AN INTEGRATED APPROACH TO IMPLEMENT AND SUSTAIN ENERGY EFFICIENCY AND GREENHOUSE GAS MITIGATION IN SOUTH AFRICA

by

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...to the most precious persons in my life, my loving wife, Christina, and our beautiful daughter, Isabella.

ABSTRACT

Title: An integrated approach to implement and sustain energy efficiency and greenhouse gas mitigation in South Africa.

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South Africa is one of the most industrialised countries in Africa. The country is extremely energy-intensive for a number of reasons, which include a lack of awareness of energy efficiency and demand-side management (DSM), the low cost of electricity, the absence of energy conservation regulations and standards, lack of driving force, limited experience and track record of energy service companies as well as the financial viability of projects.

It is anticipated that South Africa will have run out of excess capacity by 2007, a fact that is forcing Eskom to take action to reduce peak demand by means of certain initiatives. This in turn has led to electricity becoming more expensive during certain periods of the day. The result is an increasing need for energy efficiency and demand-side management by end users, regulating bodies and Government. It is, however, critical that projects, implemented under the above-mentioned barriers, deliver impacts that can be sustained over time, otherwise the benefits would only be short-term and of no value to the stakeholders.

Measurement and verification are important and necessary aspects of any energy-efficiency, demand-side management or clean development mechanism (CDM) project. It allows for the objective quantification of the project's impacts by a third party, thus lending credibility to the project outcomes. Its greatest benefit, if conducted correctly, is the increased sustainability of projects and their impacts.

Energy efficiency also makes a direct contribution to the reduction of greenhouse gas emissions. The fact that South Africa is able to participate in greenhouse gas (GHG) mitigation through the clean development mechanism offers an opportunity to increase the financial viability of energy-efficiency projects, whilst achieving GHG mitigation. Once again measurement and verification would be critical to the success and sustainability of these energy-related greenhouse gas mitigation projects over time.

A need was subsequently identified to develop an integrated approach that provides a clear methodology that could be applied to accurately quantify and verify the savings and impacts that emanate from energy efficiency, demand-side management and greenhouse gas mitigation

projects. If applied correctly, the integrated approach would help with the sustainable implementation of energy efficiency, demand-side management and greenhouse gas mitigation projects in South Africa.

This study proposes such an integrated approach that provides a methodology that builds on international protocols. It provides a flexible, clear, accurate and transparent methodology to assist in the sustainable implementation of projects.

The integrated methodology has been accepted as the standard by which South Africa's parastatal utility, Eskom, prefers implementation together with measurement and verification on their DSM-funded projects. The approach has proved to be flexible, transparent and replicable. It has facilitated better project implementation on a number of occasions and proved to provide accurate and verified results to all the stakeholders, which include the demand impact during each time-of-use (TOU) period, the impact on electricity consumption, the impact on the monthly and annual electricity accounts of end users and the environmental impacts such as GHG emissions and water consumption.

OPSOMMING

Titel:	'n Geïntegreerde benadering energie effektiwiteit and groenhuis gas verminderings in Suid-Afrika te implementer en te volhou.
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Suid-Afrika is een van die mees geïndustrialiseerde lande in Afrika. Die land is uiters energie-intensief om verskeie redes, wat insluit 'n gebrek aan bewustheid van energie effektiwiteit en lasbeheer, die lae koste van elektrisiteit, 'n gebrek aan energie besparings regulasies en -standaarde, gebrek aan dryfkrag, beperkte ondervinding van energie diens maatskappye en die finansiële lewensvatbaarheid van projekte.

Daar word verwag dat Suid-Afrika se oortollige kapasiteit teen 2007 opgebruik sal wees wat Eskom dwing om stappe te doen om piekaanvraag deur middle van sekere insentiewe te verminder. Dit het daartoe gelei dat elektrisiteit duurder geword het gedurende sekere periodes van die dag. Die gevolg is 'n groeiende behoefte aan energie effektiwiteit en las beheer deur verbruikers, regulerende liggame en die Regering. Dit is egter belangrik dat projekte wat onderhewig aan die bogenoemde struikelblokke geïmplementeer word, resultate sal lewer wat volhoubaar sal wees oor tyd, andersins sal die voordele slegs korttermyn wees en van geen waarde vir belanghebbendes nie.

Meting en verifiëring is belangrike en nodige aspekte van enige energie effektiwiteit, las beheer of groenhuis gas verminderings projek. Dit maak voorsiening vir die objektiewe kwantifisering van die projekimpakte deur 'n objektiewe derde party en verleen dus integriteit aan die projekuitkomste. Die grootste voordeel, indien dit korrek toegepas word, is 'n verbetering in die volhoubaarheid van projekte en hul impakte.

Energie effektiwiteit lewer ook 'n direkte bydrae tot die vermindering van groenhuis gas emissies. Die feit dat Suid-Afrika aan groenhuis gas vermindering kan deelneem deur midde van die skoon ontwikkelingsmeganisme bied die geleentheid on die finasiële lewensvatbaarheid van energie effektiwiteit projekte te verhoog, terwyl groenhuis gas verminderings bereik word. Weer eens sal meting en verifiëring uiters belangrik wees vir die sukses en volhoubaareid van hierdie projekte oor tyd.

'n Behoefte is gevolglik geïdentifiseer om 'n geïntegreerde benadering te ontwikkel wat 'n duidelike metodologie sal bied wat toegepas kan word om akkurate kwantifisering van

projekimpakte moontlik te maak wat volg uit energie effektiwiteit, las beheer en groenhuis gas vermindering projekte. Indien die benadering korrek toegepas word, sal dit die volhoubare implementering van energie effektiwiteit-, las beheer- en groenhuis gas verminderings projekte in Suid-Afrika bevorder.

Hierdie studie stel so 'n geïntegreerde benadering voor wat 'n metodologie bied wat bou op internasionale protokolle vir die meting en verifiëring. Dit lewer 'n aanpasbare, duidelike, akkurate en deursigtige metodologie om te help met die volhoubare implementering van projekte.

Die geïntegreerde benadering is aanvaar as die standaard waarteen Suid-Afrika se elektrisiteitsvoorsiener, Eskom, implementering verkies tesame met meting en verifiëring op hul las beheer projekte. Die' benadering het getoon dat dit aanpasbaar, deursigtig en herhaalbaar is. Dit het beter projek implementering by verskeie geleenthede moontlik gemaak en bewys dat dit akkurate en geverifieerde resultate aan alle belangebbendes bied, wat insluit die las impak in kritiese periodes, die impak op elektrisiteitsverbruik, die impak op die maandelikse en jaarlikse elektrisiteitsrekening van verbruikers asook die omgewingsimpakte soos groenhuis gas emissies en water verbruik.

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- My daughter Isabella, the greatest joy one could ever know.

MAJOR CONTRIBUTIONS OF THIS STUDY

The major contributions of this study could be summarised as follows:

1. An extensive literature survey was conducted to identify the present barriers and the need for energy efficiency and greenhouse gas mitigation projects in South Africa and what the potential impacts could be if their implementation were increased and sustained.

2. An integrated approach is presented that allows for the accurate and repeatable measurement and verification of energy-efficiency project impacts, not only in an energy-efficiency scenario, but also under the current structure of clean development mechanism projects. It provides a clear methodology that could be followed to quantify and verify project impacts.

3. The integrated approach would help with the implementation of energy-efficiency projects in South Africa in the sense that it would facilitate better project and system design, allow for better determination of project impacts, increase the energy impacts through better knowledge of energy use, reduce the financial risk associated with projects and allow for the tracking of environmental impacts.

4. The integrated approach was tested in numerous case studies to determine its practical applicability. It was successfully applied to determine not only the electricity consumption, maximum demand and electricity cost-saving impacts of an energy-efficiency project, but also the environmental impacts required for clean development mechanism projects.

5. A selection model was developed during this study to assist in the determination of a scenario and the selection of projects from a large project pool that would best satisfy the set requirements of a project's financing party.

6. *Energy Engineering*, a respected international journal, requested that an article on the proposed methodology to measure and verify be published in their journal. The integrated approach thus came under review from international peers and was subsequently published in 2001.

7. The following articles have been published in international and accredited scientific journals on the proposed integrated approach or parts that relate to this study:

    - W.L.R. DEN HEIJER & L.J. GROBLER. 2001. The potential needs and barriers to emission trading, joint implementation and the clean development mechanism in South Africa. *Journal of Energy in Southern Africa*. 12 (2), May 2001.

- L.J. GROBLER, W.L.R & DEN HEIJER. 2001. Benchmarking, tracking and evaluation of energy cost and emission savings. *Energy Engineering, the Journal of the Association of Energy Engineers.* 98 (5).

- W.L.R. DEN HEIJER & L.J. GROBLER. 2002. The use of statistical sampling during the measurement and verification of the Kruger National Park lighting efficiency project. *Electricity & Control.* Jun.

- L.J. GROBLER & W.L.R. DEN HEIJER. 2002. The position of measurement and verification in DSM projects in South Africa. *Electricity & Control.* Aug.

- W.L.R. DEN HEIJER & L.J. GROBLER. 2003. The scenario development of the carbon emission offset projects for the 2002 World Summit on Sustainable Development. *Journal of Energy in Southern Africa.* Mar.

- W.L.R. DEN HEIJER & L.J. GROBLER. The development of a greenhouse gas emission footprint model for the 2002 World Summit on Sustainable Development. Paper awaiting publication in *Journal of Energy in Southern Africa.*

8. The following papers have been presented at international conferences on the proposed integrated approach or parts that relate to this study:

   - L.J. GROBLER & W.L.R. DEN HEIJER. 2001. The development of a carbon trading and evaluation system to be used in conjunction with the clean development mechanism- and joint implementation projects in Southern Africa. (Paper presented by Willem den Heijer at the International Conference on Domestic Use of Energy, Cape Town, April 2001.)

   - L.J. GROBLER & W.L.R. DEN HEIJER. 2002. The use of statistical sampling during the measuring and verification of the Kruger National Park lighting efficiency project. (Paper presented by Willem den Heijer at the International Conference on Domestic Use of Energy, Cape Town, April 2002.)

   - W.L.R. DEN HEIJER. 2003. The scenario development of the carbon emission offset projects for the 2002 World Summit on Sustainable Development. (Paper presented by Willem den Heijer at the International conference on Domestic Use of Energy, Cape Town, April 2003.)

   - W.L.R. DEN HEIJER & L.J. GROBLER. 2003. The development of a greenhouse gas emission footprint model for the 2002 World Summit on Sustainable Development.

(Paper presented by Willem den Heijer at the 2nd International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics, Victoria Falls, Zambia, June 2003.)

9. The proposed integrated approach has been fully or partially applied to the following demand-side management projects sponsored by Eskom:

   - Kruger National Park, South Africa – Lighting retrofit of tourist accommodation for the Skukuza, Satara and Letaba camps;
   - Civic Centre in Braamfontein, Johannesburg – Lighting retrofit of a commercial building;
   - The Carlton Centre in the Central Business District, Johannesburg - Lighting retrofit of a commercial building;
   - Harmony Gold's Elandsrand Gold Mine – Scheduling and load shifting of the cold-water pumping system;
   - Anglo Gold's Kopanang Gold Mine – Scheduling and load shifting of the cold-water pumping system;
   - Harmony Gold's Harmony 3 shaft Gold Mine – Scheduling and load shifting of the cold-water pumping system;
   - Harmony Gold's Bambanani Gold Mine – Scheduling and load shifting of the cold-water pumping system;
   - Harmony Gold's Masimong 4 shaft Gold Mine – Scheduling and load shifting of the cold-water pumping system;
   - The Technology Services International (TSI) head office building in Rosherville, Johannesburg – Energy efficiency and load shift retrofits on the heating, ventilation and air-conditioning system on the office building; and
   - The integrated approach is also currently being applied with great success by various other measurement and verification team members to fourteen other demand-side management and energy-efficiency projects throughout South Africa.

CONTENTS

NOMENCLATURE

Abbreviations:

AAU	Assigned amount unit
AE	Applicant entity
bbl/d	Barrels per day
bkWh	Billion kilowatt-hour
CDM	Clean development mechanism
CER	Certified emission reduction(s)
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of Parties
DB	Distribution board
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DNA	Designated national authority
DOE	Designated operational entity
DSM	Demand-side management
EB	Executive board of the clean development mechanism
EIA	Environmental impact assessment
ESCO	Energy service company
ET	Emission trading
FCCC	U.N. Framework Convention on Climate Change
FEMP	Monitoring and verification guidelines for federal energy management projects
GDP	Gross domestic product
GEF	Global environmental facility
Gg	Gigagrams
Gg/year	Gigagrams per year
GHG	Greenhouse gas
GWh	Gigawatt-hour
GWP	Global warming potential
HVAC	Heating, ventilation and air-conditioning
IET	International emission trading
IPCC	International Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol

JCL	Johannesburg Climate Legacy
JI	Joint implementation
kg	kilograms
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
M&E	Monitoring and evaluation
M&V	Measurement and verification
mmst	Million short tons
mmt	Million metric tons
MOP	Meeting of parties
MSGB	Multi-stakeholder governing body
MVC	Measurement and Verification Centre
MVSC	Measurement and Verification Steering Committee
MW	Megawatt
MWh	Megawatt-hour
N_2O	Nitrous oxide
NER	National Electricity Regulator
NRS	National recording system
PDD	Project design document
PP	Project participant
PRS	Project recording system
SD	Sustainable development
tCO_2e	Ton carbon dioxide equivalent
TSI	Technology Services International
TWG	Technical Working Group
UNFCCC	United Nations Framework Convention on Climate Change
USCSP	US Country Studies Program
WSSD	World Summit on Sustainable Development

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CHAPTER 1

Introduction

An important prerequisite for this study is to place the issues of energy efficiency in perspective for the South African situation. For this purpose Chapter 1 first provides an introduction to the study and states the needs and barriers to energy efficiency that need to be addressed. This chapter explains how this study addresses these issues, after which it proceeds to the objectives and scope of the study.

Chapter 1: Introduction

1.1 Background

Eskom, a parastatal electricity utility, currently generates approximately 95.7% of South Africa's electricity. The generation balance is made up of private generators (3.1%) and municipalities (1.2%) [1]. During 2002, the total electricity sold by Eskom was 187,957 GWh [2].

South Africa is one of the most industrialised countries in Africa. In comparison to developed countries, however, South Africa has lower levels of automobile and home appliance ownership per capita, and consumes a higher proportion of "non-commercial" energy. As a result, the country's per capita levels of energy consumption and energy-related carbon emissions, while higher than in most of Africa, are lower than in the United States of America and many other developed countries. Historically, South Africa has also been known as one of the countries with the lowest electricity prices in the world. This is mainly due to the country's large natural reserves of coal, uranium, liquid fuels and gas [3].

Another contributing factor to the low cost of electricity was the Government-driven objectives during the years spent in isolation due to international sanctions and the apartheid-inspired United Nations oil embargo. The energy policy of the South African Government before 1994 was driven by the following social imperatives [4]:

- Social security;
- self-sufficiency; and
- secrecy.

The excess capacity that Eskom has is a direct result of the above-mentioned imperatives of the pre-1994 government. The emphasis of energy policies before 1994 was more on the supply side.

However, this scenario has changed drastically with the election of a new government, which sought to shift the focus more to the demand-side or the end users. The Government subsequently developed the White Paper on Energy of 1998 [5]. This White Paper shifted the focus of Government and the electricity sector towards achieving the following objectives:

- Increasing access to affordable energy services;
- improving energy governance;
- stimulating economic development;
- managing energy-related environmental impacts; and
- securing supply through diversity.

The pre-1994 historical imperatives coupled with the low cost of electricity in South Africa have resulted in a lack of awareness in the field of energy efficiency and demand-side management (DSM). It is common for South African electrical end users to have oversized heating, ventilation and air-conditioning (HVAC) systems and inefficient lighting and water-heating systems for which the operational hours are not matched to the needs (i.e. operation for 24 hours of the day, but only needed for 10 hours during weekdays). International comparisons of energy intensities are determined by linking the overall output of the economy, the gross domestic product (GDP), and the total amount of energy consumed to produce that output. South Africa's economy is highly energy-intensive compared to many other countries in the world [6]. The energy-intensive nature of the South African economy can also be seen in the fact that the electricity sales growth has been consistently higher than the GDP [7].

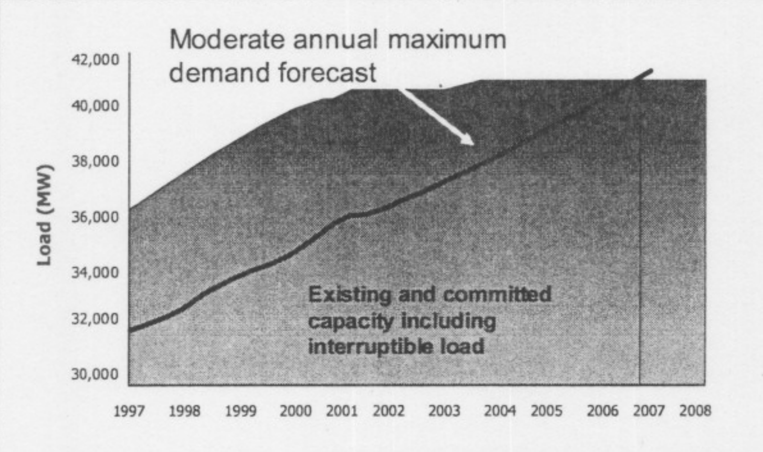

Figure 1.1: Eskom generation capacity position and long-term maximum demand forecast.

