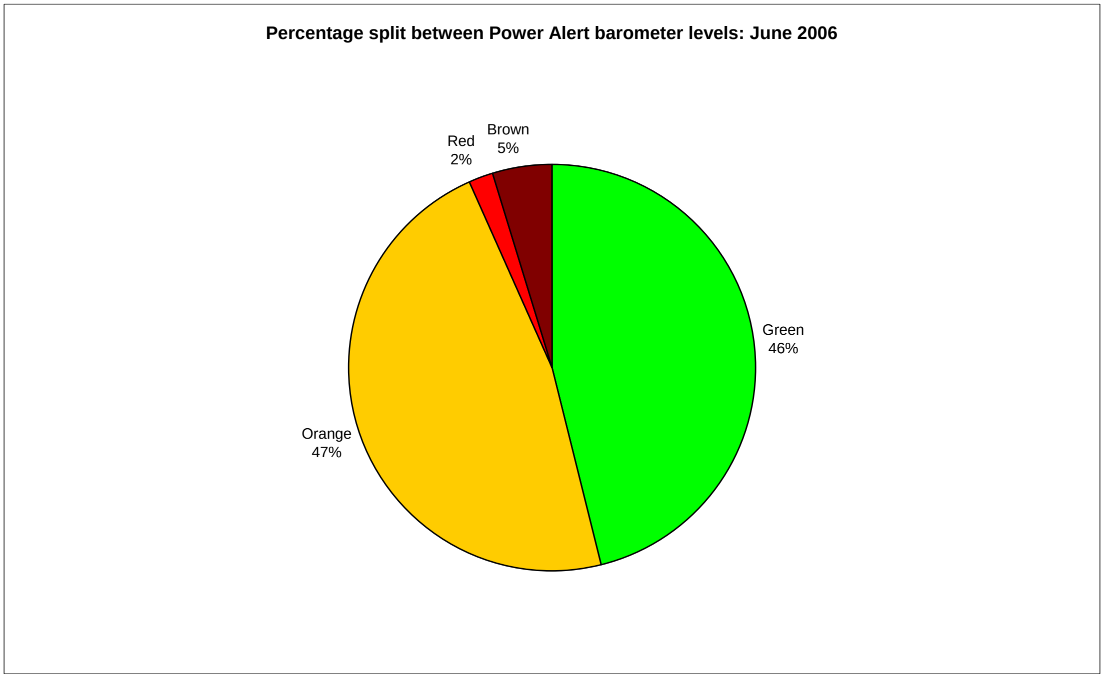
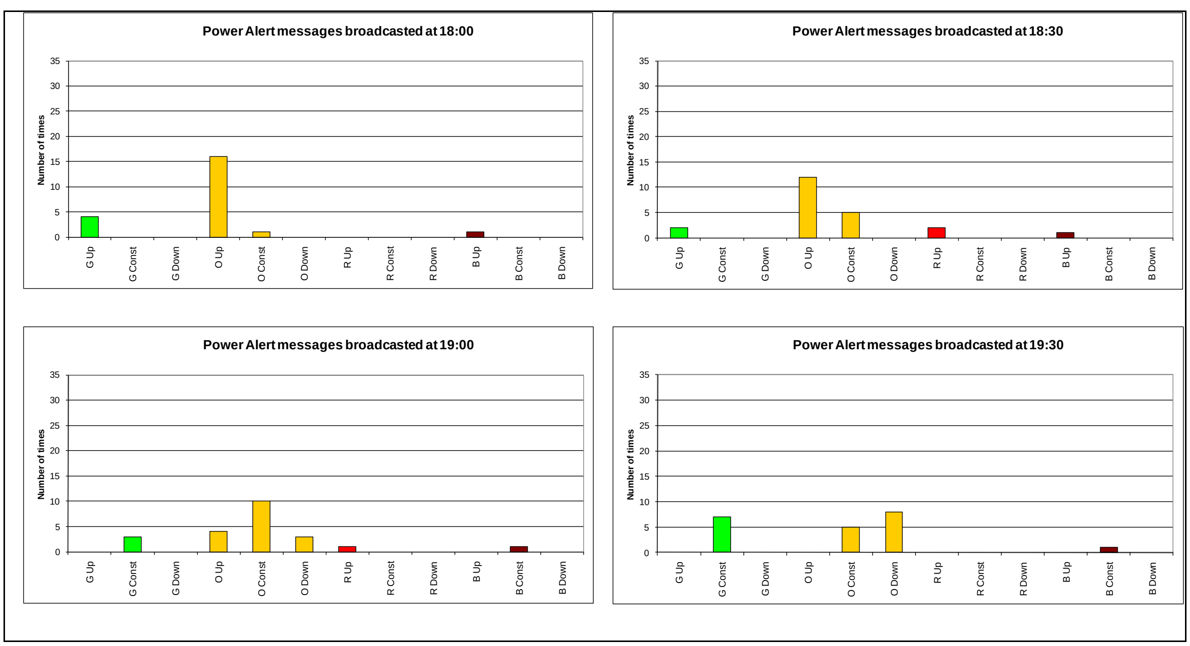


Figure 6-2: Percentage split of Power Alert message levels in June 2006



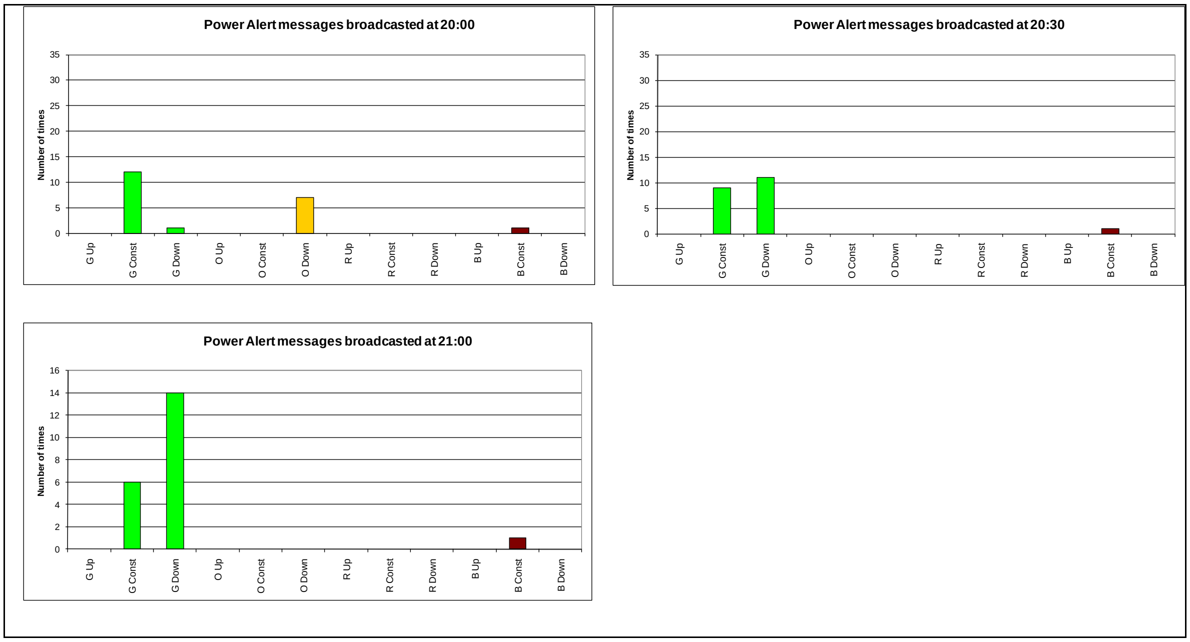


Figure 6-3: Power Alert codes broadcasted in June 2006

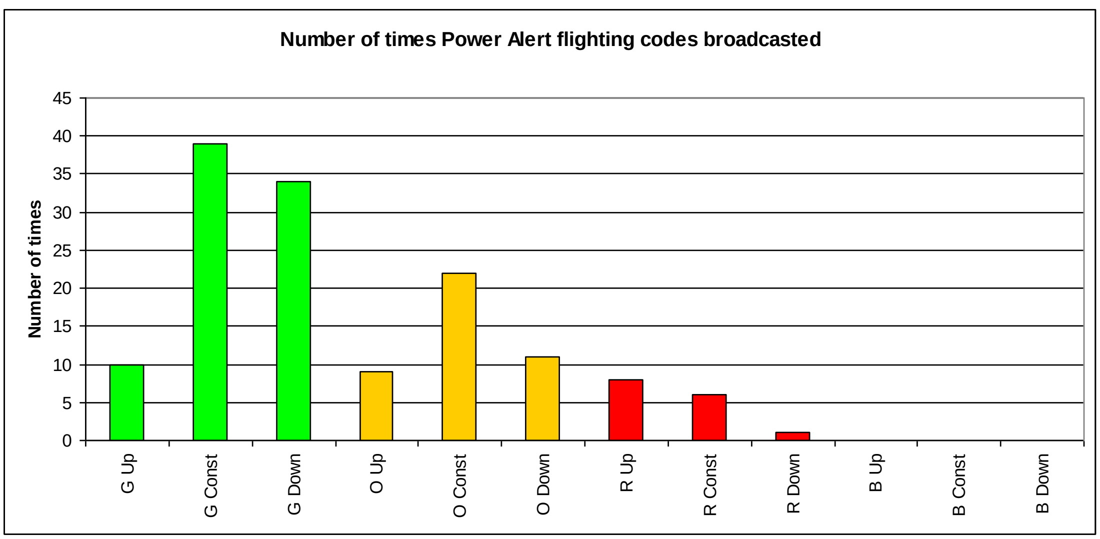


Figure 6-4: Number of times different specific Power Alert messages was flighted during July 2006