The looming deregulation of Eskom and the steady growth in electricity demand and consumption has, however, necessitated a greater need for action and awareness in the energy sector for both suppliers and end users. Eskom's residential electrification programmes have a target of 5 million additional connections by the year 2007 [7]. The expected annual growth rate in the residential sector alone is 15%. To make the situation worse, projections have estimated that Eskom will have run out of excess capacity by 2007. This can be seen in Figure 1.1, where the maximum demand forecast is shown against the available capacity. The lead times for new plant construction are lengthy - up to 10 years for pumped storage hydro capacity. The decision to build new capacity should therefore have been taken already. Energy efficiency and DSM become an extremely attractive alternative when considering the cost implications of new generation capacity provision. New generation capacity is inevitable, energy efficiency and DSM will, however, allow the utilities and end users to "buy time" whilst new generation capacity is being developed.

1.2 Need for energy efficiency

The growing electricity demand is, however, not the only problem facing South Africa. Energy efficiency has a very real and direct impact on the economy and environment. Millions of Rands are wasted every year on the demand side due to the inefficient use of electricity. Energy efficiency is one of the few variable costs in any operation that carry the benefits directly to the bottom line, saving the end user money and reducing the impacts on the environment.

The benefits of increased energy efficiency are numerous:

1. Energy efficiency saves the end user money. The price of electricity in South Africa has historically been low, but the situation is changing, with rising costs. Organisations will soon find that energy is becoming one of the important factors in their operational costs that could greatly influence the viability of production in certain markets.

2. Energy efficiency improves the environment through a reduction in the pollution and consumption of our natural resources. For each megawatt-hour (MWh) of electricity that a South African end user consumes, 0.53 tons of coal is burnt, 1,270 litres of water are consumed and 0.29 kg of relative particulate matter is emitted by local power stations [2].

3. Energy efficiency within an operation raises the awareness in the current energy use of the operation and often leads to the identification of additional actions that could be taken to further increase the efficient use of energy. This awareness would also lead to a better understanding of how an increase in fuel prices would affect the organisation.

4. Energy efficiency directly contributes to the reduction in certain greenhouse gas (GHG) emissions implicated in global warming and climate change. One of the most significant GHG culprits in global warming is carbon dioxide (CO_2). For each MWh that a power station generates and an end user consumes, 0.96 tons of CO_2 emissions will be released into the atmosphere [2].

1.3 Barriers to energy efficiency

The lack of awareness is probably the principal barrier to energy efficiency in South Africa. This lack of a "need" for energy efficiency has had the effect that there is a very limited pool of expertise in South Africa. The energy service companies (ESCOs) present in either South Africa or its neighbouring countries are not long-established with proven track records. The majority of these ESCOs have not been active for more than two years. The market is thus still in its infancy and often lacks the capacity to actively promote, develop and implement energy-efficiency solutions.

Another major barrier is the low cost of electricity in South Africa. This provides no incentive for the efficient use of energy on the one hand, and the installation of efficient energy production technologies on the other hand by the end user. The exclusion of external costs of electricity generation and the inclusion of subsidies in the tariffs distort the market price of electricity, a situation that reduces the tariffs to the extent that no economic incentives exist to influence investor and consumer behaviour to allocate their resources efficiently. Eskom's electricity price is among the lowest in the world, one of the reasons that hinder the installation of efficient energy-driven appliances on the demand side [6].

While most countries have energy conservation regulations, energy-efficiency standards in South Africa are lacking. There has been recognition over the past few years of the benefits that would accrue from the introduction of energy-efficiency standards, most have not been implemented. Barriers to improvements in energy efficiency include inadequate long-term policies and the absence of codes and standards [3]. However, the Department of Minerals and Energy (DME), as well as the National Electricity Regulator (NER), have expressed a need for increased energy efficiency, respectively through the White Paper on Energy and proposed policy changes for the electricity industry. This provided a clear signal that Government and regulating bodies support energy efficiency although the energy market in South Africa is still not sufficiently mature to achieve this.

Eskom is the principal driving force of DSM in South Africa. Energy efficiency unfortunately lacks the same driving force that DSM is experiencing. The reason is that the utility will lose revenue through reduced electricity consumption sales when energy efficiency increases. Eskom, however, only provides a financial incentive for DSM projects and not for projects that are exclusively energy-efficiency projects. It is, however, common that DSM projects have an energy-efficiency component.

Apart from the lack of driving force it is often found that large energy-efficiency projects are not driven by viable business cases. Energy efficiency offers the largest and most cost-effective opportunity for both industrialised and developing nations to limit the enormous financial, health and environmental costs associated with burning fossil fuels. Available global cost-effective investments in energy efficiency are estimated to be tens of billions of dollars per year [8]. However, the actual investment level is far less, representing only a fraction of the existing financially attractive opportunities for energy-saving investments. The viable projects often have input costs (or risks) that are simply too high for the clients to implement with confidence. A typical hurdle rate for an energy-efficiency project would be a 3-year payback period. This means that projects costing the end user R300 000 to implement need to save R100 000 per year to allow the client to pay for the complete project from his annual energy cost savings over a period of 3 years. The reasons for these poor business cases are the following:

1. The cost of technology is often expensive, resulting in substantial capital requirements to implement energy-efficiency projects; and

2. the price of electricity is too low to allow the project to pay for itself from the resulting energy savings. It is often the case that a project is not financially viable within South African borders, while a similar project results in an exceptional business opportunity when implemented in neighbouring countries that have much higher electricity tariffs.

1.4 Proposals to overcome the barriers

The cost of electricity is rising. This has prompted a slow but steady increase in the number of projects to be implemented to achieve DSM with an associated energy-efficiency component. The lack of awareness is, however, still contributing to the low national implementation rate of energy efficiency. Awareness needs to be improved amongst end users with regard to the benefits and potential impacts of energy efficiency. ESCOs also need to be trained and developed to deliver a competent service to these end users.

Energy is a necessary input in economic development due to the fact that an increase in energy consumption indicates economic development [6]. Although it is logically consistent that energy consumption tends to increase as the economy grows, it is not sufficient to rely on this conclusion if energy efficiency has not been taken into account. It is from this very point where long-term policies, codes and standards by Government and governing bodies would provide a much-needed boost to the energy-efficiency market. These policies would provide consumers and utilities with an incentive to implement energy efficiency and could result in a market-based driving force.

The financial feasibility of energy-efficiency projects is one of the major barriers that need to be overcome if the market in South Africa were to be stimulated in a sustainable manner. The cost of electricity is rising slowly but surely, but the rate is not sufficient to provide a market-driven force for the sustainable implementation of energy efficiency. Projects need to become "cheaper", or the financial benefits of energy efficiency would need to increase.

In order to deal with this problem and stimulate the market for energy efficiency, one should first look at another topical issue that has taken the world by storm. This issue is global warming, but more importantly, the Kyoto Protocol that was developed to address global warming. The introduction of market-based instruments, standards and regulations, voluntary agreements and the potential mitigation options at regional and global levels (e.g. the clean development mechanism) would substantially reduce GHG emissions.

The above-mentioned may provide incentives to consumers, ESCOs and utilities to install environmentally friendly and energy-efficient technologies. GHG mitigation can thus become a vehicle to make energy-efficiency projects more financially attractive, whilst at the same time stimulating the market with regard to increased and sustainable implementation. It has a significant positive impact on the business cases of projects where it could increase the internal rate of return by 5% [9].

Global warming and climate change have become imperative issues in recent years, sparking significant international efforts to reduce the emissions of greenhouse gases into the atmosphere. GHGs, such as carbon dioxide, methane (CH_4) and nitrous oxide (N_2O), have the function of trapping the heat that is released by the earth's surface into the atmosphere. Although it is impossible to connect any single weather event to global climate change, the past few years have been marked by a world-wide pattern of unusually severe weather, such as floods and droughts.

Energy is by far the largest source of GHG emissions in the world and South Africa in particular. A recent study by the United States Department of Energy showed that the energy sector contributed 75% of all anthropogenic CO_2 emissions [6]. An increase in energy efficiency directly leads to a reduction in CO_2 emissions, one of the major culprit greenhouse gases. The Kyoto Protocol enables South African end users to "sell" their reductions in CO_2 emissions to developed countries. This is achieved through the Kyoto Protocol where a developed country could invest in projects in a developing country that result in reductions in GHG emissions. The South African end user benefits by investment into its projects and the developing country could claim the GHG emission reductions against its offset targets. The above concepts are available in a number of flexibility mechanisms of the Kyoto Protocol (emissions trading, joint implementation and the clean development mechanism). The Kyoto Protocol will be discussed in more detail in the chapters that follow. The important aspect is, however, that the above concept could be an extremely valuable means of stimulating the South African energy-efficiency market by combining and structuring energy-efficiency projects to facilitate greenhouse gas mitigation in South Africa.

It all sounds very simple, but one major problem is that many of the issues under the Kyoto Protocol are still unresolved. Climate change is not seen as a problem in developing countries but the need to adopt policies and measures that could curb the currently debated problem is essential. GHG emissions in developing countries are increasing at an alarming rate and the expected impacts of climate change in these countries would be enormous [6]. South Africa needs to be proactive and ensure that systems are in place to facilitate GHG mitigation.

A structured approach to energy efficiency is required to overcome the barriers mentioned above. An integrated approach needs to be developed for the South African context that would stimulate the local energy-efficiency market. If this approach were applied correctly, energy efficiency would be sustained through proper implementation that correctly quantifies all project impacts for all the project stakeholders. The integrated approach would also promote the financial viability of energy-efficiency projects through the incorporation of greenhouse mitigation- "ready" or "friendly" procedures. This approach would provide stakeholders (the utility, client and ESCO) in energy efficiency with a clear set of procedures to implement their projects in such a manner that they could ascertain the financial and technical viability of the project through a third party. This would provide all the relevant data and information to assist in the eventual certification of emission reductions (if the project qualifies for greenhouse gas mitigation). This integrated approach would guide ESCOs and utilities when designing and implementing energy efficiency and greenhouse gas mitigation projects.

1.5 Objective of the study

The objective of the study is to propose an integrated approach to implement and sustain energy efficiency and greenhouse gas mitigation in South Africa.

1.6 Scope of the study

The scope of the study is to focus on the development of an integrated approach to implement and sustain energy-efficiency projects in South Africa, whilst using greenhouse gas mitigation as a tool to promote the implementation through increased financial viability and strengthened sustainability.

The scope includes project-related issues to increase sustainable implementation of energy efficiency, such as project screening, energy-efficiency project stages, greenhouse gas mitigation project stages and issues such as measurement and verification, monitoring and project baselines. Baselines will, however, be discussed in the context of the integrated approach and its application therein and not considered in detail as a separate entity.

1.7 Profile of the study

This thesis comprises of seven chapters, which are organised in a structured framework in an attempt to meet the above-stated objective.

Chapter 1 provides the introduction, background, objective and the scope of the study. A literature-based overview of the South African energy market is provided in Chapter 2. Chapter 2 also gives the rationale behind the Kyoto Protocol and its flexibility mechanism. The most critical mechanism for South Africa, namely the clean development mechanism, is discussed in more detail.

Chapter 3 looks at the implementation mechanisms for energy efficiency and DSM, as well as their project stages. This chapter also explains the need to place additional emphasis on the process of monitoring and verification.

Chapter 4 takes a closer look at measurement and verification and explains why it is critical that this forms part of any energy efficiency and DSM project.

Chapter 5 provides the proposed integrated approach to implement and sustain energy efficiency and greenhouse gas mitigation in South Africa.

Chapter 6 discusses two case studies relevant to the integrated approach. The first case study provides the process of linking project impacts to emission impacts relevant to GHG mitigation. It also looks at a proposed process to select a basket of projects most likely to suit the needs of a funding party or utility. This process was originally used for this purpose during the World Summit on Sustainable Development hosted in South Africa during 2001. The second case study provides a typical application of measurement and verification components of the integrated approach.

Chapter 7 presents a summary of the study together with its conclusions, contributions and its recommendations.

1.8 Summary

The following primary conclusions were reached for this chapter:

- The need for energy efficiency in South Africa is increasing and has been expressed by Government and regulating bodies;
- energy efficiency in South Africa is hampered by numerous factors, which include low electricity prices; a lack of awareness; inadequate long-term policies; absence of codes and standards; and the difficulty of obtaining financially sound business cases due to low electricity costs and high technology costs;
- greenhouse gas mitigation and the Kyoto Protocol can be used to simulate the energy efficiency market in South Africa; and
- an integrated approach is, however, required to stimulate and sustain the implementation of energy efficiency in South Africa. This integrated approach needs to be able to provide the relevant information and data needed for greenhouse gas mitigation projects to allow for the potential combination of the two.

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CHAPTER 2

The South African energy sector and the Kyoto Protocol

This chapter provides a literature-based overview of the South African energy sector and places it in context on an international and national level. The clean development mechanism is also described in the context of the Kyoto Protocol and its other flexibility mechanisms. The importance of CDM for South Africa is explained, together with an assessment of the potential impacts that could be achieved under an improved energy-efficiency scenario.

Chapter 2: The South African energy sector and the Kyoto Protocol

2.1 Introduction

Since the beginning of the twentieth century human activities have added 925 billion tons of CO_2 to the atmosphere [1]. CO_2 as well as other greenhouse gases, such as methane and nitrous oxide, have the function of trapping heat that is released by the earth's surface into the atmosphere. Although it is impossible to connect any single weather event to global climate change, the past few years have been marked by a world-wide pattern of unusually severe weather, such as floods and droughts.

The efforts to establish a global climate change agreement began in Toronto in 1988 and culminated in the development of the Kyoto Protocol. This Protocol focussed on approximately 168 industrialised countries (also known as Annex B countries) and set legally binding emission reductions (5.2% below 1990-levels on average) for the countries that ratify the Kyoto Protocol [2]. The Kyoto Protocol is seen as a decisive step regarding the issue of global climate change. Although many issues are still being developed, many countries have already started to take advantage of the flexibility mechanisms that the Protocol provides.

The problem of global warming and greenhouse gas emissions is, however, far from being solved. The deficiency of the Kyoto Protocol figures can be seen when compared with what is eventually needed to stabilise CO_2 concentrations and avoid global warming and climate change. According to the International Panel on Climate Change (IPCC), the official scientific body that advises the Conference of Parties, the amount of reduction that would eventually be required is not 5.2%, but 60 to 80% below the 1990-levels for industrialised countries [1].

When emissions of developing countries are added to those of industrialised countries covered by the Protocol, the global total is projected at some 30% above the 1990-level by 2010 if developing countries continue to emit at the present rate. This means that developing countries also need to get their house in order and join in the issue of climate change. It also means that future emission reduction targets would become increasingly strict and demanding. It is for these reasons that South Africa has to start early in the development of structures dealing with climate change and emission reduction issues, all within the framework of the Protocol. Electricity consumption is the largest contributor to GHG emissions in South Africa (as shown later in this chapter). South Africa could greatly benefit from an integrated approach to stimulate the implementation and sustainability of the energy-efficiency and greenhouse gas markets.

Flexibility mechanisms were included in the Kyoto Protocol to make it less expensive for an Annex B country to meet the Protocol's goals by utilising the mechanisms in other countries if domestic actions were too expensive or limited. These mechanisms include the use of "sinks" for carbon sequestration, emission trading, the clean development mechanism and joint implementation (JI). It is through these flexibility mechanisms that South Africa could become part of the global climate change initiative.

South Africa ratified the United Nations Framework Convention on Climate Change in 1997. This ratification admitted South Africa as a full member to the Convention for the first time at the Third Conference of Parties held in Kyoto, Japan, during December 1997. Prior to that, South Africa had had only observer status and therefore no say in the proceedings. Because South Africa has ratified the UNFCCC as a Non-Annex B (developing) country, it is therefore not subject to mandatory emission limitations and reductions. The South African Government ratified the Kyoto Protocol during March 2002 without debate and with full consensus [3]. The ratification showed a clear support of GHG mitigation in South Africa.

This chapter will firstly focus on South Africa's position with regard to national energy use and GHG emissions. It will then describe the global perspective towards greenhouse gas emissions and provide a brief description of the global warming problem and the Kyoto Protocol. The global positions of some of the major industrialised countries are stated. International actions to address climate change and greenhouse gas emissions are briefly discussed as well as the actions that South Africa needs to take. The needs and barriers that have to be addressed are then identified for South Africa. To conclude the chapter the potential markets for the CDM in the country are discussed.