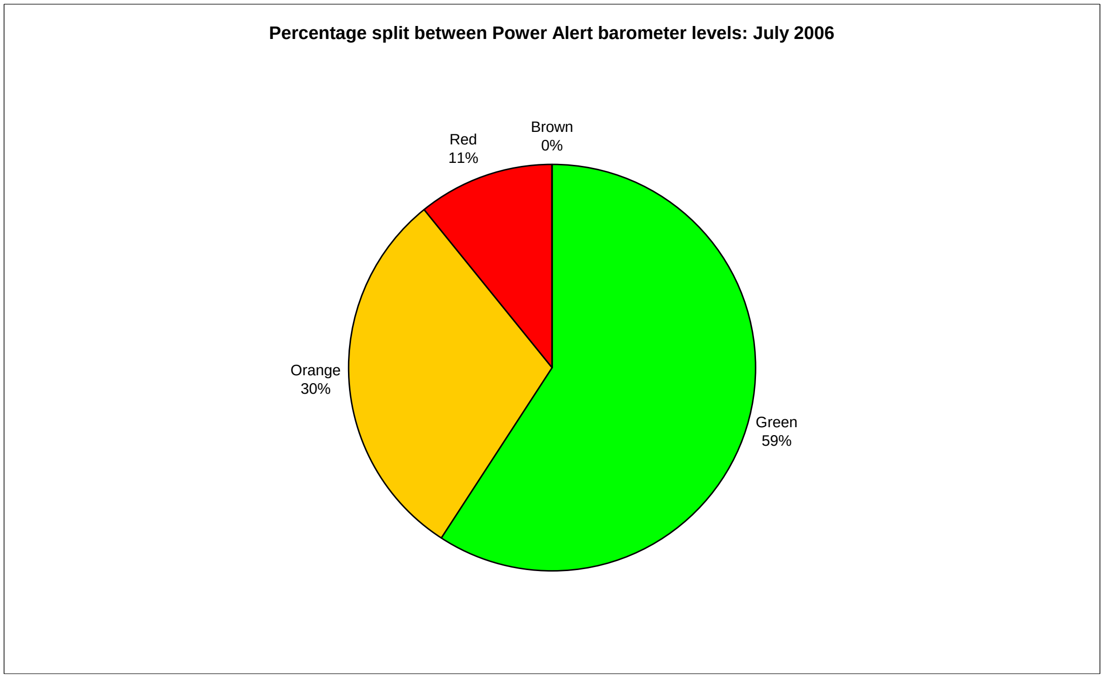


Figure 6-5: Percentage split of Power Alert message levels in July 2006

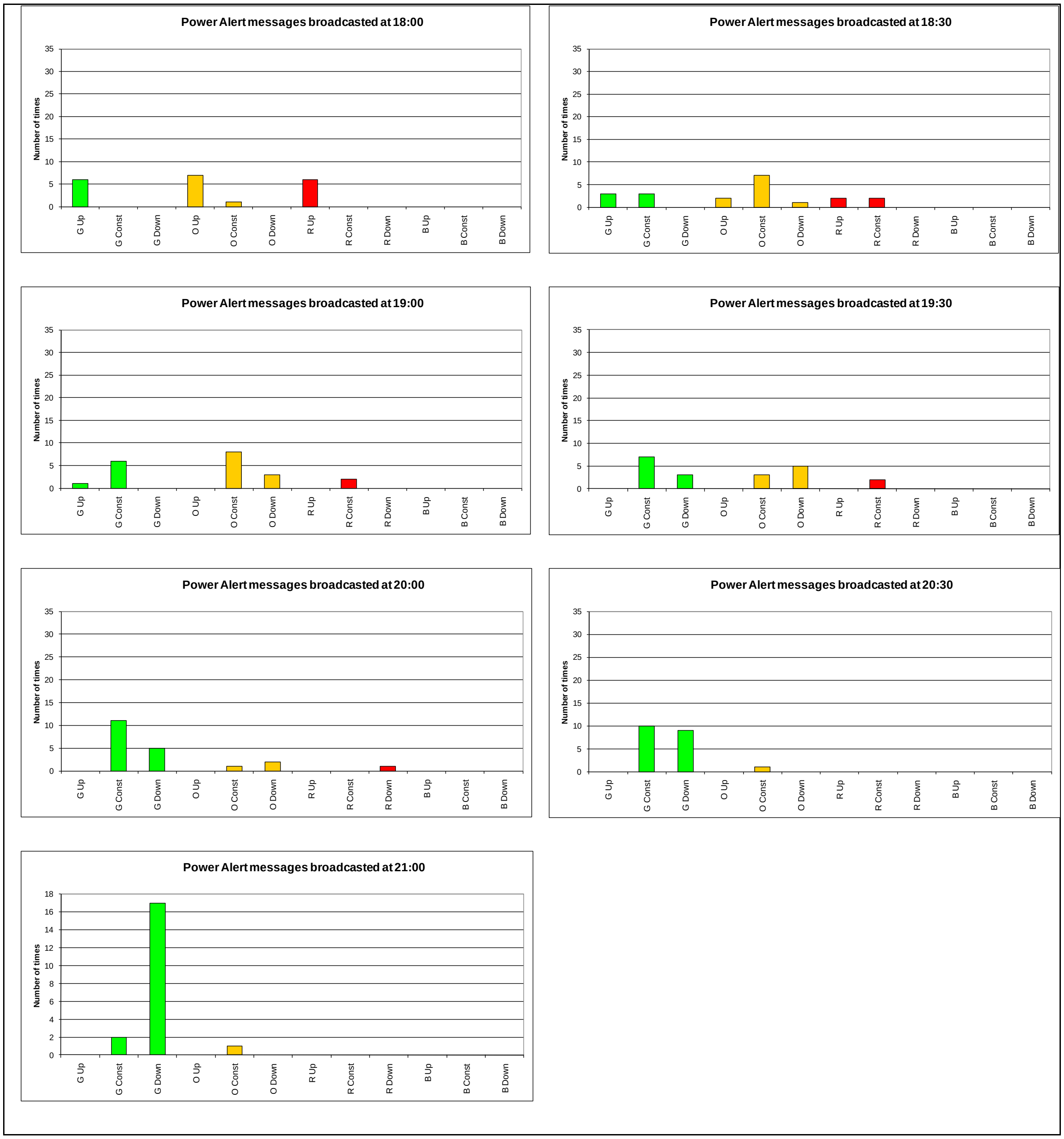


Figure 6-6: Power Alert codes broadcasted in July 2006

6.4. First Methodology for Load Reduction Calculations

The first approach to calculate load reductions was to use results from the Cape Top-down M&V campaign (discussed in the next chapter). Figure 6-7 shows the half-hourly DSM impacts from the Cape Top-down M&V campaign for May, June and July 2006. It was seen from the graph that the DSM impact for June and July was higher than what the impact was during May.

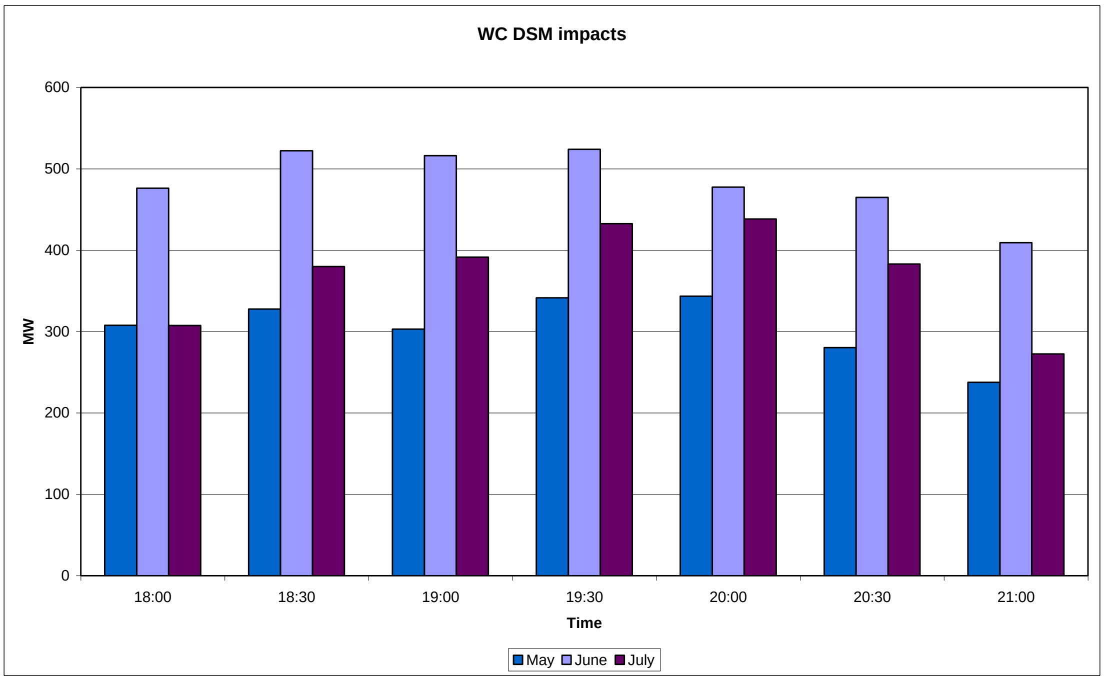


Figure 6-7: Cape DSM impacts for May, June and July 2006

It was assumed that the M&V calculated impact in May was purely due to DSM and therefore that Power Alert did not affect the demand profile at all during the week operation in May as Power Alert was broadcasted only during the last few days of May. The DSM impacts in June and July additional to what was achieved in May was determined. Figure 6-8 and Figure 6-9 schematically illustrate the methodology.

Figure 6-8 conceptually shows the DSM impacts determined for May, June and July. The idea shown in the figure is that a certain DSM impact was expected in May 2006. That impact would be without the additional impact of Power Alert. An additional impact was expected in June and July 2006 due to Power Alert. If the impact of May 2006 could be calculated, the additional impact of June and July would most likely be that of Power Alert as no other DSM projects were implemented during that time. The concept behind this methodology is to calculate the additional impact in June and July compared to May.

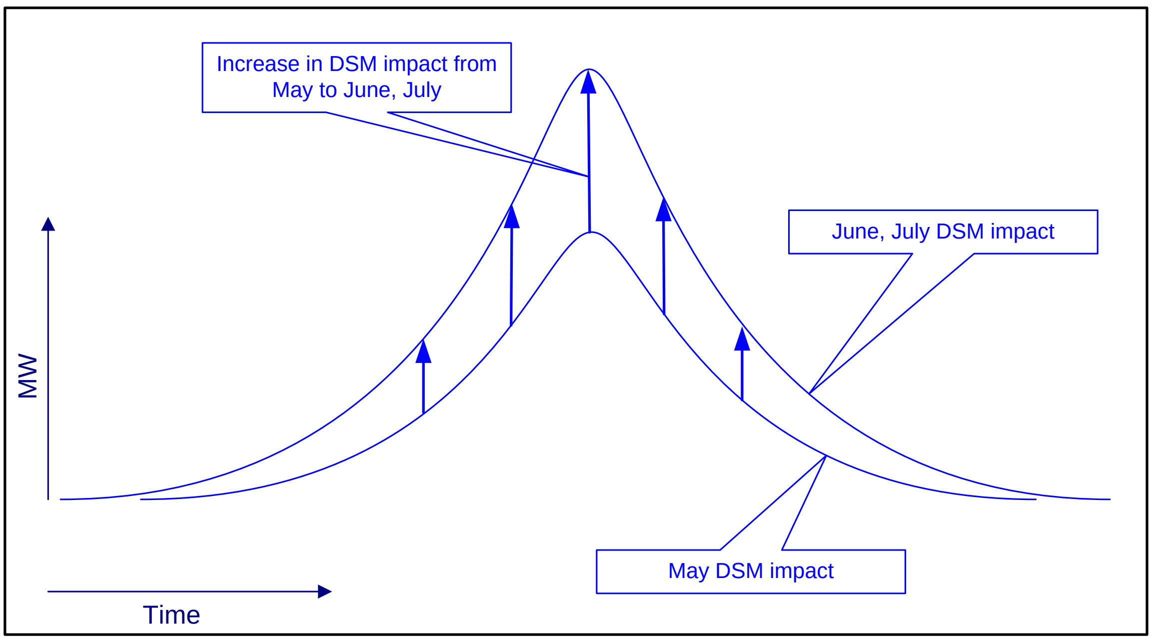


Figure 6-8: Illustrated growth in DSM impacts from May to June, July

Figure 6-9 shows how the DSM impacts obtained in May were made zero to determine the additional DSM impacts obtained in June and July.

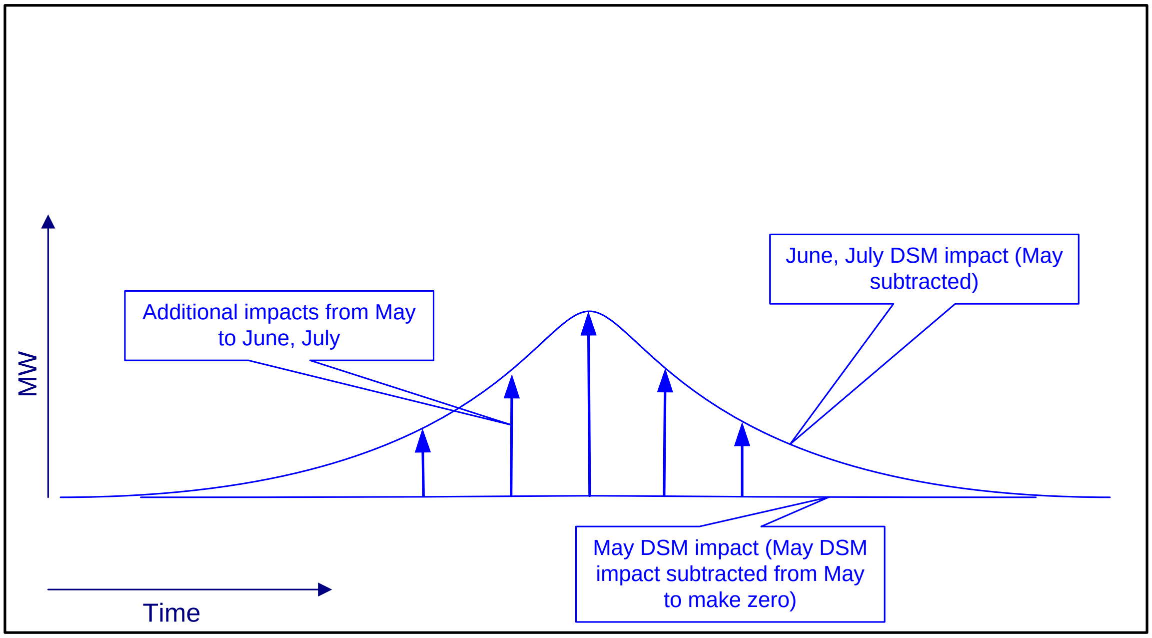


Figure 6-9: Impacts additional to May

6.4.1 Methodology 1: June 2006

Figure 6-10 shows the calculated impact in June 2006 of DSM projects additional to May 2006. The average increase in DSM impact during June over the evening peak period was 178MW. It is also seen in the graph that the impact increases from 18:00 to 19:00. This is in line with a previous observation that the load increases to around 19:00 at night. It could be concluded that as more people starts to watch television, more people reacts to the Power Alert messages.