2.2 Overview of the South African position

Approximately 75% of South Africa's primary energy comes from indigenous coal. Another 10% comes from imported crude oil. South Africa also exports over 60 million tons of coal annually, contributing significantly to foreign exchange earnings. Coal is the primary fuel produced and consumed in this country. South Africa is responsible for more than 90% of all burnt coal in Africa. The country is the third leading coal exporter in the world, and coal is its second largest foreign exchange earner after gold. The estimated domestic consumption of coal was 177.1 million metric short tons (mmst) in 1998 [4]. The majority of domestic consumption is coal used to produce steam for electricity generation. Other major coal-consuming sectors include gold mining, the cement industry as well as the brick and tile industry.

The parastatal utility Eskom generates nearly all (approximately 95%) of South Africa's electricity. It has a generating capacity of 36,500 MW, which is primarily coal-fired, but also includes one opposed to undertaking equivalent domestic actions and projects. It is for these reasons that South Africa holds great potential for CDM and JI projects. In order to gain from this situation, the country must be prepared for international emission trading and related projects.

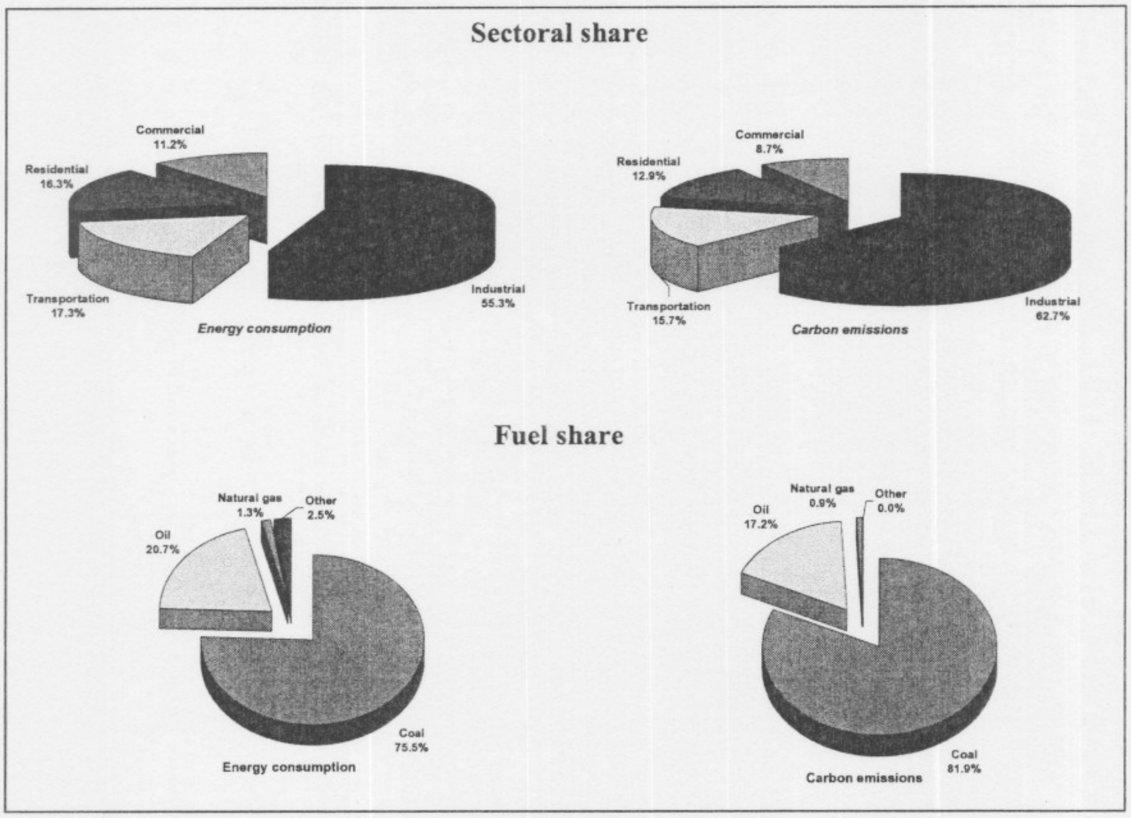

Figure 2.1: Sectoral and fuel share of annual energy consumption and carbon emissions in South Africa [4].

Table 2.1 provides a more detailed breakdown of the South African energy balances for energy use for 1997 (the most recent year for which such a detailed breakdown is available) [4]. From the data in Table 2.1 it can be seen that the South African industrial sector poses the largest potential for electricity consumption reductions, which would result in the largest emission reductions due to decreased electricity requirements. These emission reductions do not include the reduction decreases due to process changes in the industry itself. The potential emission reductions then become even larger.

Table 2.1 shows that for sectors burning their own coal for energy, the chemical and petrochemical sector is the largest user, followed by the iron and steel industry. Road vehicles are the largest consumers of petroleum products for energy. Gas use for energy purposes are relatively small compared to other fuels. Here the iron and steel industry is again the largest consumer. If electricity from utilities were considered, the mining and quarrying industry is the largest consumer, followed by non-specified industry and the iron and steel industry. The residential sector is the largest single consumer of energy generated by utilities. This large consumption of the residential sector, however, comprises a large number of small users. This would make reductions more difficult to achieve than would be the case for sectors such as mining or the iron and steel industry.

The Kyoto Protocol requires that Annex B countries reduce their GHG emissions with 5.2% on average below the 1990 levels. If such a 5.2% reduction in carbon dioxide were achieved across the spectrum of South African energy-consuming sectors, it can be seen from Table 2.1 that the largest single reductions would firstly be achieved in the non-specified industrial sector. The residential sector, the mining and quarrying sector and the iron and steel industry respectively follow this.

Figure 2.2 illustrates which sectors are the largest consumers of energy in South Africa. In order to determine the potential value of these CO_2 reductions, an average price of R 27.98 (US$4.00 [7] at an exchange rate of R 6.98 per US$1) per CER unit was assigned. This value was applied to the 5% CO_2 emission reductions from Table 2.1. It can be seen that the potential market value of CDM projects to South Africa is approximately R 350 million per year.

The above estimation could, however, drastically change as countries start to implement and utilise the available flexibility mechanism. The Dutch Carbon Credits Purchase has completed transactions for carbon credits resulting from CDM for between US$ 3 to US$ 9 per ton of CO_2e (tCO_2e) [8]. The UK Emission Trading Scheme traded at a price of US$ 9/tCO2e. This price doubled between April and September 2002, reaching between US$ 8-16/tCO_2e [8]. The World Bank Prototype Carbon Fund expects to pay around US$ 3/tCO_2e [8]. It can thus be seen that there exists no set price for the trade in CERs and that this price would be governed through normal markets of supply and demand.

Table 2.1: South African balances for electrical energy and resulting emissions per year [9].

Description		Energy Balance [TJ]				Total energy balance for all fuels [TJ]	Total CO_2 emissions [ton]	5% CO_2 emission reduction [ton]	Emission value due to reductions [Rand]	Additional cost savings due to energy reductions [Rand]
		Coal	Petroleum products	Gas	Electricity					
Industry sector		**620,359**	**72,595**	**28,468**	**329,507**	**1,050,929**	**146,043,076**	**7,302,154**	**203,876,135**	**1,509,268,082**
	Iron and steel	134,172	-	8,372	64,349	206,893	29,062,144	1,453,107	40,570,753	261,584,224
	Chemical and petrochemical	242,283	-	2,948	9,133	254,364	25,332,357	1,266,618	35,363,970	79,287,243
	Non-ferrous metals	-	-	1,230	52,501	53,731	13,072,010	653,601	18,248,527	184,460,993
	Non-metallic minerals	28,942	-	5,918	4,276	39,136	4,097,075	204,854	5,719,517	30,265,911
	Transport equipment	-	-	174	38	212	18,224	911	25,441	436,281
	Machinery	-	-	5,414	458	5,872	387,549	19,377	541,019	11,059,491
	Mining and quarrying	33,691	20,453	549	109,405	164,098	31,526,927	1,576,346	44,011,590	444,991,270
	Food and tobacco	-	-	1,181	1,941	3,122	540,762	27,038	754,904	8,805,692
	Paper pulp and print	-	-	393	3,706	4,099	938,240	46,912	1,309,784	13,556,442
	Wood and wood products	-	-	879	2,146	3,025	576,274	28,814	804,478	8,989,356
	Construction	-	14,260	-	60	14,320	852,500	42,625	1,190,091	40,802,513
	Textile and leather	-	-	20	1,849	1,869	459,195	22,960	641,036	6,455,633
	Non-specified (industry)	181,272	37,876	1,391	79,645	300,184	39,179,611	1,958,981	54,694,737	418,557,879
Transport sector		**45**	**567,087**	**12**	**16,425**	**583,569**	**37,385,670**	**1,869,283**	**52,190,395**	**1,671,400,031**
	International civil aviation	-	-	-	-	-	-	-	-	-
	Domestic air transport	-	28,248	12	-	28,260	1,659,895	82,995	2,317,213	80,435,007
	Road	-	479,313	-	28	479,341	28,161,784	1,408,089	39,313,850	1,364,564,976
	Rail	-	7,498	-	12,185	19,683	3,459,876	172,994	4,829,986	63,657,085
	Pipeline transport	-	-	-	239	239	59,224	2,961	82,677	829,928
	Internal navigation	-	-	-	-	-	-	-	-	-
	Non-specified (transport	45	52,028	-	3,973	56,046	4,044,891	202,245	5,646,668	161,913,035
Other sectors		**103,863**	**90,700**	**1,415**	**210,465**	**406,443**	**67,378,012**	**3,368,901**	**94,059,705**	**1,009,695,095**
	Agriculture	6,498	57,655	-	20,304	84,457	9,032,697	451,635	12,609,645	235,770,637
	Commerce and public services	36,815	1,226	902	79,686	118,429	23,327,644	1,166,382	32,565,391	288,187,549
	Residential	60,750	31,820	512	110,476	203,558	35,017,927	1,750,896	48,885,026	485,741,479
	Non-specified (other)	-	-	-	-	-	-	-	-	-
	Total	**724,267**	**730,382**	**29,895**	**556,397**	**2,040,941**	**250,806,758**	**12,540,338**	**350,126,235**	**4,190,363,208**

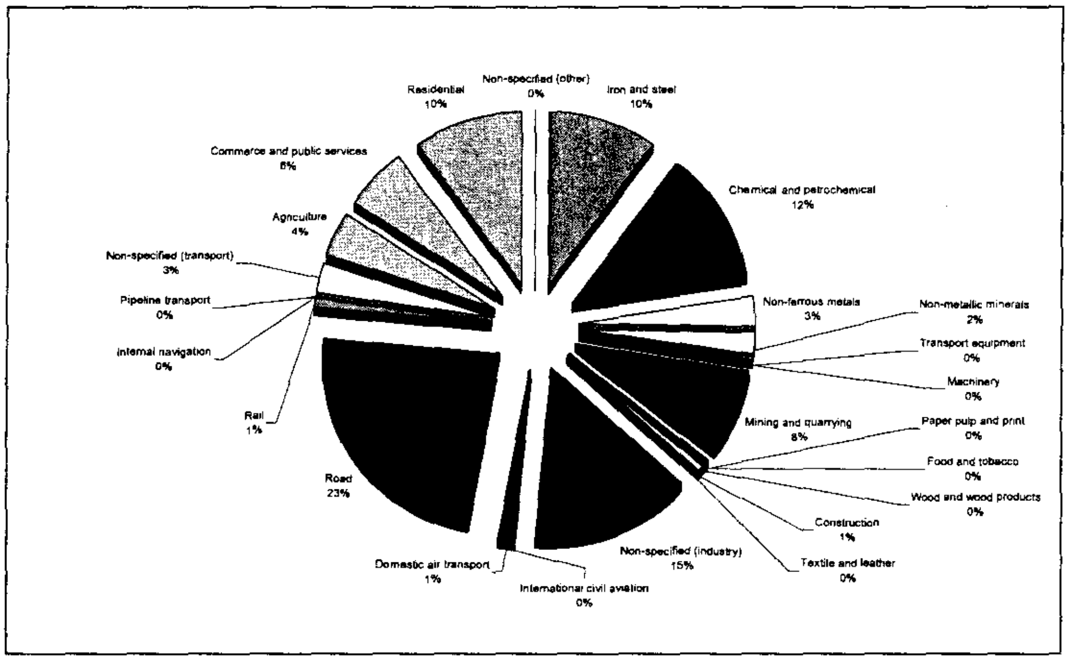

Figure 2.2: Breakdown of the total annual South African energy balances per sector for all fuels [9].

In addition to the value of the CER units and their potential market value, the various sectors would also directly benefit from the reduced energy use from the different fuels, such as liquid

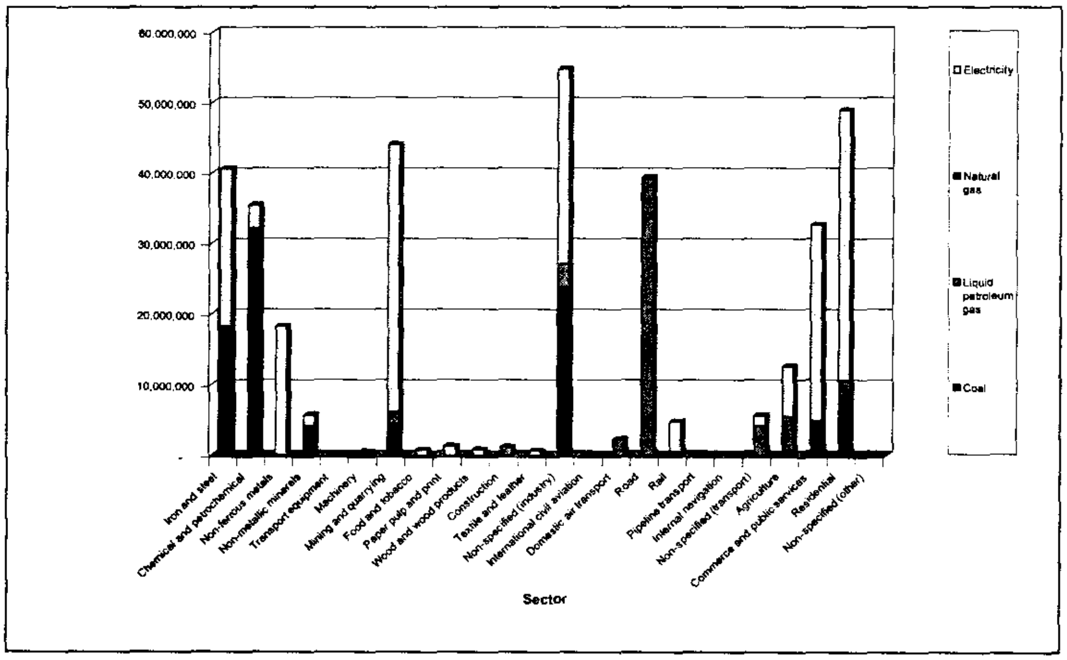

Figure 2.3: Cost potential per year for a 5% CO_2 emission reduction for all sectors for the different fuels.

petroleum gas, coal, natural gas and generated electricity [10]. The potential savings in fuel and electricity costs due to a conservative 5% consumption reduction are estimated at approximately R 4.2 billion per year.

2.3 Why emission reductions?

The danger of increased greenhouse gas emissions is global warming, which in turn affects weather conditions. In the long term the earth must shed energy into space at the same rate that it absorbs energy from the sun. Solar energy in the form of short-wave radiation heats the earth's surface. The earth sheds this energy, which is then absorbed into the atmosphere by water vapour, CO_2 and other greenhouse gases. These gases prevent energy from passing directly from the surface into space, but rather transport it higher into the atmosphere from where it radiates into space. This slower, more indirect process serves to create a blanket around the earth. Without it, the earth's surface would be some 30° C colder than it is today [11].

By increasing the atmosphere's ability to absorb infrared energy, greenhouse gas emissions are disturbing the way that the climate maintains this balance between incoming and outgoing energy. The most direct result is likely to be a global warming of 1.5°C to 4.5°C over the next century [11]. The effects can also be seen in more severe weather conditions, floods, droughts and the rising of the sea level.

2.4 Global perspective

Industrialised countries are responsible for 74% of carbon emitted since 1950 [12]. These countries produce 60% of today's annual emissions. While developing countries have been responsible for only 26% of carbon emissions since 1950, it is estimated that the projected carbon output of developing countries will, in the absence of any new policies and actions, outgrow that of the industrialised countries as early as 2020.

Until now, developed countries have been the major sources of emissions. In future large developing countries, such as China, will be an increasingly important source of emissions. These countries argue that if the world has to reduce emissions of carbon dioxide and other greenhouse gases, the United States of America, Europe and Japan should reduce the most [12]. For years, they argue, these developed countries have been the largest emitters and they have already enjoyed the associated benefits of economic development. Whilst this is true, developing countries could also help by doing more to control population growth.