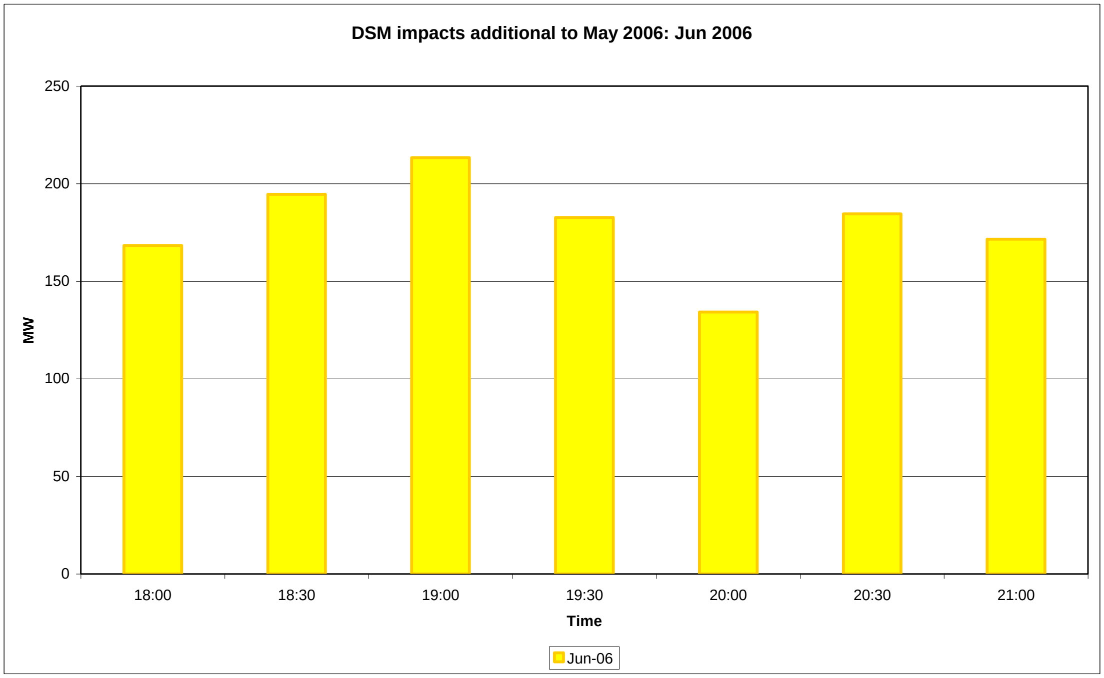


Figure 6-10: DSM impacts achieved in June 2006 additional to May 2006

6.4.2 Methodology 1: July 2006

Figure 6-11 shows the additional impact of DSM from May to July 2006. The average increase in DSM impact in peak periods from May to July 2006 was 66MW. That is 112MW less than from May to June 2006.

With these results it was asked why the impacts were lower in July than in June. Figure 6-2 (see also Figure 6-1) and Figure 6-5 (see also Figure 6-4) gave some insight to this finding.

During June the Green and Orange messages were flighted respectively 46% and 47% of the time. Red and Brown were flighted 7% of the time. During July the Green and Orange messages were flighted respectively 59% and 30% of the time. Red and Brown were flighted 11% of the time. 13% more Green messages were flighted in July than in June and 17% less Orange messages were flighted in July than in June.

It can be concluded from this that the number of specific flightings therefore has a direct impact on the load reductions. When more green messages were flighted, the impact was lower than when orange messages were flighted. During orange messages the public was informed that the strain on the network was increasing and they were requested to switch some appliances off. When green messages were flighted, the public was not requested to switch off as much appliances as during orange. The importance here is that it was demonstrated that the public truly participated in the Power Alert campaign and that the public responded to what was asked.

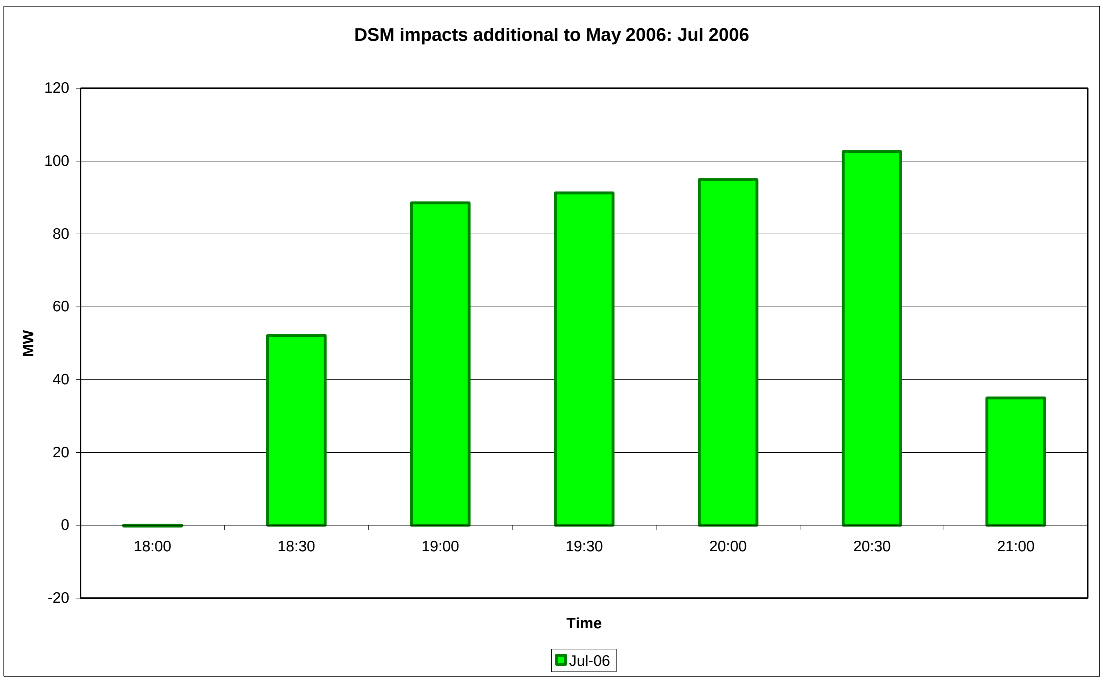


Figure 6-11: DSM impacts achieved in July 2006 additional to May 2006

6.5. Second Methodology for Load Reduction Calculations

The second methodology made use of the official Eskom forecast. The forecast used for the calculations was the official forecast done on the 10th of May 2006. The reason for using this forecast was that it was the earliest forecast that included expected demands until end of August 2006 and was not influenced by Power Alert at all.

The basic steps that were done to get to the expected demand were the following:

- Use the official Eskom forecast of the 10th of May 2006.
- Use actual data obtained from Eskom.
- Adjust the Eskom Forecast with demand market participation (DMP) and other generation sources (Figure 6-12).
- Adjust the DMP adjusted forecast so that the forecast and the actual profile is energy neutral before Power Alert started for the evening (Figure 6-13).
- Determine the difference between the adjusted forecast and the actual demand profile during peak hours (18:00 to 21:00).

The Cape Top-down M&V results discussed in the next chapter was also used to see that the claimed impact of Power Alert did not exceed the calculated impact of DSM in the Western Cape Integrated Recovery Plan. It would be impossible that the impact of one project be higher than the impact of all projects as determined through the Cape Top-down M&V.

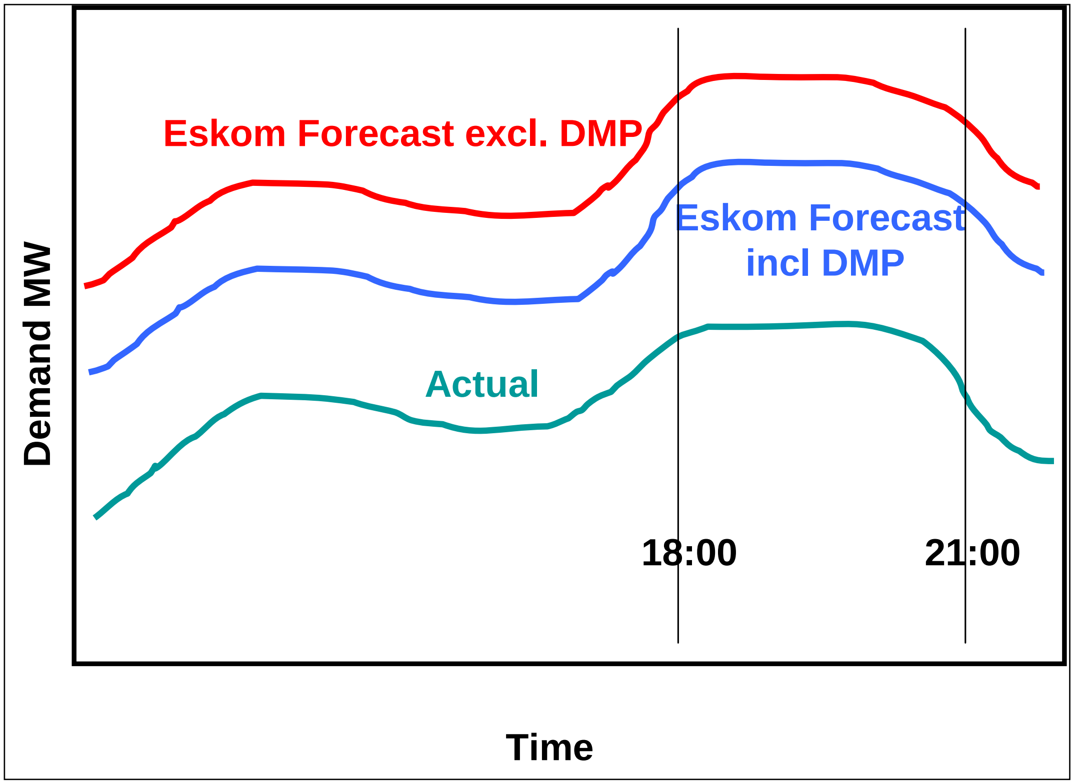


Figure 6-12: Demand profiles before any adjustments. Original forecast and forecast with DMP subtracted as well as actual profile