World carbon emission for 1998 was 6,124 million metric tons (mmt), 2,658 mmt due to petroleum, 1,264 mmt due to natural gas and 2,202 mmt due to coal. If total carbon emissions were considered, Canada contributed 2.3%, the U.S.A. 24% and Germany 3.7%. Africa was responsible for 3.9% and South Africa for 1.7% [6]. The official plan produced by the White House in July 1998 would achieve up to 75% of the U.S.A. reduction requirement by purchasing allowances through the Kyoto Protocol flexibility mechanism, namely emission trading, JI and CDM projects [1]. This is where South Africa could benefit from energy-efficiency improvements linked to CDM. Fossil fuels account for 75 to 80% of human's CO_2 emissions and contributed some 6 billion tons of carbon to the atmosphere in 1990 [12]. The contribution is now in excess of 6.3 billion tons and is still increasing.

Industrial energy use accounts for nearly 30% of the total greenhouse gas emissions [13]. These emissions primarily result from electricity use, product transportation, the burning of fossil fuels to power boilers and produce steam, and the use of gasoline to power vehicle fleets. Some industrial processes also produce greenhouse gases. There are many cost-effective opportunities for industry to reduce these emissions and minimise its impact on the climate.

At global level, countries around the world have expressed a firm commitment to strengthen international responses to the risks of climate change. The U.S.A. is working to strengthen international action and broaden participation under the auspices of the Framework Convention on Climate Change. A large number of emission trading, JI and CDM projects are being initiated around the world each year. However, many key issues still need to be addressed with regard to the flexibility mechanisms.

2.5 The Kyoto Protocol

The efforts to establish a global climate agreement began in 1988 in Toronto with a major scientific conference, which called for a 20% cut in CO_2 emissions by 2005 [1]. At the 1992 Earth Summit in Rio de Janeiro, the Framework Convention on Climate Change was forged, but did not include legally binding limits. The climate treaty culminated in the signing of a protocol to the convention that included legally binding emission limits in Kyoto, Japan, in December 1997. The Kyoto Protocol focussed on approximately 168 industrialised countries. The Conference of Parties (COP) then convened in Buenos Aires in November 1998 to address key issues that were seen as major weaknesses in the Protocol.

The Kyoto Protocol was a landmark development in the history of climate change, creating not only the precedent for binding emission reductions for developed countries, but also mechanisms that enable such reductions to be undertaken cost-effectively and supportive of sustainable development.

The Kyoto Protocol requires that all Annex B parties reduce their fossil fuel emissions by 5.2% on average below their 1990 emission levels. The U.S.A. has to reduce its emissions with 7% below its 1990 levels, while Australia could increase their emissions with up to 8% above the 1990-levels [2]. These reductions have to be achieved by 2010 with a measurement period that extends from 2008 – 2012. The Kyoto Protocol also requires that all countries ratifying the Protocol have a national recording system (NRS) in place for estimating emissions and removals by 2008, at which time the inventories must be submitted [14].

Under the Kyoto Protocol, parties that sign will ensure that emission of specified greenhouse gases do not exceed assigned amounts. The assigned amounts, which are listed in Annex B of the Protocol, are expressed as a percentage of the base year (1990) emissions. The assigned amount for the majority of countries is 92% (thus a 8% reduction below 1990 base year levels), but a number of countries negotiated targets above this level. Some examples are given below.

Table 2.1: Emission limitations for some Annex B countries negotiated at Kyoto.

Country	**Emission limitation (or reduction commitment)**
Australia	108%
Canada	94%
Croatia	95%
Hungary	94%
Iceland	110%
Japan	94%
New Zealand	100%
Norway	101%
Poland	94%
Russian Federation	100%
Ukraine	100%
United States of America	93%

The Kyoto Protocol requires that the United States of America achieve a decrease in greenhouse gas emission of 7% below the 1990-level by 2010 with a measurement period that extends from 2008 – 2012. As a compromise to a proposed earlier deadline, however, the Protocol requires that Annex B countries shall have made "demonstrable progress" in achieving their commitments by 2005.

2.6 *Annex B and Annex 1 countries*

Annex I countries are the 36 industrialised countries and economies in transition listed in Annex I of the United Nations Framework Convention on Climate Change (UNFCCC). Their responsibilities under the Convention are various, and include a non-binding commitment to reduce their greenhouse gas emissions to 1990-levels by the year 2000 [15].

Annex B countries are the 39 emission-capped industrialised (developed) countries and economies in transition listed in Annex B of the Kyoto Protocol. Legally binding emission reduction obligations for Annex B countries range from an 8% decrease (e.g. various European nations) to a 10% increase (Iceland) in relation to 1990-levels during the first commitment period from 2008 to 2012 [15].

In practice, Annex I of the Convention and Annex B of the Kyoto Protocol are used almost interchangeably. However, strictly speaking, it is the Annex I countries that could invest in clean development mechanism projects as well as host JI projects, and non-Annex I countries that could host CDM projects. This is true, despite the fact that it is Annex B countries that have emission reduction obligations under the Kyoto Protocol.

Non-Annex B countries are those countries that do not currently have binding emission reduction targets, namely most developing countries. These are basically the same countries as Non-Annex 1 countries, which are not included in Annex 1 of the UNFCCC, which was the forerunner convention of the Kyoto Protocol.

Under the UNFCCC, South Africa is classified as a developing country (Non-Annex I country). Under the Kyoto Protocol, South Africa is classified as a Non-Annex B country, which allows it to only participate in one of the three Kyoto mechanisms, namely the CDM. South Africa does not have any commitment in terms of emissions limits, as is the case with Annex B countries. Because South Africa ratified the Protocol it now has permission under the Kyoto Protocol to host CDM projects. South Africa companies would, however, be allowed to initiate and implement their own CDM projects as long as it has a company from an Annex B country in partnership in the project. South African companies can therefore also indirectly sell the credits generated through these CDM projects on the international emission trading (IET) market through their project partner company from an Annex B country.

2.7 *Flexibility mechanisms of the Kyoto Protocol*

Flexibility mechanisms were built into the Kyoto Protocol to promote flexibility and cost-effectiveness for developed nations and to provide incentives for developing countries to participate in global emission reductions without actually being compelled to do so [16]. These flexibility mechanisms are emission trading, the clean development mechanism, joint implementation and the use of emission sinks.

The first flexibility mechanism of the Kyoto Protocol is emission trading. Emission trading allows an Annex B country with an excess of emission units, presumably from reducing emissions below commitment levels, to sell its credits to another Annex B country unable to meet its commitments. It is stipulated that emission trading should be supplemental to domestic actions to meet emission reduction requirements. In order for developing countries to participate in the trading regime, they would most likely have to assume emission limitations under the Kyoto Protocol [17].

The clean development mechanism allows industrialised countries to implement emission reduction projects in developing countries in order to meet their emission objectives. CDM promotes sustainable development. In contrast, the purpose of JI, according to the Protocol, is simply to help Annex B countries meet their emission commitments. There are several discrepancies in the construction of the clause on CDM compared with the other flexibility mechanisms. There is no requirement that CDM activities be "supplemental" to domestic actions. Therefore, an Annex B country could forego domestic measures completely and use credits obtained through the CDM to meet its obligations. The clause on CDM differs because parties could start acquiring certified emission reduction (CER) credits in 2000 as opposed to JI projects that do not start accruing until the beginning of the first commitment period in 2008 [17]. CDM projects are monitored on a project-by-project level [15].

Joint implementation allows Annex B countries of the Protocol to work together to meet their emission targets. They may acquire or transfer assigned amount units (AAU) resulting from projects and activities implemented in other Annex B countries. The Protocol states that JI projects must be supplemental to any domestic actions to reduce emissions [17]. South Africa is not an Annex B country since it has not accepted binding emission reduction targets under the Kyoto Protocol as a developing country. For this reason JI projects are of little relevance for South Africa. Actions implemented jointly (AIJ) were established at the first Conference of Parties as a pilot phase of joint implementation.

Carbon sequestration with "sinks" is another flexibility mechanism. Sequestration is defined as the natural biogenic process where atmospheric CO_2 is removed and stored by trees and other plants, which are referred to as "carbon sinks" [17]. These carbon sinks can be used to offset some of the projected increases in a party's carbon dioxide and other GHG emissions. Carbon sequestration may be accomplished through forest preservation to reduce deforestation; forest management techniques to enhance existing carbon sinks; creating new carbon sinks by cultivating pasture, agricultural land, or degraded forest sites; and storing carbon in wood products. The use of "sinks" in JI and CDM still needs to be addressed at a future conference of parties.

A number of successful emissions trading, CDM and JI projects have been undertaken internationally. The majority of these projects focus on efficiency improvements or fuel switching at utility companies. Other projects that have also proven successful are the development and management of carbon sinks or forests that sequestrate GHG emissions. The introduction of these flexibility mechanisms has opened up the possibility for South Africa to become part of the global emission trading market through CDM projects.

2.8 What is happening internationally?

Due to the nature of global warming and climate change, a large number of international actions are being initiated annually. Countries from around the world are working together to share technologies, resources and talent to lower greenhouse gas emissions and reduce the threat of global climate change.

The United States of America, for instance, participates in and supports several international efforts designed to address climate change. The US Countries Studies Program [18] has provided developing countries with funding and technical assistance to support the development of greenhouse gas inventories and make future projections of GHG emission levels for their countries, identifying and evaluating options for controlling GHG emissions and for increasing GHG emission sinks.

Assistance was also provided to support mitigation assessments, vulnerability and adaptation response assessments and national action plans for addressing climate change in their own countries, and to assessing related technological needs that increase public understanding of climate change [18]. Through the development process, states identify strategies that are tailored to their specific circumstances and needs.

In the mitigation assessments, countries identify and evaluate technology and policy options to reduce greenhouse gas emissions and sequester carbon. It basically helps countries to identify and evaluate short and long-term options to reduce greenhouse gas emissions. Mitigation assessments also address specific technical, market, or economic conditions that could hinder the widespread implementation of emission reduction technologies or practices.

The vulnerability assessments focussed on the vulnerability of the climate-sensitive resources of countries to determine what the potential physical and economic impacts of climate change would be for each country. The adaptation assessments served to determine what steps each country could take to respond to the physical impacts of climate change. The formulated action plans would help countries to implement a portfolio of mitigation and adaptation measures.

International efforts are also underway to establish guidelines for land use; land use change and forestry practices that reduce greenhouse gas emissions and increase carbon sinks. The key to successful co-operation is activities that would help all countries - developed and developing - to achieve their economic, environmental and developmental goals in a climate-friendly manner.

Emphasis is also placed on technology development and co-operation where it would have an optimum environmental effect. To a large degree this would call for technological co-operation between nations, the private sector, non-governmental organisations and international organisations. International efforts are focussing on programmes that facilitate the management of carbon conservation, storage and substitution.

Efforts are also being made internationally to develop procedures for the monitoring, evaluation, reporting, verification and certification of projects that address climate change. On national level countries are encouraged to develop and implement activities, programmes, technologies and policies that are aimed at energy efficiency and pollution control as their primary targets, and delivering greenhouse gas emission reductions as a co-benefit. Another important action that is being taken to address global climate change is demonstration projects, and informational and educational programmes.

Countries and states typically set up a climate change task force that brings together experts to develop a comprehensive strategy to address climate change. Task force members generally include state planners, policy analysts, natural resource specialists, environmentalists, and representatives from the private sector. Their expertise often represents a range of disciplines - engineering, science, economics, policy analysis, planning, education, community development - and sectors - energy, industry, transportation, agriculture, forestry, and waste. Collectively, they identify and select policy options based on several characteristics, including GHG reduction potential, cost-effectiveness, ancillary benefits, political feasibility, and public acceptance.

Despite population pressure and economic growth suggesting that emissions from developing countries would increase in future, more than two-thirds of 35 USCSP participants conducting mitigation assessments demonstrate the ability to reduce CO_2 emissions by at least 10% below projected baselines by 2010 [16]. In addition, most participating countries expect to achieve emission levels close to their 1990-levels by 2010, even without considering mitigation options. This means that even though South Africa has not submitted its mitigation assessments yet, reductions of 10% should be achievable and could double the estimated reductions and savings from the analysis presented in this chapter.

The most important mitigation options found from the USCSP experiences as well as other studies and initiatives conducted internationally, was in the energy sector. In near-term, energy-efficiency improvements proved to be the most important, followed by a focus on development and transition to renewable energy sources. For the industrial sector it was found that energy-efficiency improvements also proved the most important mitigation option. For residential and commercial sectors, energy-efficient lighting posed the largest mitigation potential.

2.9 Opportunities in South Africa

A number of pilot CDM projects have been implemented in South Africa. These included a small-scale wind project, a landfill gas project and a natural gas project [19].

South Africa has a large industrial sector, which is responsible for the largest part (62%) of national GHG emissions [6]. Focus must be placed on these sectors for the initiation of CDM projects.

One of South Africa's largest consumers of coal is Iscor's steel-producing industries. Three-fourths of the requirements (about 3.9 mmst annually) are met by Iscor's mining operations. Iscor also imports coal to satisfy the remainder of its requirements. Sasol's synthetic fuel and petrochemical operations are another significant domestic coal consumer. In 1995, these facilities consumed nearly 40 mmst of coal, while Sasol's mines met 95% of these requirements [6]. This high consumption contributes to GHG emission. Emphasis must also be placed on Eskom's electricity generation.

It is, however, clear that the industrial sector, and especially the iron and steel industry (Iscor, Highveld Steel and Vanadium), the chemical and petrochemical industry (Sasol, Mosgas) and the mining and quarrying industry (Anglo American, De Beers) show a significant potential for emission reductions. The residential sector also has a large potential for emission reductions, but due to the fact that this sector is comprised of a large quantity of small energy users, emission reduction would be more difficult to achieve than in most other sectors. The commercial sector is also expected to deliver substantial emission reductions due to energy-efficiency improvements.

Emission reductions for the transport sector and especially road transport users of petroleum products would, however, be difficult to achieve. These emission reductions could be achieved in the development of public transport to end with fewer motor vehicles on the South African roads.

2.10 What does South Africa have to do?

The Kyoto Protocol states that each country or party be held responsible for the development of its own systems to deal with emission reduction, emission trading, CDM and JI projects [17]. It is therefore crucial that systems, strategies and procedures be developed to aid South Africa in the CDM project market to avoid exploitation by industrialised countries.

In order for South Africa to take advantage and learn from the actions taken by other countries on an international scale, there are a number of actions that have to be taken. South Africa is a participant in the USCSP. A greenhouse gas inventory for the country has already been submitted [18] to the USCSP. South Africa is, however, still in the process of conducting vulnerability and adaptation assessments. No action plan to address climate change has been initiated.

In order for South Africa to participate in the international climate change actions and benefit from the flexibility mechanisms, a number of key issues have to be addressed and implemented.

- An infrastructure must be developed to support new technologies and new energy sources. Focus must be placed on energy-efficiency improvements across all sectors.
- Policies and regulations that favour development of new technologies and energy sources need to be developed.
- Training, education and public awareness on the matter of climate change and what could be done to address the issue need to be increased.

Apart from the financial benefits that the development of the above requirements hold for the different national sectors and companies in terms of international emission trading, the ancillary benefits also include improved energy efficiency, lower monthly bills for energy, less pollution and environmental damage, and powerful marketing tools.

2.11 Needs and barriers for South Africa in emission trading projects

In order to become part of the Kyoto Protocol, South Africa must firstly become involved on a governmental level. Emission inventories and national recording systems must be in place by 2008. The following lists the needs and barriers that South Africa has to overcome or address in order to develop an environment conducive to CDM and climate change mitigation:

- Capacity building is an important aspect of South Africa's position towards climate change. Adequate capacity is required to address the adverse effects of climate change on South Africa and opportunities presented under mechanisms such as CDM in a strategic manner.

- There is currently a lack of project expertise in South Africa. The fact that many aspects of the methodologies to address climate change have not been finalised also contributes to this problem.

- The adverse effects of global climate change on ecosystems, human health and welfare need to be determined and addressed. South Africa has significant sensitivity to climate change effects, but also has adequate adaptive resources to address potential harmful effects [20].

- The effects on the South African economy need to be determined. International protocols and agreements on climate change would lead to a reduced demand for coal. Europe is the primary export market destination, followed by the Pacific Rim, where most trading partners have quantified emission reductions under the Kyoto Protocol [20]. A recent international energy agency study indicated that South Africa is the most vulnerable coal-exporting developing nation in that a –4% impact on GDP could be expected under a Kyoto Protocol scenario [19]. Additional vulnerability needs to be addressed in the energy and carbon-intensive South African economy under international climate change agreements. The costs to the economy to deal with changing ecosystems and human health concerns also need to be dealt with.

Greenhouse gas inventories need to be kept up to date and the major greenhouse gas emitters must be benchmarked at a project as well as a national level. Baselines to track the emission reductions must be developed at a project level. These baselines will be used during CDM projects to determine the verified reductions in GHGs.

A project recording system (PRS) for CDM projects is needed and would be responsible for the estimation of GHG emissions and removals of emissions. The aim of the project recording system is also to record certified emission reductions (CER) issued by parties in the CDM projects. Transfers and acquisitions also need to be recorded by the PRS in order to keep track of emission credit ownership and all transactions during CDM projects. The PRS must be aligned with national policy on climate change mitigation.

Strategic action plans and guidelines are needed to deal with CDM projects. Criteria must be drafted and implemented for the selection of projects. It is important that sustainable development and technology transfer be an integral part of all projects. The strategic action plans must also address project-related issues such as rules for monitoring, trade of emission reduction units, credit sharing, intellectual property rights, transparency, information disclosure. It must also provide appropriate incentives for compliance to aid in efficient operation of the market. These programmes should also include the articulation of energy-sector priorities, proposing criteria for project approval, establishing the role of each stakeholder [21].

Certification institutions and systems are needed to provide certification to CERs resulting from CDM projects. Systems need to be developed with which the certification institution could verify the emission reductions that result from CDM projects. Rules and mechanisms to monitor the projects, as well as auditing systems and procedures also need to be developed [21].

Government involvement and supportive policies are essential to provide initiatives and regulation to address and encourage climate change projects. This involvement needs to take South Africa's obligations and opportunities under the UNFCCC and the Kyoto Protocol into account.

Training and education are needed to promote public awareness on the issue of climate change and the benefits that GHG mitigation and CDM projects can hold for sectors, companies and individuals.

The infrastructure to promote and facilitate international technology transfer and research and development needs to be developed and continuously expanded. South Africa needs to determine its position relating to technology such as technology needs and needs assessment, technology information, enabling environments, capacity building and mechanisms for technology transfer.

An important barrier in the process is the fact that the rules for emission trading and other flexibility mechanisms of the Protocol have not been definitively set. This leaves uncertainty in the development of systems to deal with CDM projects. Developments regarding the Kyoto Protocol need to be followed closely and the modus operandi of the systems that are being developed must be followed in such a manner that the systems are flexible and adaptable to changes in the Kyoto Protocol.

Climate change issues in South Africa can currently be addressed through CDM projects. Joint implementation is of little relevance to South Africa, as it can only be undertaken between Annex B countries of the Kyoto Protocol. International emission trading is also a mechanism for use among Annex B countries. South Africa could, however, opt into the trading system by assuming national emission limits [20].

2.12 Summary

South Africa is vulnerable to climate change. It is also economically vulnerable to the Kyoto Protocol's scenario of emission reductions. The export of coal to countries that have accepted emission reduction targets under the Kyoto Protocol will influence South Africa. A study by the International Energy Agency has indicated that South Africa is the most vulnerable coal-exporting nation in that a –4% impact on the GDP could be expected.

South Africa has a carbon and energy-intensive economy and is one of the top twenty greenhouse gas emitters in the world and the largest one on the African continent. The potential for emission reductions and energy efficiency is, however, significant.

South Africa has ratified the Kyoto Protocol. For this reason the clean development mechanism holds the most promise for South Africa to participate in international GHG emission reduction projects, together with developed countries.

The sector that holds the greatest potential for emission reductions and energy-efficiency improvements is the industrial sector. This sector is responsible for almost 63% of carbon emissions. In this sector the non-specified part is the largest, followed by the chemical and petrochemical industry, iron and steel, and mining and quarrying industry. The transport and residential sectors emit almost 16% and 13% respectively. The balance is due to the commercial sector. Focus must therefore be placed on the industrial sector in order to achieve the largest impact. The residential sector also holds significant potential in terms of energy-efficiency projects. However, this is more difficult to achieve, since it comprises of a large number of small end users.

South Africa has the largest potential for emission reductions on the African continent and is a very attractive candidate for emission reduction projects from other countries. If a 5% emission reduction could be achieved in this country across the board, the market potential for emission reduction projects in South Africa is significant. The "carbon market" is estimated at R 350 million per year through the sale of emission offsets. The resulting lower demand for energy and the improved efficiency will mean additional total savings of R 4.2 billion per year. These figures could easily double if energy efficiency savings or reductions of 10% were achieved, which is possible. Apart from these benefits, there are also the benefits of improved environmental policies, less pollution, influx and the development of new technology.

South Africa, however, needs to develop control structures for projects that fall under the clean development mechanism. Once in place, the systems and strategies would encourage international participation in CDM projects in South Africa. The CDM projects would, in turn, encourage energy efficiency and emission reductions for South African industries and result in sound environmental policies.

Some of the more important needs and barriers that have been identified were the development of infrastructure to support new technology and renewable energy sources. Project expertise is also very limited. Recording systems are needed to deal with both CDM projects to keep track of emissions and reductions for these projects at project and national levels. Strategic plans and guidelines need to be developed as well as certification institutions to provide certification of the emission reduction units prior to its sale or offset use. Training and education are also critical to promote awareness across all sectors in South Africa. In this regard an integrated approach would play a major role in the development of project expertise and training. This approach would not only facilitate the implementation and sustainability of GHG mitigation projects, but also drive the sustainable implementation of energy efficiency in South Africa.

The integrated approach would also quicken the pace at which South Africa addresses climate change. It would create a market for innovative ways to reduce emissions cost-effectively and foster rapid development and diffusion of new technologies for energy efficiency that are environmentally "green". CDM projects could greatly aid sustainable development in South Africa. All the above structures and systems would help to protect the country from international exploitation in the emission trading market. It will also help prepare South Africa for the expected emission trading rush prior to the first commitment period of the Kyoto Protocol (2008 – 2012).

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CHAPTER 3

Implementing mechanisms

This chapter describes the various implementing mechanisms that provide an alternative to building new generation capacity and assists end users to reduce their increasing electricity costs. These implementing mechanisms would also assist South Africa with GHG mitigation.

Chapter 3: Implementing mechanisms

3.1 Introduction

The previous chapter described the current situation of South Africa with regard to energy usage and GHG emissions together with the needs and barriers. This chapter describes the various implementation mechanisms that would provide an alternative to building new generation capacity and assist end users to reduce their increasing electricity costs. These implementing mechanisms would also assist South Africa with GHG mitigation.

South Africa could participate in greenhouse gas mitigation through the clean development mechanism since it was classified as a developing country by the Kyoto Protocol and the country ratified the Protocol.

Under the CDM parties not included in Annex 1 (developing countries such as South Africa) will benefit from project activities resulting in certified emission reductions. Parties included in Annex 1 (developed countries such as the U.S.A. and Europe) may use the CERs accruing from such project activities to contribute towards compliance with part of their quantified GHG emission limitation or reductions commitments.

Substantial portions of clean development mechanism projects follow the usual path in terms of project development and the financing process when compared to other energy and emission-related projects. CDM projects have, however, their own particular requirements that include:

- Proving environmental additionality;
- gaining host country acceptance and proving sustainable development;
- developing acceptable monitoring protocols and procedures; and
- undergoing independent verification.

This chapter firstly describes the implementing mechanisms with their associated project stages. Emphasis is then placed on the CDM project activity cycle stages that are additional to the conventional project stages common to all the implementing mechanisms.

3.2 Implementing mechanisms

There are a number of implementing mechanisms to achieve energy efficiency, demand reduction and GHG mitigation. Figure 3.1 shows a number of DSM options that could serve as implementing mechanisms [1].

Interruptibility involves reducing load during peak on the distributor's system. The measures that are normally used include time-of-use tariffs. Load shifting involves shifting loads from peak to off-peak, without affecting the total electricity used and hence increasing the utilisation of electricity generation. Popular measures include use of storage water-heating, storage space heating, cool storage, and customer load shifts that take advantage of time-of-use or other special rates. Strategic load growth increase end use consumption during certain periods (usually outside of the peak periods that form the focus of DSM). The result is a general increase in energy sales beyond the valley-filling strategy. Strategic load growth may involve increased market share of loads that are, or could be, served by competing fuel, as well as area development. Energy efficiency is an option that aims at reducing overall electricity consumption (kWh) of the end user. Such savings are generally achieved by substituting technically more efficient equipment to produce the same level of end-use services with less electricity.

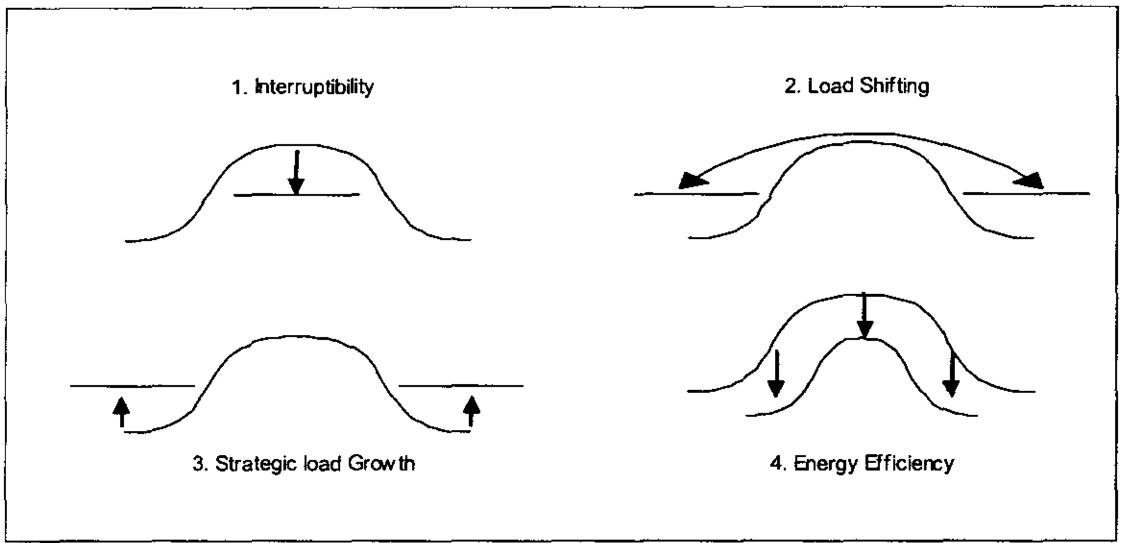

Figure 3.1: Demand-side management options.

Utilities and distributors are most likely to invest in interruptibility, load shifting and strategic load growth options in order to manage peak load. This is clear in the current strategy of Eskom to invest in interruptibility and load shifting, since the national electricity industry is continuously facing an unbearable peak demand in the evening and morning periods, especially in winter. Anther factor is the fact that South Africa will be running out of its peak capacity in the near future.

The electricity industry throughout the world has tried to influence consumer consumption patterns by implementing DSM options, including energy efficiency as one such options. DSM options could however, be defined as programmes that improve the financial performance of the utility and help the utility to manage its peak load. The programmes do not result in a reduction in electricity consumption. Unfortunately, energy efficiency is the one DSM option that falls through the cracks in terms of investment by the utility (Eskom), since it does not necessarily improve the utility's financial performance [1]. However, energy efficiency is one of the intervention mechanisms in the distribution of electricity, as it provides an alternative to the building of new generation capacity.

Furthermore, South Africa is a signatory to international commitments, which include the Kyoto Protocol that highlights the importance of preserving the environment in the process of providing energy. Energy-efficiency programmes are regarded as one of the mitigating strategies that ensure that customers use less energy and thereby decrease the need for generating more electricity from coal (in the South African context) that emits pollutants and GHG emissions into the atmosphere. Energy efficiency thus enables South Africa to establish a direct link with CDM projects.

The rising cost of electricity in South Africa has, however, resulted in not only that the utility invest in DSM, but also the end users reduce the demand component of their electricity bill. The implementing mechanisms can thus be utility-funded or privately-funded. In the past it was the responsibility of end users to fund their energy-efficiency projects with private funding. The National Electricity Regulator's energy efficiency and DSM policy is, however, placing energy efficiency increasingly in the spotlight due to the benefits it poses to utilities, end users and society. This policy is forcing the utilities to invest more in energy efficiency. The funding models that are currently available for DSM and energy-efficiency projects in South Africa are:

- Shared savings;
- in the case of energy efficiency, the utility must make a 50% contribution and the client or end user the other 50% contribution. The client, however, gets to retain all the savings that result from the project;
- in the case of load management, the utility pays for the complete project, the client retains all the savings but has to guarantee the demand impacts. Failure to deliver the MW reductions results in penalties payable by the client and/or the ESCO;
- own or private funding by the client or end user; and
- sale of "green" credits or certified emission reductions that result from energy-efficiency projects in a CDM environment and implementing mechanism.

The above are all implementing mechanisms that would assist South Africa in the following:

- Providing an alternative to the building of new generation capacity;
- reducing electricity-related costs for end users under the increasing electricity costs; and
- GHG mitigation under the CDM.

The following common project stages are all associated with energy efficiency, DSM and energy-related GHG mitigation in the project environment:

- Project identification;
- energy audit;
- recommendations for implementation;
- approval for funding;
- detail design;
- implementation;
- commissioning; and
- operation and maintenance.

In the case of GHG mitigation under the clean development mechanism, a number of additional stages and project activities are required. These project activities are described in the following sections of this chapter.

3.3 CDM role players

Figure 3.2 provides a graphical layout of the CDM project activity cycle that is discussed in more detail in the sections that follow. Each of these project activities has role players that are responsible for certain tasks under each of the stages. The role players in a CDM project activity cycle are the following:

- Project participants (PP);
- the executive board of CDM (EB);
- designated national authority (DNA);
- applicant entity (AE); and
- designated operational entity (DOE).

The companies and organisations developing and investing in the project are referred to as the project participant. The project participant is basically the implementing party of the CDM project and is responsible for the design of the project and the development of the project design documentation.

It is the responsibility and function of the executive board to supervise the CDM under the guidance of the Conference of Parties (COP) and the Meeting of Parties (MOP). The executive board is responsible for the operationalisation of accreditation procedures and standards and reports to the COP. The executive board is elected by the COP and is charged with the relatively rapid progress of developing CDM rules.

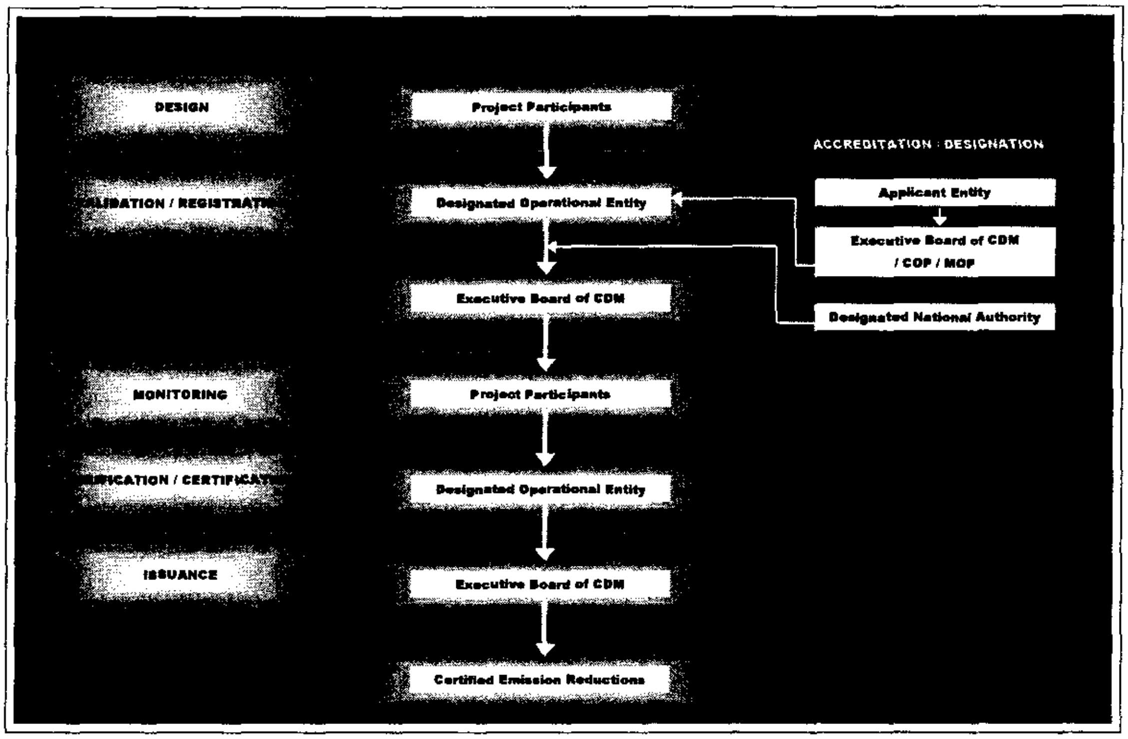

Figure 3.2: CDM project activity cycle and responsible parties for each cycle.

The designated national authority has been established within the Department of Environmental Affairs and Tourism (DEAT). It is the role of the DNA to administrate the national GHG inventory as well as developing and managing the records of all project applications received. The DNA also grants authorisation for CDM projects to proceed to the validations stage [2].

It is essential for all CDM projects to be closely assessed and monitored. It is the function of the designated operational entities to play a key role in the following CDM project stages:

- Design;
- authorisation;
- validation and registration;
- monitoring;
- verification and certification; and
- issuance and trading.