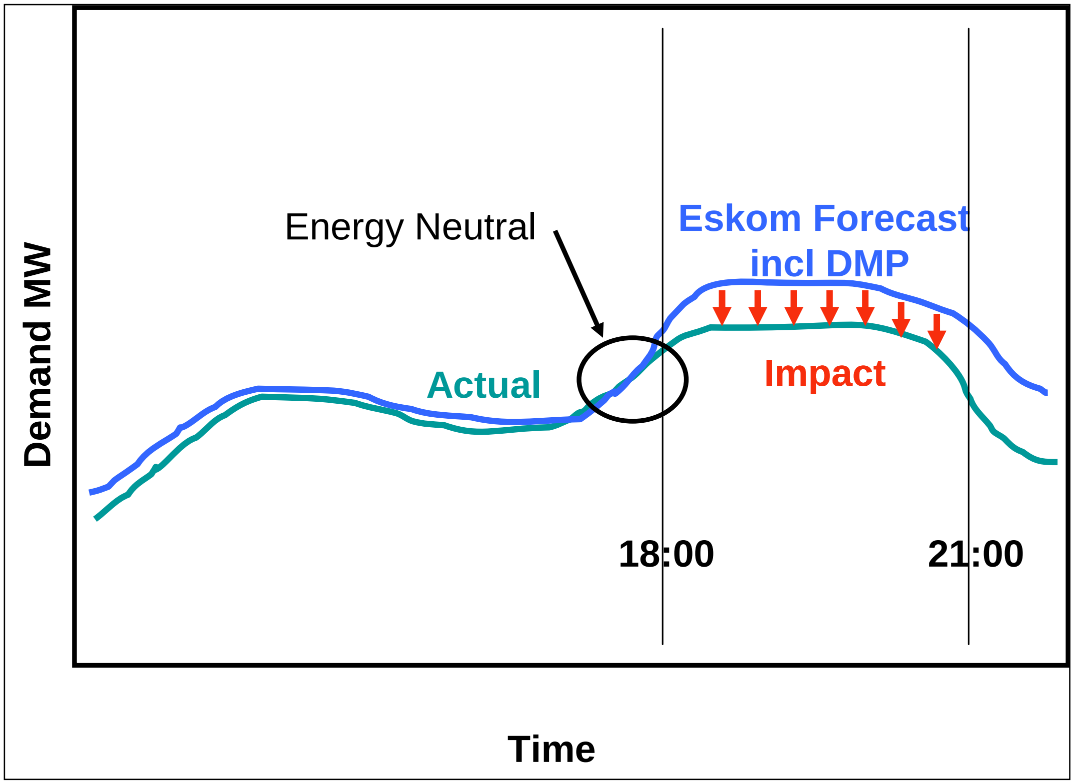


Figure 6-13: Adjusting the Eskom forecast so that it is energy neutral just before Power Alert starts

The described methodology was applied to June and July 2006 data. The obtained results are shown in the following paragraphs.

6.5.1 Methodology 2: June 2006

Figure 6-14 shows the impact achieved by Power Alert in June 2006. Figure 6-1 shows the number of times each Power Alert message was broadcasted. Figure 6-15 shows the Power Alert impact for June 2006.

The average impact of Power Alert was 73MW over the whole of June during the evening peak period between 18:00 and 21:00. The average impact between 18:00 and 20:00 was just below 100MW. Again it can be seen that there is a relation between impact and increased strain on the network. Remember that when the strain on the network increased, residents were asked to switch off more appliances.

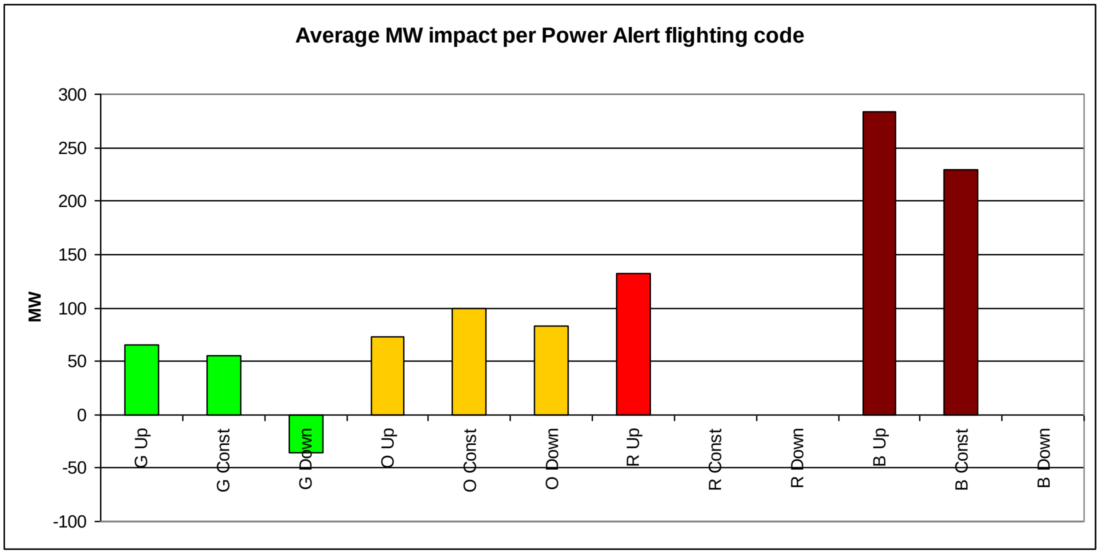


Figure 6-14: Impacts of Power Alert during June 2006

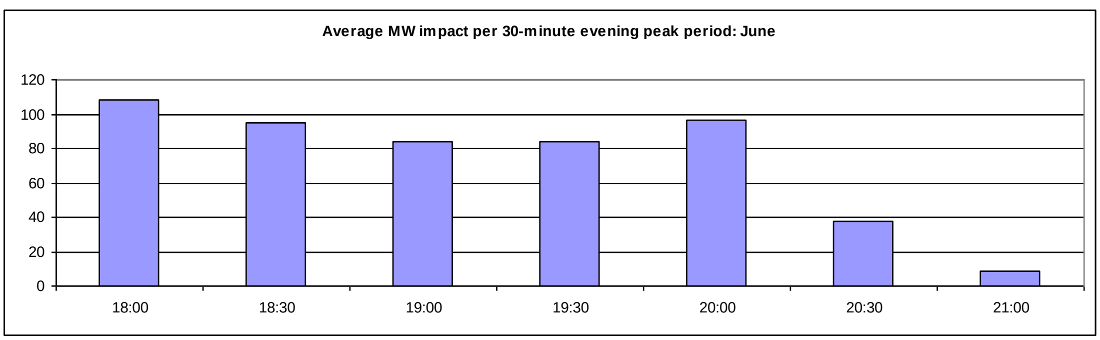


Figure 6-15: Average MW impact: June 2006

The most notable impact of Power Alert was seen on 9 June 2006. Koeberg went off-line on the 8th of June at 18:00. For the 8th, all Power Alert messages were cancelled due to the trip. On the 9th, Brown Up and Brown Constant messages were broadcasted. Load shedding was done throughout the day in the Western Cape.

The first Power Alert message was broadcasted at 18:00. Load shedding in the Western Cape stopped at 18:00 and no load was shed throughout the rest of the evening of Friday the 9th. The whole of the Western Cape was with electricity during the evening and over the weekend even though Koeberg was off-line. Koeberg was back on-line on Sunday. Power Alert was a key factor in averting load shedding during this period.

Figure 6-16 shows the demand profile of the Western Cape from 18:00 and also the Power Alert messages broadcasted. Notice the sharp drop in demand when the 18:00 Brown up Power Alert message was broadcasted. Also note the change of slope in the demand profile at 18:30 when the second Brown up Power Alert message was broadcasted. The average impact achieved on 9 July between 18:00 and 20:00 was 291MW and for the period 18:00 to 21:00 it was 245MW.