The designation of an operational entity starts with a private or public body (Entity X in Figure 3.3) that submits a request as an applicant entity (AE) for accreditation to the executive board of the CDM. The executive board checks that Entity X meets the requirements set in the modalities and procedures for a clean development mechanism [3]. Once Entity X has met all the set requirements, the executive board grants accreditation to the entity.

Once accreditation has been granted, the executive board then makes a recommendation to the Conference of Parties and the Meeting of Parties. The COP/MOP then designates entity X as a designated operational entity (DOE). The executive board of the CDM will review the accreditation of the DOE every three years. The executive board will also conduct spot-checks on the designated operational entity. This will ensure that the DOE continues to meet the accreditation standards or applicable provisions. If this is, however, not the case, the executive board may recommend to the COP/MOP to suspend or withdraw the designation of a designated operational entity.

The designated operational entity could then validate project activities as a single function or may verify and certify CERs that result from CDM projects as an alternative function. It may request the executive board to allow a singe designated operational entity to perform the validation as well as the verification and certification.

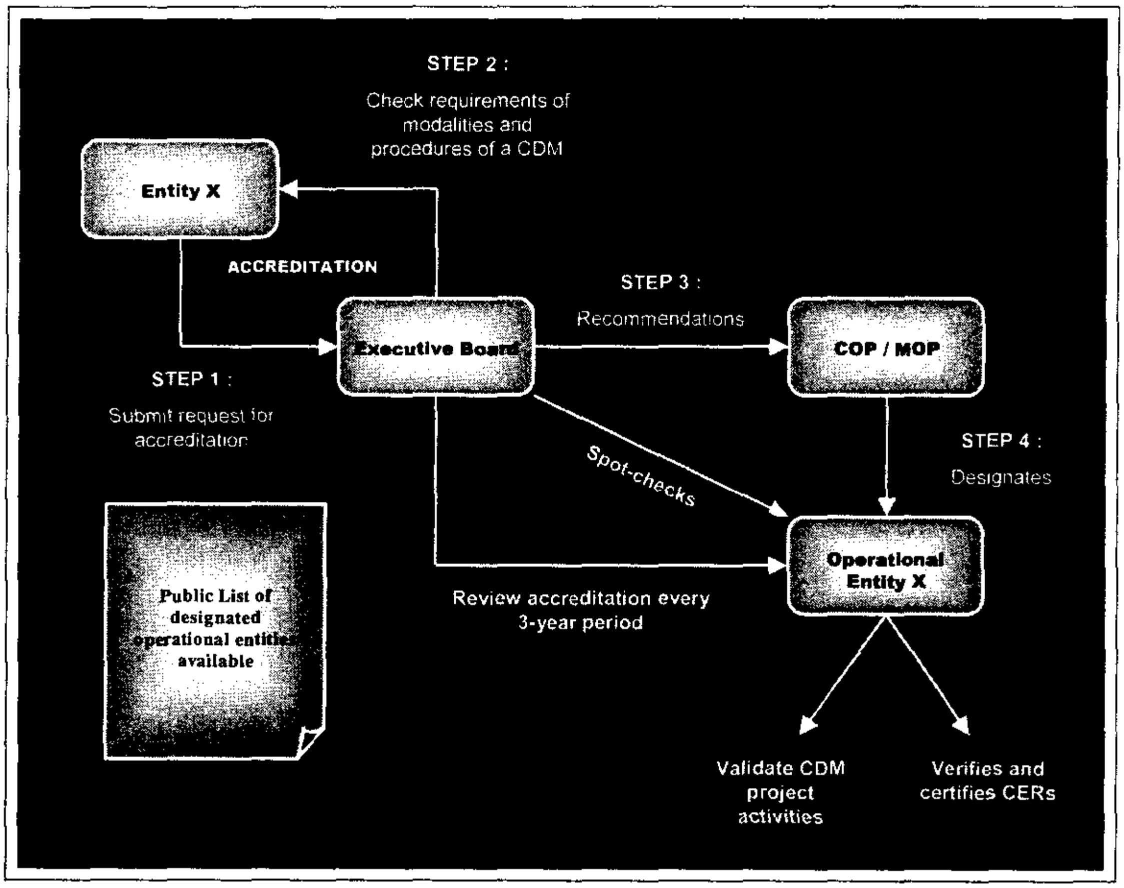

Figure 3.3: Designation of an operational entity.

The designated operational entity needs to review the project participant's design document and all supporting documentation to ensure that the requirements of the modalities and procedures of a clean development mechanism are met [3].

Project participants would need to appoint a designated operational entity to validate the project design document and a different DOE for the verification of the project performance. The DOEs will typically be consultants working under contract to the project participant and are selected by standard procedures such as competitive tendering.

3.4 CDM project activity cycle

The CDM project activity cycle has a number of additional steps when compared to conventional energy-efficiency projects. The activity cycle for a CDM project are characterised by the following five distinct stages [3]:

1. Design of the CDM project activities;
2. authorisation, validation and registration;
3. monitoring;
4. verification and certification; and
5. issuance.

More detailed information of each of the above-mentioned stages is provided in the sections that follow.

3.4.1 Stage 1: Design of a CDM project activity

The project participant (PP) is responsible for the design of the CDM project. There are two critical considerations in project design. The first is additionality of the emission reductions and the second is the baseline methodology [2]. Other issues of importance during the project design stage are the crediting period, the project boundary and leakage. Each of these issues is discussed in more detail below.

Additionality is judged and quantified by establishing the baseline on a project-specific basis. The baseline represents the anthropogenic GHG emissions that would have occurred in the absence of the proposed project activity. A CDM project is deemed additional if anthropogenic GHG emissions were reduced below those that would have occurred in the absence of the proposed project activity.

The project participants need to develop the project baseline through the use of approved methodologies. Baselines need to be established for all greenhouse gases that fall inside the boundary of the project. Baselines may be obtained through methodologies previously approved by the executive board. The baseline may take only direct project activities into account. It is also important that baselines are established in a transparent and conservative manner regarding the choice of approaches, assumptions, methodologies, parameters and data sources.

It is also important that uncertainty be taken into account for the baselines, as well as national and industry policies and circumstances [4]. The project baseline could include a scenario where future anthropogenic emissions are projected to rise above current levels. The baseline must be defined in a way that CERs cannot be earned for decreases in activity levels outside the project activity or due to circumstances beyond the control of the project participants.

In choosing a baseline methodology for the project, project participants must select the most appropriate approach from among the following:

- Existing actual or historical emissions, as applicable; or
- emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or;
- the average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20% of their category.

The choice from the above must, however, be justified by the project participant. If a new baseline development methodology were used, it needs to be reviewed by the executive board for approval prior to project registration.

The crediting period is the time period during which credits arising from the project could be claimed and is not necessarily equal to the operational lifetime of the project itself. The project participants need to select one of the following crediting periods [5]:

- An initial seven-year period, which may at most be renewed a twice to result in a total maximum crediting period of twenty-one years; or
- a maximum crediting period of ten years with no option for renewal.

The project boundary clearly identifies the sources and sinks of the GHG emissions that would be reduced by the project and sets the physical area in which the emissions would be reduced. GHG reductions (or increases) that result due to the project but outside the selected project boundary, are called leakage [5].

The project participant needs to submit a project design document (PDD), of which the main function is to provide all relevant information and background on the potential project. This document must also give an indication of the amount of certified emission reductions expected to result from the proposed project.

The following elements form part of the project design document [4] as outlined in Appendix B to the modalities and procedures for a CDM [6]:

1. A statement of the project purpose;
2. a description and justification of the project's boundary;

3. the proposed baseline methodology accompanied by a statement of the approved methodology selected for the project with a description of the manner in which it will be applied during the project. If an approved methodology is not selected or available, the PDD must include a description of the new methodology and a justification of the choice of baseline methodology. In either case the PDD must describe how national and industry policies and circumstances were taken into account;
4. an estimation of the operational lifetime of the project and the crediting period that was selected for the project;
5. the project participant needs to include a description of the manner in which the GHG emissions would be reduced below those that would have occurred without the project;
6. an analysis of the environmental impacts need to be included, such as transboundary impacts and a environmental impact assessment (EIA) in accordance with local environmental requirements if the impacts were considered significant;
7. information on public funding from Annex 1 parties and an affirmation that this funding would not divert official development assistance;
8. comments by local stakeholders, including a description of the consultation process, the comments received and a report of the response to these comments;
9. a monitoring plan which includes the identification and description of the data needs and quality with regard to accuracy, comparability, completeness and validity. Also required is a description of the methods to be used in data collection, monitoring and reporting (including quality assurance and quality control). In the case of new monitoring methods, a description and assessment on the strengths and weaknesses of the method would be required; and
10. a description of formulae used to calculate and estimate anthropogenic emissions of GHGs from the project activities within the set boundaries.

From the above it is clear that the project participant also needs to submit monitoring plans. The proposed monitoring methodology may be one that was previously approved by the executive board. However, new methodologies need to be submitted to the executive board for approval. Emission factors for greenhouse gases are used in a monitoring and verification protocol to convert actual measured fuel or electricity production or savings into GHG reductions. It is, however, important to note that monitoring and verification are the most critical aspects of the project, since it is the means of assessing the impacts of the project and forms the basis of trust in the GHG emission reductions and ultimately the issuance of CERs.

3.4.2 Stage 2: Authorisation, validation and registration

The second stage in the CDM project activity cycle is the authorisation, validation and registration stage of the CDM project.

The project must be authorised by the host country. This is achieved by submitting the PDD to the South African Designated National Authority (DNA) that has effectively been established inside DEAT. The project will be assessed against sustainability criteria. The sustainability criteria for South Africa are not yet available but are not expected to be more onerous than current legislations. It is likely that environmental impact assessments would be required for large projects and authorisation can only be granted to a project once an EIA has been completed [4].

Once authorisation has been granted, the project can proceed to be validated. Validation is the process of independent evaluation of a project activity by a designated operational entity (DOE) against the requirements of the CDM. Project participants must select and contract a DOE to validate their project. The designated operational entity then performs a validation requirement evaluation of the project design document, based on the methodologies that would be used to develop the baselines and the monitoring methodologies.

The validation requirements are the following:

- Parties that participate in the project need to designate a national authority for the CDM;
- the project participant needs to provide to the designated operational entity with a written approval of voluntary participation by the designated national authority of each involved party;
- the host party needs to confirm that the project activity assists in achieving sustainable development;
- a party not included in Annex 1 may participate in a CDM project activity if it is a party to the Kyoto Protocol;
- comments by local stakeholders have been invited and due account was taken of any comments received within 30 days;
- documentation on this analysis needs to include environmental impact and transboundary impacts of those impacts considered significant by the project participant or the host country;
- the project activity is expected to result in additional greenhouse gas emission reductions;
- the baseline and monitoring methodologies are approved by the executive board, or comply with the modalities and procedures for establishing a new methodology;
- provisions for monitoring, verification and reporting are in accordance with CDM requirements; and
- the project activity conforms to all other requirements for CDM project activities.

Registration is the formal acceptance by the executive board of a validated project as a CDM project activity. Registration is the prerequisite for the verification, certification and issuance of CERs related to that CDM project activity.

Figure 3.4 provides a schematic layout of the processes associated with this stage. The designated operational entity has a repository of approved methodologies at its disposal. This repository includes all methodologies that have been accepted by the executive board of the CDM as well as the Conference of Parties (COP) / Meeting of Parties (MOP).

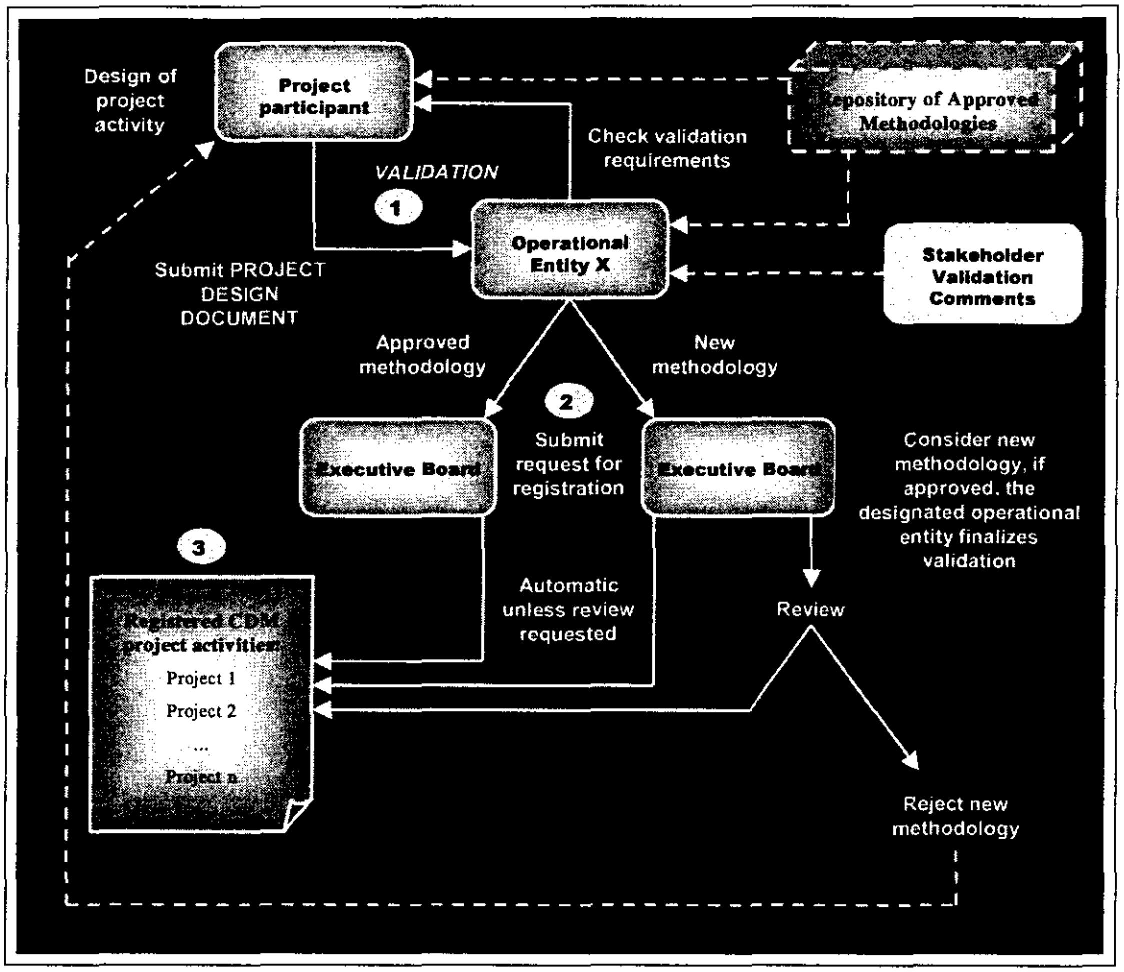

Figure 3.4: CDM project activity validation and registration process.

If the project method is one of the approved methodologies approved in the repository, the methodology is submitted to the executive board of the CDM. If the executive board does not request a review of the methodologies within eight weeks, the CDM project activity will be registered. If a review is requested within eight weeks (by one involved party or three board members), the executive board will conduct and conclude the review within two meetings. The

CDM project can be registered or rejected if the executive board is not satisfied with the review, whereupon the process needs to start again at the design stage.

If the project method is not one of the methodologies approved in the repository, it is classified as a new methodology. The designated operational entity submits the new methodology to the executive board for approval. The executive board then reviews the new methodology where it can then be rejected or added to the repository of approved methodologies. The COP/MOP can also disapprove of the methodology and provide guidance to the project participant in the design of the methodologies.

A proposed project activity that is not accepted may be reconsidered for validation and subsequent registration, after appropriate revisions, provided that it follows the procedures and meets the requirements for validation and registration, including those related to public comments.

3.4.3 Stage 3: Monitoring

The third stage of the CDM project activity cycle is monitoring. Monitoring is the responsibility of the project participant or a third party to the project [7]. A monitoring plan needs to be submitted during the project design stage. This plan needs to provide for the following:

- Collection and archiving of all relevant measuring and estimation data;
- baseline data collection and archiving;
- quality assurance and control procedures to monitoring process;
- periodic calculation procedures; and
- documentation of calculations.

It was seen during stage 2 that the monitoring plan can be based on a previously approved monitoring methodology, or a new methodology could be submitted to the executive board for approval.

The project participant (or third party) is responsible for the implementation of the monitoring plan contained in the registered project design document. Any revisions to the monitoring plans may only take place if it:

- Improves the accuracy of information and data; and
- the completeness of information and data.

These revisions need to be justified by the project participant and submitted to the designated operational entity for validation.

The implementation of the registered monitoring plan is a compulsory condition for verification, certification and issuance of CERs.

A monitoring report must be submitted by the project participant to the designated operational entity that is contracted to perform verification and certification. This may only be the same designated operational entity that has performed the CDM activity validation upon request to the executive board.

3.4.4 Stage 4: Verification and certification

Verification and certification is the fourth stage in the CDM project activity cycle. This function needs to be performed by a designated operational entity other that the one that performed the validation of the CDM activity. The designated operational entity may perform both functions (validation / verification and certification) only after the executive board allows it after a request has been submitted.