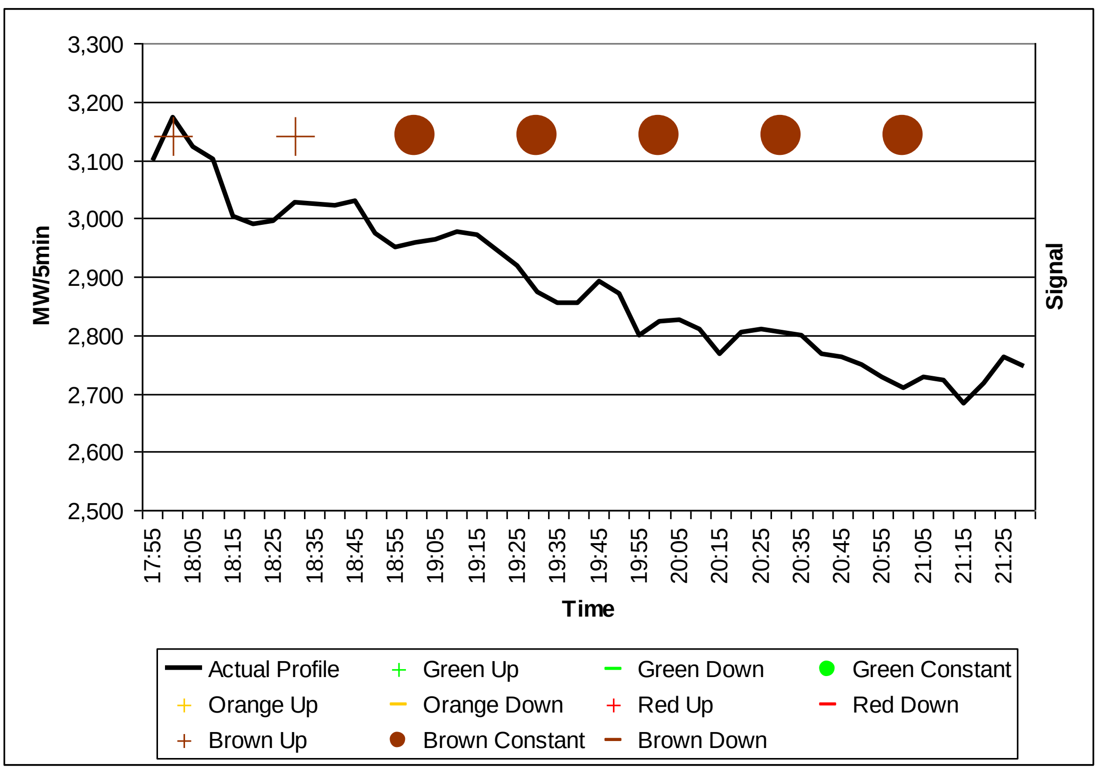


Figure 6-16: Demand profile of Friday 9th of June 2006

6.5.2 Methodology 2: July 2006

Figure 6-17 shows the impact achieved by Power Alert in July 2006. It was interesting to note in this figure that the impact of both green up and orange up messages was higher than the impact of red up. It did not make sense until the messages broadcasted on television related to the specific barometer level were considered.

With green up messages the public was requested to switch off lights and unused appliances. With orange up messages the public was requested to switch off lights, unused appliances and geysers. It is also seen that the impact of orange up messages was higher than the impact of green up messages. The red up message requested the public to switch off all appliances, heaters & stoves. No mention was made of lights or the geyser. The impact of those energy consumers appeared to be lost during red up strain levels.

It was therefore concluded that the public may have switched equipment off not due to the strain on the network (barometer level), but rather what they were asked to switch off.

Figure 6-18 shows the Power Alert impact for July 2006. The average impact for July was 120MW during the evening peak periods. No load shedding took place in July.

The second unit of Koeberg also came back on-line during the last week of July. The Power Alert messages were accordingly reduced from seven per evening to only two per evening. All the Power Alert messages during that time indicated green barometer levels.

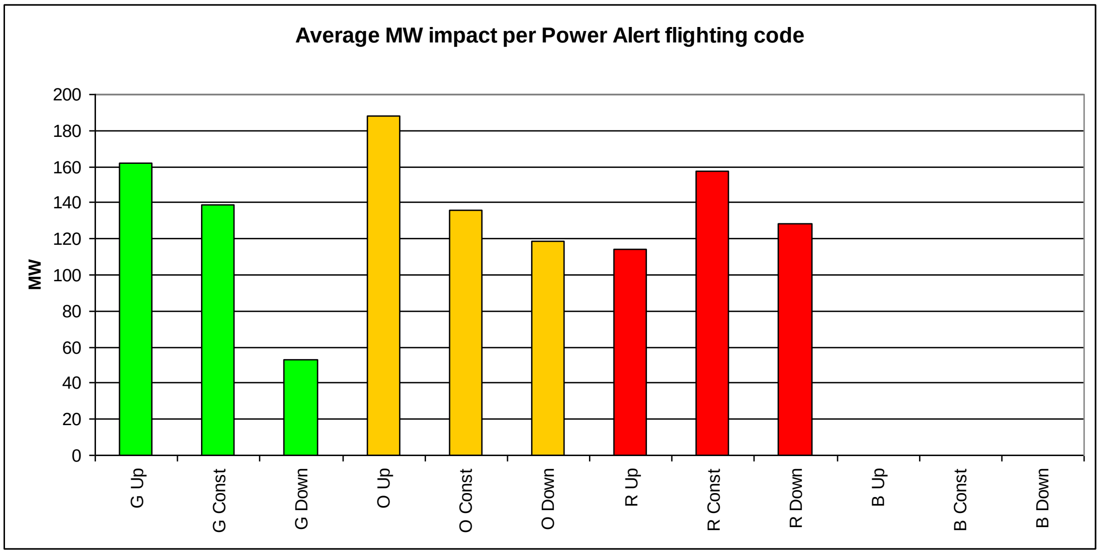


Figure 6-17: Impacts of Power Alert during July 2006

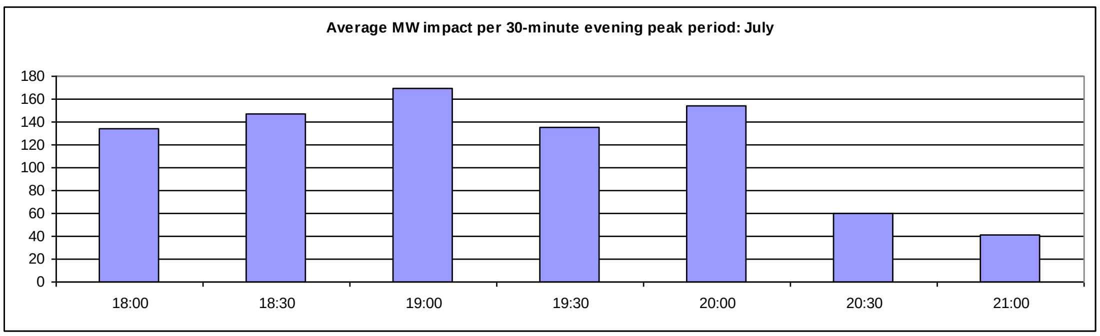


Figure 6-18: Average MW impacts: July 2006

Unlike the impacts calculated using Methodology 1, the impacts achieved during July were more than the impacts achieved in June. A possible reason is that the Eskom forecast used during this methodology was done in May which was two months earlier. That meant that external factors that were not expected at that stage actually made a change to the demand. Factors such as weather (cold fronts) and other factors that could not be forecasted could not be taken accurately into account with the lengthy forecast period.

6.6. Combined Average Impact Using Both Methodologies

Two completely separate methodologies were used to determine the impact of Power Alert. Both the methodologies indicated that there was an impact made. A question could arise as to which of the two methodologies could be trusted as the values obtained with the two methodologies are significantly different. The variation in values is in no way an indication that one of the two methodologies is more believable than the other. It is also impossible to tell which of the two methodologies are the more accurate of the two as the *true* impact made by Power Alert will never be known because one will never be able to say with 100% certainty what the load would have been if Power Alert was not implemented. What can be concluded from the impacts of the two methodologies is that small changes in the baseline and actual load have a significant impact on the determined savings especially since a small impact relative to the total load is being calculated. The only disqualifying criterion of any of the methodologies is the impact of the top-down M&V. The impacts of Power Alert alone could never be higher than the impacts of all the DSM interventions combined; the impacts as determine from the top-down M&V. With both the methodologies all the calculated impacts were always below the impacts of the DSM interventions. Neither of the methodologies could consequently be distrusted on this basis.

To avoid selecting only the highest value all the time, the average of the values of the two methodologies is taken as the most likely impact of Power Alert.

Figure 6-19 shows a summary of the combined average impacts of the two methodologies for June. Figure 6-20 shows a summary of the combined average impacts of the two methodologies for July.