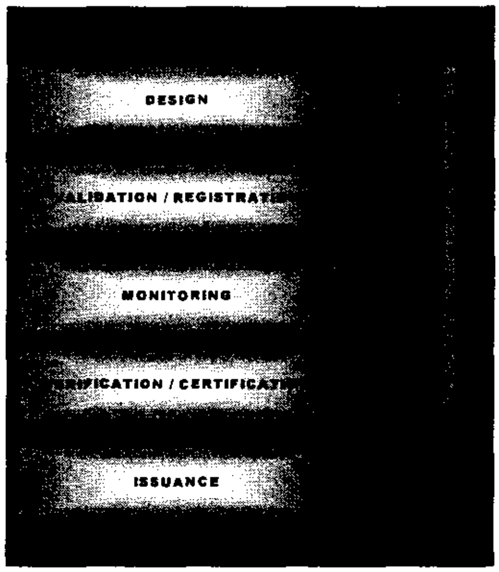

Figure 3.5: CDM project stages.

Verification is the periodic independent review and determination by the designated operational entity of the monitored reductions (achieved by the project participant) in anthropogenic emissions by sources of greenhouse gases that have occurred as a result of the registered CDM project activity during the verification period.

The designated operational entity would carry out its verification tasks as follows:

- Determine if project documents are in accordance with the requirements of the registered project design document;
- determine the reductions in GHG emissions that have occurred as a result of the project, using the procedures described in the project design document and monitoring plan;
- review monitoring results and verify that monitoring methodologies have been applied correctly and that all documents are complete and transparent;
- conduct on-site inspections that include a review of performance records, interviews with project participants and local stakeholders, the collection of measurements, the observation of established practices and the testing of the monitoring equipment's accuracy;

- recommendations may be made for changes to the monitoring methodologies; and
- identify and inform project participants of any concerns relating to the conformity of the project and its operation with the project design document;

A monitoring report will then be made available to the public (excluding propriety or confidential information) by the designated operational entity.

Certification of the CERs is achieved when the designated operational entity, based on its verification report, certifies in writing that the CDM activity has achieved the verified amount of additional emission reductions during the specified time period. This certification needs to be submitted to the project participants, stakeholders and the executive board. The certification report is then made available to the public.

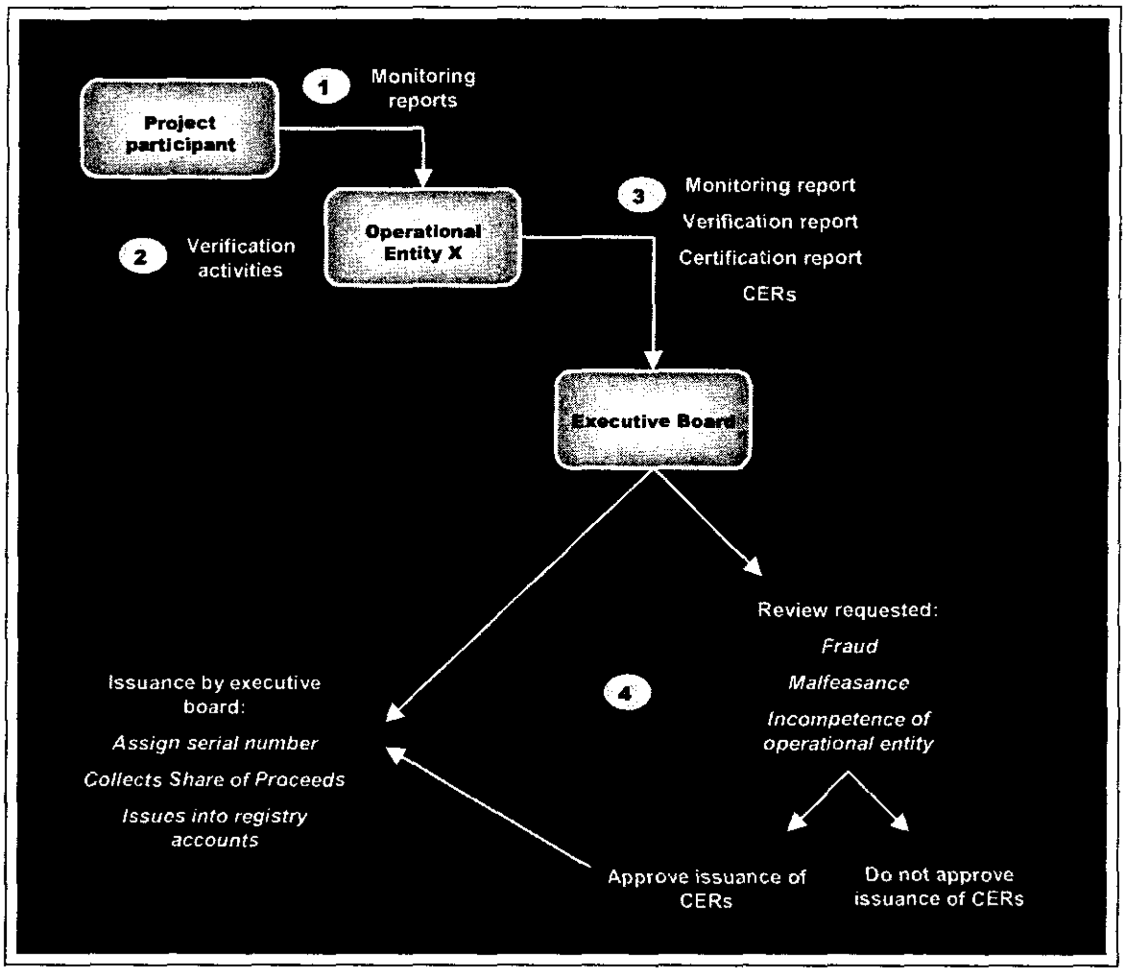

Figure 3.6: CDM project activity stages for verification, certification and issuance.

Certified emission reductions obtained during the period 2000 up to the beginning of the first commitment period can be used by developed countries to assist in achieving compliance in the first commitment period.

3.4.5 Stage 5: Issuance

The final stage in the CDM project activity cycle is issuance of CERs. The certification report submitted by the designated operational authority to the executive board constitutes a request of issuance of CERs equal to the verified amount of reduction in GHG emissions.

The issuance will be final after fifteen days (after request for issuance has been received by the executive board) if an involved party to the project or three members of the executive board requests no review. Reviews are limited to issues of fraud, malfeasance or incompetence of the designated operational entities. Reviews need to be completed within 30 days after a request was made.

The executive board gives the CDM registry administrator (working under the authority of the executive board) instructions to issue the specified amount of CERs into the registry accounts of the parties. The schematic process in shown in Figure 3.6.

3.5 Characteristics of energy-efficiency projects and the CDM

Energy-efficiency projects have several special features that would impact on the design of a CDM project. These features include the following:

- Some technologies are already cost-effective to energy consumers and they (the consumer) can sufficiently recover his input costs through the energy savings. This is, however, not always the case in the South African context due to the low cost of electricity;
- high initial cost; lack of information and financing; and perverse investment priorities, rather than poor rate of return contribute to the fact that some technologies are not widely used; and
- some electricity-efficient technologies are also financially beneficial to the power utility through a reduction in peak demand, which contributes to the deferral of new capacity.

The simplest energy-efficiency or fuel substitution project is one where an energy user invests in a high-efficiency technology or measures at his own site. The resultant savings pay for the cost of the technology, and GHG emissions are reduced either on-site (if a fuel is saved), or upstream (if electricity is saved). A CDM contribution would improve the financial return to the user, in return for the CERs.

3.6 *Role of M&V in climate change mitigation*

International efforts to reduce greenhouse gas emissions have also increased the need for standardised tools such as the IPMVP, to cost-effectively measure the economic and environmental benefits of projects [5]. The flexible, market mechanisms to reduce greenhouse gas emissions included in the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (FCCC) makes the need for an international consensus on monitoring and verification protocol more urgent. Guidelines have recently been developed by the Lawrence Berkeley National Laboratory that address the monitoring, evaluation, reporting, verification, and certification of energy-efficiency projects for climate change mitigation [8]. The LBNL study determined that the IPMVP is the preferred international approach for monitoring and evaluating energy-efficiency projects because of its international acceptance, because it covers many key issues in monitoring and evaluation and because it allows for flexibility. The IPMVP will make a necessary and important contribution to establishing a framework on which international greenhouse gas trading could be built [5].

Application of the IPMVP could provide increased confidence in the measurement of actual energy savings, and therefore provide greater confidence in determining associated reductions in emissions. It is becoming an important element in international greenhouse gas emission mitigation and trading programmes because of the broad international participation in its development and its growing adoption internationally.

Combined with the specific M&V plan of each project, the IPMVP enhances consistency of reporting and enables verification of energy savings. However, to verify an emission credit the IPMVP must be used in conjunction with the credit trading programme's specific guidance on converting energy savings into equivalent emission reductions.

3.7 *Summary*

South Africa is running out of peak capacity and the rising cost of electricity is forcing end users in the residential, commercial and industrial sectors to take a look at their electricity accounts. A number of implementing mechanisms exist that are critical for South Africa to provide an alternative to building new generation capacity and that provide end users with a means of achieving reduced electricity costs. These mechanisms also cater for GHG mitigation. Although the basics project stages associated with them are the same, GHG mitigation under the clean development mechanism requires a number of project activities that are additional to energy efficiency and DSM project activities.

It is clear that CDM projects require stages that are additional to normal energy-efficiency projects. These additional stages include additionality and sustainable development criteria.

Apart from the design of the project by the project participant, the most critical stage in the CDM process, as in any other implementing mechanism, is the monitoring and verification stage. This stage forms the basis of trust in the CERs.

It is, however, important to note that typical energy-efficiency or DSM projects in South Africa do not require the client or ESCO (equivalent to the project participant in the case of CDM projects) to perform the monitoring. This task is usually combined into a complete monitoring and verification process performed by an independent third party. In the case of CDM projects, the project participant performs the monitoring and is also responsible for the development of the monitoring plan. The third party or designated operational entity performs only the verification based on the data and documentation received from the project participant. The involvement of the DOE is thus greatly reduced in the M&V process in the case of CDM projects. As described in the next chapter, it is preferred that the project participant should not conduct the monitoring for verification purposes during the project for impartiality purposes.

This issue needs to be taken into account when an integrated approach is to be developed for energy efficiency and GHG mitigation, since M&V by an independent third party should deliver results that are completely impartial when compared to a shared M&V process between the project participant and the designated operational entity.

3.8 References

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CHAPTER 4

Measurement and verification

This chapter provides an overview of the measurement and verification process and describes what the process entails and how it fits into the context of the implementing mechanisms described in the previous chapter.

Chapter 4: Measurement and verification

4.1 Introduction

Both energy-efficiency and DSM projects are implemented to achieve energy consumption and demand savings, and ultimately cost savings. The basis of successful energy-efficiency and demand-side management projects is the fact that electricity reductions can be determined to a degree of accuracy and trust that is acceptable to all stakeholders. The same principle holds for GHG mitigation projects where the GHG reductions need to be quantified. This process is known as measurement and verification (M&V). The previous chapter described the mechanisms of implementation; this chapter describes how to sustain it through M&V.

The M&V process is designed to provide an impartial quantification and assessment of project impacts and savings that result from energy-efficiency and DSM activities. Once the project impacts are known, the utility can monitor and evaluate (M&E) the performance and progress of all the DSM and energy-efficiency project activities. This will help to identify present and future focus areas for energy efficiency and DSM, as well as potential problems with implementation. M&V therefore makes a critical contribution towards the successful implementation of energy efficiency and DSM in South Africa.

This chapter describes the concept of M&V. There is no difference between M&V of energy efficiency or DSM projects. This chapter will answer the following questions:

1. What is measurement and verification?
2. Why should we measure and verify?
3. How does one measure and verify?
4. What are the next steps in the application of measurement and verification as it is currently structured?

4.2 What is measurement and verification?

There are a number of stakeholders in any energy-efficiency or DSM project. These include the utility, the client, the energy service company (ESCO) and the financier or financial institution. The clients want to reduce their monthly energy costs when they reduce their peak demand and/or energy consumption. The financial institutions want to protect their investments in the project. The ESCO wants to share in the energy cost savings when implementing energy efficiency under risk (Figure 4.1). This situation necessitates that the project impacts be determined to a certain level of accuracy that is acceptable to all stakeholders.

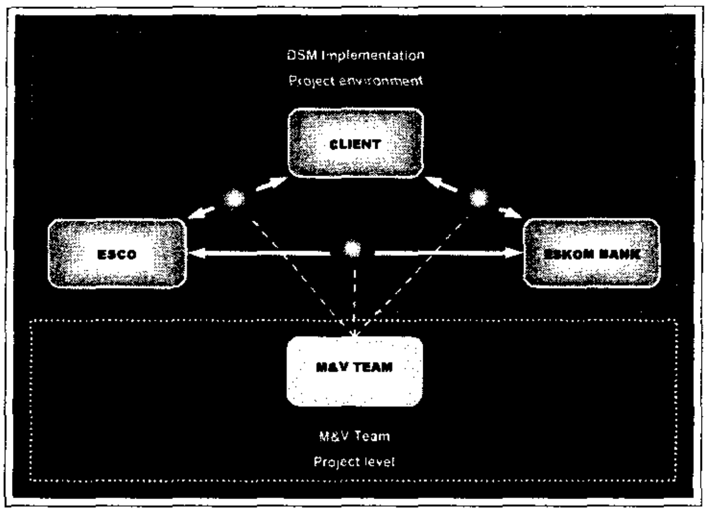

Figure 4.1: M&V project interaction with energy-efficiency stakeholders.

The ESCO or the client usually does the project identification and/or savings calculations as part of the preliminary and design phases of the energy-efficiency project. Once the energy-efficiency intervention has been implemented, these savings need to be quantified to determine the effectiveness of the energy-efficiency intervention. Since project payback or performance-based contracts rely on accurate and impartial savings information, the task of saving assessment and quantification need to be performed by a party outside the principal project stakeholders.

The primary questions that all energy-efficiency stakeholders want answered are: How much have been saved and are the savings being sustained? The dynamics in energy-efficiency projects make it difficult, and certainly not preferable to assign any one of the stakeholders to deliver an objective assessment of the savings. The quantification and assessment of the savings must remain impartial and the process transparent. The long-term success of many energy-efficiency projects is often hampered by the inability of project partners to agree on the quantity of savings that have been obtained. It is for this reason that another party needs to be included in the energy-efficiency process to determine and verify the savings.

M&V is the vehicle to provide all the energy-efficiency project stakeholders with an impartial quantification of the savings. Figure 4.1 shows a schematic representation of the interaction between the principal stakeholders and the M&V team. It can be seen that the M&V team is active on all the levels between the various project stakeholders. The M&V team, however, stands apart from the project environment in order to ensure impartiality. However, the project parameters are measured, baselines are developed and the savings calculated by the M&V team within the project environment. It is thus the purpose of M&V to facilitate agreement between the stakeholders on the project outcomes.

Accurate measurement, a replicable methodology, as well as a consistent and reliable process are some of the requirements to determine the savings that result from energy efficiency and DSM projects.

4.3 *Why should we measure and verify?*

The South African utility Eskom, has embarked on a national DSM initiative in the industrial, commercial and residential sectors. The projects that fall under the scope of DSM form part of Eskom's long-term strategy to reduce South Africa's electricity demand during peak periods [1]. Variable-sized energy-efficiency components are associated with the majority of these projects.

The importance of M&V to the success of energy efficiency and DSM in South Africa is becoming more apparent. Large financial investments are being made and an increasing number of clients are coming to realise the need for energy efficiency and DSM to maintain sustainability in their operations. An increasing number of performance agreements are also being forged between project stakeholders. M&V is designed to quantify and assess the savings that result from projects in an impartial manner. If the project impacts are known, stakeholders can identify focus areas for energy efficiency, as well as potential problems. M&V will also help with the proper implementation of energy-efficiency projects. M&V is therefore an essential part of any energy-related project.

M&V encourages investment in the energy-efficiency and DSM industry and reduces the risk for financial investors. M&V thus help to overcome barriers to the implementation of energy and demand-reducing projects. It will also become a crucial requirement when participating in international markets under the clean development mechanism, which allows countries to benefit financially from emission reductions that result from energy-efficiency activities. The process of M&V provides credibility and broad-based acceptance to the energy market.

The process of M&V also provides valuable feedback to stakeholders regarding the way in which savings are influenced. Efforts can thus be focussed to optimise the impacts of energy efficiency. The fact that the savings are measured and verified encourages better design and management of projects. M&V not only provides energy consumption and cost savings, but could also provide demand impacts.

4.4 *How does one measure and verify?*

The South African energy market has had very little experience with regard to M&V. The focus was subsequently placed on international measurement and verification protocols in order to gain an understanding of M&V and its requirements.