As was mentioned earlier, the average impact from 18:00 to 21:00 using Methodology 1 for June was 178MW. Using Methodology 2 the average impact for June was 62MW.

The average impact of the two methodologies for June was 120MW. The maximum achieved impact for June based on the average of the two methodologies was 145MW at 19:00.

For July the average impact from 18:00 to 21:00 using Methodology 1 was 77MW and for Methodology 2 it was 118MW. The average between the two methodologies for July was 98MW. The maximum achieved impact for July based on the average of the two methodologies was 129MW at 19:00.

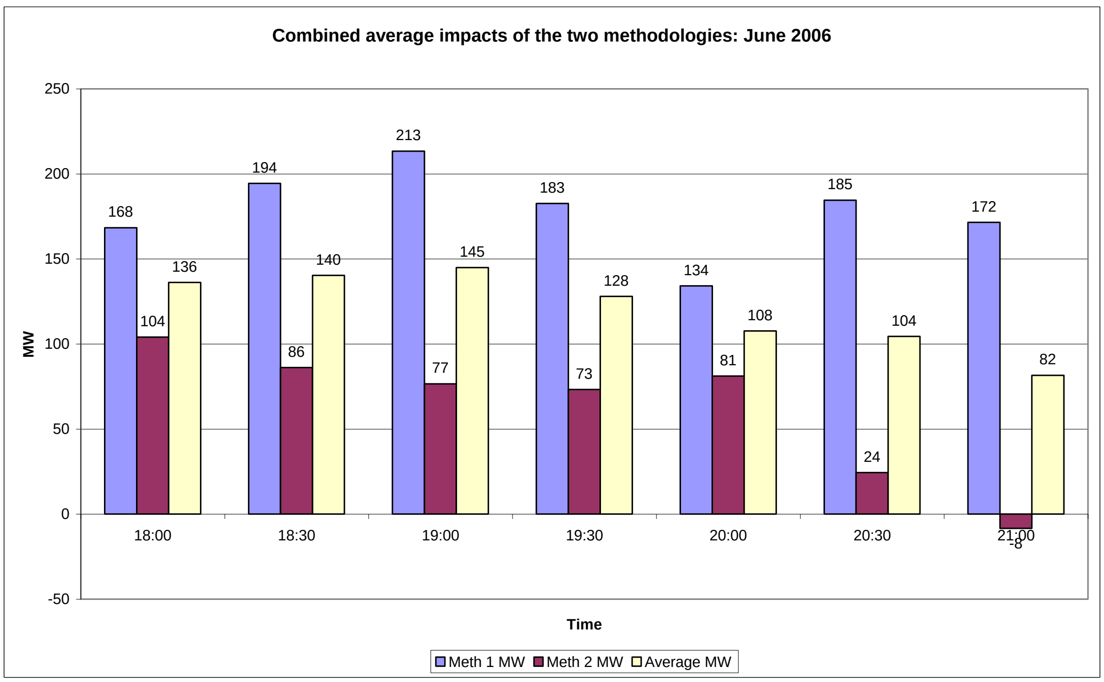


Figure 6-19: Combined average June impacts of the two methodologies in the evening peak

What is apparent from the impacts shown for both June and July is how the impacts increase as television viewers increase (18:00 to 19:00) and then decrease as television viewers decrease (19:300 to 21:00). Again this indicates that Western Cape residents participated and reacted to the Power Alert messages.

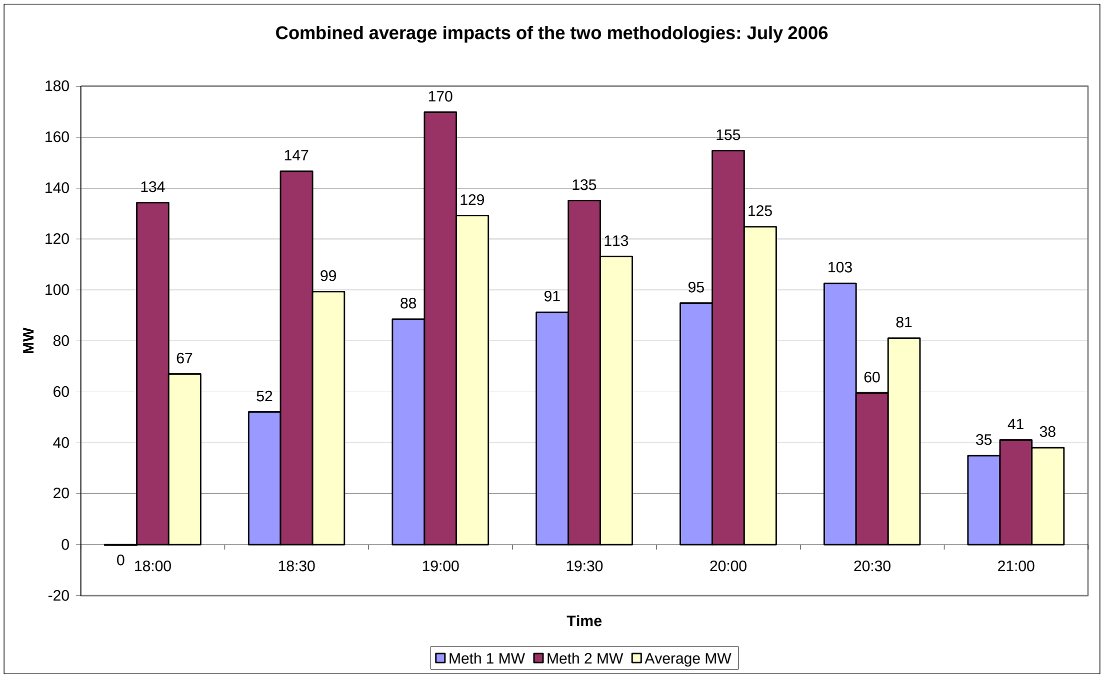


Figure 6-20: Combined average July impacts of the two methodologies in the evening peak

6.7. Lessons Learned

One of the most important lessons learned from the campaign was that people will not do what you expect them to do, but rather what you ask them to do.

During the proposal stages of the project it was assumed that the strain on the network will be low at 18:00. Messages were therefore based on this assumption in order to keep the messages on television as short as possible, but to maximise the impact achieved. Should the strain on the network increase during the evening, the messages would prompt for more equipment to be switched off so that the reduced load accumulates. Ideally, as shown in Figure 4-6, it was expected that the load would increase from 17:00 to 19:00, stabilise for a while, and decrease from around 20:00. The Power Alert message broadcasted would then be as follows:

18:00: Green Up - Please switch off non-essential appliances and lights.

18:30: Orange up - Switch off geysers, non-essential appliances and unnecessary lights

19:00: Red up - Switch off all appliances - heaters & stoves except the TV and essential lights.

At 19:00 the accumulated load reduction would be due to appliances, lights, geysers, heaters and stoves that have been switched off.

But what happened in reality? Normally when the network was not under strain at 18:00 chances were small that the strain on the network would increase from say a green to a red status level. When the network was under heavy strain at 18:00 no green or orange messages were broadcasted; red was immediately broadcasted.

It was assumed that people were aware of the risks associated with the heavy strain level at 18:00 and that they would act accordingly. Instead, the actual response was more related to what was asked rather than what was told about the strain on the network. They were told that the network was under strain, but was asked to *switch off all appliances (except the TV), heaters & stoves and essential lights.* The accumulation effect from green, orange to red was lost. People switched off appliances, heaters and stoves, but probably did not switch off geysers and unnecessary lights simply because they were not asked to do so! Figure 6-17 clearly shows that the impact achieved with orange up messages was more than the impact achieved with red up messages. Considering the impact and the message (rather than the barometer level) broadcasted, it could be expected because the public was asked to switch off geysers, appliances and lights in orange up messages.

In summary, the following should be kept in mind:

- Ask the people exactly what you want them to switch off. Be specific and as simple as possible; a blanket approach is not enough. And ask them again. And again. And yet again. “Please switch off your geysers.”
- Do not expect the people to know what you know. A red Power Alert barometer is critical. The strain on the network should be clear and the messages to which the people should respond should tie up with the strain level. The red level should ask for more equipment to be switched off rather than assuming that some equipment is already switched off.

6.8. Conclusions

In Chapter 3 it was found that an evening peak load management impact of 122MW was expected from Power Alert. Chapter 4 discussed the implementation and operation of Power Alert. This chapter aimed to determine what the true impact of Power Alert was.

Two methodologies to calculate the impacts were used. The impacts of the methodologies were also averaged to avoid being biased to the methodology that returned the highest impacts. The averaged impacts were presented as the true impacts of Power Alert.

The first methodology took the results from the top-down M&V (discussed in the previous chapter) as an input. The top-down M&V determined the impact of all DSM measures implemented. At the start of Power Alert no more DSM projects were being implemented and consequently, any increase in impacts would be due to Power Alert.

The second methodology made use of the official Eskom forecast. The forecast used for the calculations was the official forecast done on the 10th of May 2006. The reason for using this forecast was that it was the earliest forecast that included demands until end of August 2006 and was not influenced by Power Alert at all.

The impact of the two methodologies was averaged to avoid being biased towards the methodology that returned the highest impacts. It was found that the average impact for June was 120MW and for July it was 98MW. The maximum obtained impact was 145MW for June and 129MW for July. The impacts clearly show that Power Alert influenced the Western Cape residents and that they participated and reacted to the Power Alert messages and switched appliances off when requested. This was also proven by the low number of load shedding events that took place.

Furthermore, the impacts achieved were very close to the expected impacts found in the feasibility study presented in Chapter 3.

6.9. References

1 Mzi. Jun 2009. 'Why hike the price?' http://www.news24.com/Content/MyNews24/Letters/1050/cb2c9fb18b8043398d404b4f060e1c84/30-06-2009%2012-06/Why_hike_the_price Date of access: Jun 2009.

A summary of the study, final conclusions and recommendations made during this study are presented in this chapter. The chapter concludes with the unique contributions made through this study.

CHAPTER 7

Summary, Conclusions and Recommendations

CHAPTER 7 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1. Summary

The power utility of South Africa, Eskom, expected a supply shortfall of approximately 400MW between February and August 2006 in the Western Cape. The peak of the crisis was in mid-winter (June to August). This shortfall was firstly caused when Eskom experienced a breakdown on one of the two nuclear supply units. Secondly the remaining of the Koeberg units was due for refuelling which necessitated the shut-down of the reactor. No electricity was therefore generated by both units. It was clear that if electricity demand was not effectively curbed, extensive power outages would be experienced; which was the case.

To alleviate the crisis, Eskom could either construct new power stations or they could embark on an extensive DSM programme to curb demand. Given the short time period from when the crisis was forecasted until it would be realised, adding new supply capacity was not a viable solution. DSM was therefore critical in the short-term due to the long lead times when building new power plants. In this specific power crisis, short-term meant less than six months, i.e. a DSM intervention should be proposed, investigated, approved, implemented, and operational in less than six months.

A study was done to determine the time of day when a peak demand for electricity could be expected. Investigating the demand profile of the Western Cape revealed that the peak demand for electricity occurs between 18:00 and 20:00 – the traditional evening peak period. The rise in demand for electricity during this time is caused mainly by the residential sector. DSM measures therefore had to focus on load management technologies in the residential sector.

An extensive survey was done and presented in Chapter 2 to identify residential DSM measures that could alleviate the strain on the network during the evening peak over a wide area with the requirement that it should be developed, implemented and operational in less than six months. The survey revealed no existing residential DSM measure that could meet that requirement.

It was found from the survey that very little attention was given to human behaviour. Apart from some awareness campaigns, the human behaviour aspect was not well addressed as most of the DSM methodologies focused on technologies alone for load management. The home owners, it appeared, was just a resident in his own home, a mere user that could never be requested to switch appliances off when asked. No study or project was found that actively involved the home owner when it was really needed to assist with load management – switching off the right things in their homes at the right time to alleviate pressure on the electricity distribution network. A major gap was identified: To inform home owners in real-time on the status of the electricity network and requesting their assistance in alleviating the pressure on the network

A feasibility study, presented in Chapter 3, showed that a potential of 122MW through residential load management in the evening peak existed in the Western Cape.

A method to involve the Western Cape Residents in alleviating the pressure on the electricity supply network during the evening peak was researched and resulted in Power Alert. Power Alert was designed and implemented (Chapter 4) and operated through the 2006 Western Cape power crisis to address the residential load during the evening.

Chapter 6 focused on the development of two new methodologies to calculate the impact of a residential load management programme over a wide area. The two methodologies were an attempt to eliminate the reality of actual load variations on the value of the determined impact. The two methodologies were applied to actual data and the impacts achieved were calculated. The average of the two methodologies was calculated and those values were presented as the ultimate impact of Power Alert. . It was found that Power Alert achieved an average impact of 120MW in June and 98MW during July. The maximum impacts achieved by Power Alert for June was 145MW and 129MW in July. The load reductions objectives of Power Alert by reducing the Western Cape residential demand when the supply was under pressure were achieved. The success of the system (apart from calculated load reductions) was further demonstrated through the limited incidents of load shedding experienced compared to the expectations.

All stakeholders wanted to know whether the implemented DSM actions had any impacts, was the target of 400MW reached, and also, how much was actually saved. This is what M&V aims to do: Show how much energy has been saved. A top-down M&V methodology was developed and followed (Chapter 5) because various DSM measures were implemented over the whole area and baselines (and data) were not available for the individual sites. Isolation of the impacts of the different measures would be impossible due to the number of projects in the Western Cape and also because some of the measures involved behaviour changes in the area which are impossible to quantify.

The top-down M&V showed that in May the average weekday evening peak DSM impact was 317MW. The DSM impact over the same period increased to 497MW in June. An average weekday evening peak of 513MW was seen in the first two weeks of July (1 to 15 July) while the last two weeks (16 to 31 July) revealed an impact of 278MW. The decline was a result of the Koeberg unit being back in service from 24 July and certain DSM projects not operating as aggressive from 24 July 2006. From these results it could be concluded that the DSM interventions were successful as during peak times even more than 400MW load reduction was obtained. The results were confirmed by the low number of load shedding events that took place. Those events also only took place when a generator or other load supply was lost.

7.2. Conclusion

Power Alert proved to be a valuable tool to control the residential load during the evening peak. The public in the Western Cape responded to the Power Alert messages broadcasted on television and thereby kept power outages to a minimum during the winter. Power outages during the operational period of the PACC have occurred only when Koeberg tripped (8 & 9 June) and when one of the TX-lines tripped (22 June). Power Alert therefore contributed significantly to the 400MW that had to be saved to avoid power outages in the Western Cape. It was also seen that impacts achieved by Power Alert could only be sustained when the public was constantly reminded to conserve electricity.

7.3. Lessons Learned

One of the most important lessons learned from the campaign was that people will not do what you expect them to do, but rather, what you ask them to do.

During the proposal stages of the project it was assumed that the strain on the network will be low at 18:00. Messages were therefore based on this assumption in order to keep the messages on television as short as possible, but to maximise the impact achieved. Should the strain on the network increase during the evening, the messages would prompt for more equipment to be switched off so that the reduced load accumulates. Ideally it was expected that the load would increase from 18:00 to 19:00, stabilise after that and decrease from thereon. The Power Alert message broadcasted would then be as follows:

18:00: Green Up - Please switch off non-essential appliances and lights.

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- Do not expect the people to know what you know. A red Power Alert barometer is critical. The strain on the network should be clear and the messages to which the people should respond should tie up with the strain level. The red level should ask for more equipment to be switched off rather than assuming that some equipment is already switched off.

7.4. Recommendations

To sustain and improve the impacts achieved by Power Alert it is recommended that Power Alert be:

- Made a National campaign and requests via the television network to reduce load be made to the whole of South Africa during the evening.
- Extended to regional radio stations so that stressed regions could be more specifically targeted during times of high strain.
- Extended to the internet so that whoever is driven to do load reductions and does not have access to television or radio during working hours still is informed about the strain on the network. This will also create awareness of energy savings in the working place (commercial as well as industrial). Messages should be changed so that office related equipment (air-conditioners, excessive lights, or equipment that is not in use) is targeted.
- Extended to an SMS service to which energy conservers could subscribe and constantly be kept up to date on the strain of the network.
- Moved to National Control for ease of data collection and maintenance.

It is further recommended that:

- Power Alert messages broadcasted are made more specific and that blanket approaches should be avoided.

- The messages are critically evaluated so that requests to switch off equipment ties up with the status of the strain on the network.
- Regions are targeted by Power Alert as they are controlled by the different regional control centres.

7.5. Unique Contributions of this Study

The following were unique contributions as a result from this study:

- Development of a methodology to determine the feasibility to reduce residential load through a residential load management system such as Power Alert.
- A communication channel between South Africa's electricity utility (Eskom) and the general public that could be utilised in very short time periods to request load reduction of the public during high strain periods on the electricity distribution network by utilising the national broadcasters of South Africa.
- Development of a real-time interactive residential load management system to control the residential load.
- Development of a top-down M&V methodology to M&V the true impacts of various DSM measures and programmes implemented over a wide area where it is impossible to draw the M&V boundaries close to the intervention.
- Development of a performance assessment methodology to assess the true performance of a residential load management system (such as Power Alert) affecting behaviour of residents.