These protocols were the International Performance Measurement and Verification Protocol (IPMVP) [2], as well as the M&V Guidelines for Federal Energy Management Projects (FEMP) [3]. These protocols have been in use internationally for a number of years and have proved to be a valuable source of information on the requirements of M&V.

The basic principle of M&V is to compare the measured energy consumption and demand after implementation with what it was before implementation in order to determine the impacts [2]. This is demonstrated in Equation 1.

Energy savings = (Baseyear energy use) – (Post-retrofit energy use) ± Adjustments (Eq. 1)

This baseyear is commonly described by a baseline. The baseyear represents the set of conditions under which the system in question was operating. This could include factors such as production, weather, building occupancy, system use, and tariff structure / pricing. If the above factors remain unchanged, the post-retrofit or post-implementation energy use can be compared to that of the baseyear. Adjustments are, however, necessary to bring the two time periods under the same set of operational conditions if any of the baseyear conditions were to change. Adjustments are commonly made to restate baseyear energy use under post-implementation conditions.

The basic approach for impact determination is the following [2]:

1. Select the IPMVP option (as described later in this section) that is consistent with the intended scope of the project, and determine whether adjustment will be made to post-retrofit conditions or to some other set of conditions;
2. gather relevant energy and operating data from the baseyear and record it in a way that can be accessed in future;
3. design the energy savings programme. This design should include documentation of both the design intent and methods to be used for demonstrating achievement of the design intent. This stage is done by the ESCO or the client, depending on who is implementing the project;
4. prepare a measurement plan, and a verification plan if necessary, (commonly together called an M&V Plan). The M&V plan fundamentally defines the meaning of the word "savings" for each project. It will contain the results of steps 1 to 3 above and will define the subsequent steps 5 to 8;
5. design, install and test any special measurement equipment needed under the M&V plan;

6. after the energy savings project has been implemented, inspect the installed equipment and revised operating procedures to ensure that they conform to the design intent defined in step 3. This process is commonly called "commissioning";
7. gather energy and operating data from the post-implementation period, consistent with that of the baseyear and as defined in the M&V plan. The inspections needed for gathering this data should include periodic repetition of commissioning activities to ensure that equipment is functioning as planned; and
8. compute and report savings in accordance with the M&V plan.

Steps 7 and 8 are repeated periodically when a savings report is needed.

Once a savings report has been prepared, a third party may verify that it complies with the M&V plan. This third party should also verify that the M&V plan itself is consistent with the objectives of the project [2].

The IPMVP uses four options, of which any one could be adopted for a particular impact determination task. These options are the following:

4.4.1 Option A: Partially measured retrofit isolation

Option A involves isolation of the energy use of the equipment affected by a project from the energy use of the rest of the facility. Measurement equipment is used to isolate all relevant energy usage for the pre-implementation and post-implementation periods. Only partial measurement is used under Option A, with some parameter(s) being stipulated rather than measured. However, such a stipulation could only be made where it can be shown that the combined impact of the plausible errors from all such stipulations would not significantly affect the overall reported savings.

4.4.2 Option B: Retrofit isolation

The savings determination techniques of Option B are identical to those of Option A, except that no stipulations are allowed under Option B. In other words, full measurement is required. Short-term or continuous metering may be used under Option B. Continuous metering provides greater certainty in reported savings and more data about equipment operation.

4.4.3 Option C: Whole building

Option C involves the use of utility meters or whole-building sub meters to assess the energy performance of a total building. Option C assesses the impact of any type of project, but not individually if more than one were applied to an energy meter. This option determines the collective savings of all energy-efficiency / DSM activities applied to that part of the facility monitored by the energy meter. Also, since whole-building meters are used, savings reported under Option C include the impact of any other changes made in facility energy use (positive or negative).

Option C may be used in cases where there is a high degree of interaction between implemented activities or between activities and the rest of the building, or the isolation and measurement of individual project activities are difficult or too costly.

4.4.4 Option D: Calibrated simulation

Option D involves the use of computer simulation software to predict facility energy use for one or both of the energy use terms in Equation 1. Such a simulation model must be "calibrated" so that it predicts an energy use and demand pattern that reasonably matches actual utility consumption and demand data from either the baseyear or a post-implementation year. Option D may be used to assess the performance of all project activities in a facility, similar to Option C. However, as opposed to Option C, multiple runs of the simulation tool in Option D allow estimates of the savings attributable to each project activity within a multiple activity project.

4.4.5 Rationale behind saving determination

An energy-efficiency project comprise of three basic stages. These stages are the pre-implementation phase, the implementation phase and lastly the post-implementation phase. The timeline for each of these phases may vary according to the project complexity and a range of other factors. These stages can be seen in Figure 4.2.

A system has a characteristic energy usage before an energy-efficiency intervention is implemented. After implementation the energy usage is reduced by a certain amount. In order to determine what the savings are, we need to establish what the energy usage after implementation would have been, had the energy efficiency intervention <u>not</u> taken place. This is achieved through the use of baselines that describe the energy usage based on certain known and/or measurable input variables or patterns. This enables calculation of the savings that were achieved by the energy-efficiency intervention by obtaining the difference between the baseline and the actual energy usage. All baselines are based on certain assumptions and criteria. Adjustments are made to the baseline when any of these assumptions become invalid or criteria are no longer satisfied by the baseline.

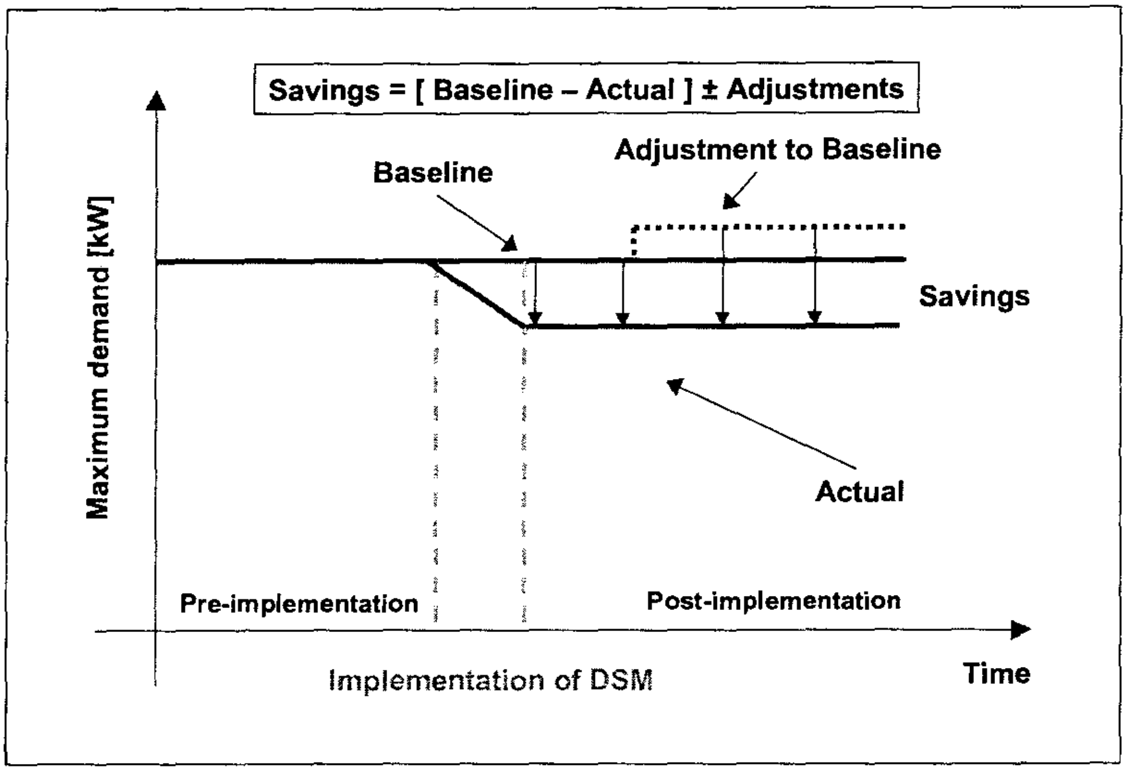

Figure 4.2: Basic energy-efficiency project stages and approach of saving calculation.

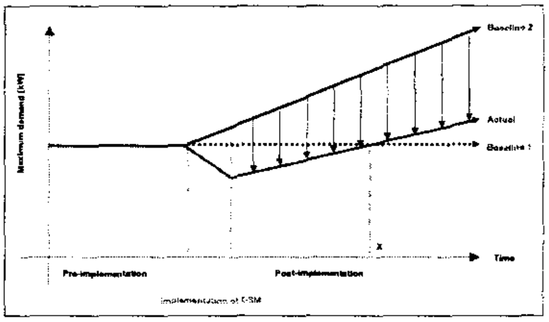

Figure 4.3: Baseline development issues.

Baselines are critical to the process and care need to be taken during the development of baselines. It is not enough just to look at what happened the previous year and use it as a baseline. It could happen that energy costs increase after implementation, and a baseline should be able to pick this up. Consider Figure 4.3. An energy-efficiency intervention is implemented, but soon afterwards the actual cost starts to rise. Saving would thus occur only to a point X in time. This could result in disputes if baseline 1 were used (simple extrapolation of previous behaviour). An accurate baseline (baseline 2) shows that the energy cost would have risen as well in the absence of the energy-efficiency intervention and that savings are actually still being achieved.

The fact that measurements are used during M&V to obtain the baseline, actual energy consumption and demand, makes the M&V process a negotiated process. The number of measurements is determined by the possibility of measurement and the cost to measure. If it were possible to measure everything, an almost perfect baseline and actual energy consumption would be available. However, the high cost to measure decreases the number of measurements and the overall accuracy of the baseline. All the involved stakeholders (the client, the energy service company and the financier) must agree on the method of calculating the savings. The level of detail of the M&V efforts should be in proportion to the size of the savings. Small savings would be measured and verified by a simple M&V process. The level of detail of the M&V process would increase as the size (quantity) of the savings increases. The cost of an M&V project preferably ranges between 2% to 15% of the energy efficiency or DSM project implementation cost.

The M&V process is extremely flexible. Statistical sampling techniques can be used to reduce the number of measurements without compromising the accuracy of the information or jeopardising project buy-in [4].

4.5 What are the next steps?

The IPMVP as well as the FEMP are widely used protocols that provide invaluable information and guidance on the requirements to perform M&V. The one thing that is lacking, however, is the exact methodology to perform M&V. Such a methodology would provide M&V teams with a set of steps to perform during each specific stage of a DSM, energy-efficiency or CDM project in order to quantify and verify project impacts in an impartial manner that is accepted and trusted by all the stakeholders. An integrated approach is thus required that would promote sustainable implementation of energy-efficiency, DSM and CDM projects.

4.6 Summary

Measurement and verification are a critical and necessary part of any energy-efficiency, demand-side management or clean development mechanism project. It provides the stakeholders with an impartial quantification of verified project impacts.

The benefits of M&V range from accurate impact determination, identification of project focus areas and problems, promotion of proper implementation, encouraging investment in projects, encouragement of better project design and verified savings.

The project baseline forms the basis of the impact determination. It is critical that the project baseline be accurate and it should be developed in such a manner as to receive buy-in from all the project stakeholders.

International protocols such as the IPMVP and FEMP provide valuable guidance on the requirements and procedures to perform M&V. It is, however, important that a methodology be developed that provides a clear set of steps that an M&V team needs to perform when determining the impacts of a project. Each of these steps in the methodology need to be associated with certain stages in the energy-efficiency or DSM project. An integrated approach is thus required that would promote increased implementation of energy efficiency and DSM when the level of risk and uncertainty is reduced within projects. This will ultimately lead to the implementation of more sustainable energy-efficiency and DSM projects.

4.7 References

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CHAPTER 5

The integrated approach

This chapter proposes an integrated approach to implement and sustain energy efficiency and greenhouse gas mitigation in South Africa. The various project stages are described and special attention is paid to critical stages.

Chapter 5: The integrated approach

5.1 Introduction

The importance of M&V for the success of energy efficiency and DSM in South Africa is becoming more apparent. Large financial investments are being made and an increasing number of clients are becoming interested in energy efficiency and DSM. The success of demand-side management is a priority in South Africa due to the fact that this country will have run out of excess capacity by 2007. The main force behind this drive is Eskom, South Africa's parastatal utility. In order to ensure the success of the initiative, Eskom needs to quantify the results of these projects against their set targets. It needs to know that DSM and energy efficiency are achieving its goal, namely to reduce the load during peak periods.

Measurement and verification have formed a logical next step and key element of the DSM and energy-efficiency initiative. It would provide Eskom with verified data and information to gauge the success of their activities and it would provide clients and ESCOs with a third-party verified quantification of the project's impacts.

A Measurement and Verification Steering Committee (MVSC) was established to manage M&V activities. The MVSC is directing the development and implementation of M&V procedures and systems for Eskom's DSM and energy-efficiency activities as an objective third-party authority. The objective is to achieve a sustainable system to measure and verify energy efficiency and DSM projects in a manner that is transparent and reliable according to international standards. The strategic intent of the MVSC is to become the body that internalises M&V expertise in the national interest and to be recognised as an independent authority in Southern Africa on all M&V-related issues.

This study was conducted to develop an integrated approach that would help to implement and sustain energy efficiency in South Africa. This approach, however, had to be flexible to allow for GHG mitigation associated with energy-efficiency projects.

The purpose of this study was to identify and propose a structure for measurement and verification for energy-efficiency and DSM activities in South Africa. International measurement and verification protocols were utilised to develop an M&V system. These protocols are the International Performance Measurement and Verification Protocol (IPMVP) [1], as well as the M&V Guidelines for Federal Energy Management Projects (FEMP) [2].

These protocols formed the backbone of the process. It was, however, critical to define an approach that would provide a methodology that could be used in industry to perform M&V in an effective manner that would assist in the implementation process and help to sustain the impacts of each project.

The integrated approach was developed in such a way as to facilitate agreement between the various stakeholders and the M&V team. Certain M&V deliverables need to be submitted before key project activities could continue. These reports form the basis of project buy-in from the energy-efficiency stakeholders into the M&V process.

This chapter will provide the integrated approach to implement and sustain DSM, energy efficiency and GHG mitigation projects in South Africa. A step-by-step guideline is provided on the application of the approach and how it fits into the project's stages associated with energy efficiency and DSM.

5.2 Key benefits

The following key benefits have been identified for the integrated approach:

1. Increased energy impacts

Knowledge is power and nothing could be more accurate in the case of energy efficiency and DSM. The integrated approach facilitates the accurate determination of project impacts and savings. It also provides valuable feedback to clients and ESCOs on the operation of a system or facility. Accurate determination of savings gives facility owners and managers valuable feedback on the operation of their facility, allowing them to adjust facility management to deliver higher levels of energy savings, greater continuity of savings and reduced variability of savings.

2. Reduced financial risk

Financial risk is reduced, providing more reliable savings through a common approach to determine the project savings and impacts. Confidence is provided to financial institutions and financing parties in the credible assessment of a project's performance.

3. Improved project design

The integrated approach provides ongoing monitoring of project performance and assists in the design of projects that sustain their savings over time. The fact that a third party verifies that the project keeps performing and continues to sustain its savings provides peace of mind to clients and encourages better operation and maintenance.

4. Tracking of environmental impacts

The main emissions that result from the use of electricity is CO_2 (the primary greenhouse gas), SO_2, NO_x and particulate matter. Not only does the integrated approach provide stakeholders with a verified quantification of the above emissions, but also of the reductions in water consumption (on the utility side) due to the project's implementation. It thus makes the integrated approach ideal for application in CDM projects as well.

5. Public awareness

The integrated approach will increase public acceptance of energy efficiency due to the above-mentioned benefits. This will in turn encourage more investment in energy efficiency and GHG mitigation, since it is now more apparent what the project impacts are and how much is actually being saved and by which activities.

6. Promote and achieve efficiency and environmental objectives

The above-mentioned benefits will result in an increased number of companies becoming involved, thus increasing investment in energy efficiency and realising environmental and health benefits.

5.3 Implementing mechanism stages

This section describes the different stages that are associated with the implementing mechanisms. These stages are the same for both energy-efficiency and DSM projects. The only difference between energy-efficiency projects and DSM projects is that DSM projects without an energy-efficiency component will not deliver any GHG emission reductions. This basically means that energy-efficiency projects could qualify for GHG mitigation and pure demand-reducing projects (or DSM projects without an energy-efficiency component). The same basic project stages are therefore associated with GHG reducing projects (as in the case with CDM projects). The only difference between a normal energy-efficiency project and an energy-efficiency project inside CDM is the additional stages coupled with CDM as described in Chapter 3 of this thesis.

The stakeholders in these project stages are the client, the financial institution and the ESCO. The project stages are shown in Figure 5.1, with a representation of the impact on a system's demand depicted in Figure 5.2.

5.3.1 Project identification

The client or ESCO identifies the need, potential or opportunity for DSM and energy-efficiency savings during this stage. An ESCO would mostly be contracted to determine the potential impacts and savings that could be achieved.

5.3.2 Energy audit / assumptions

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

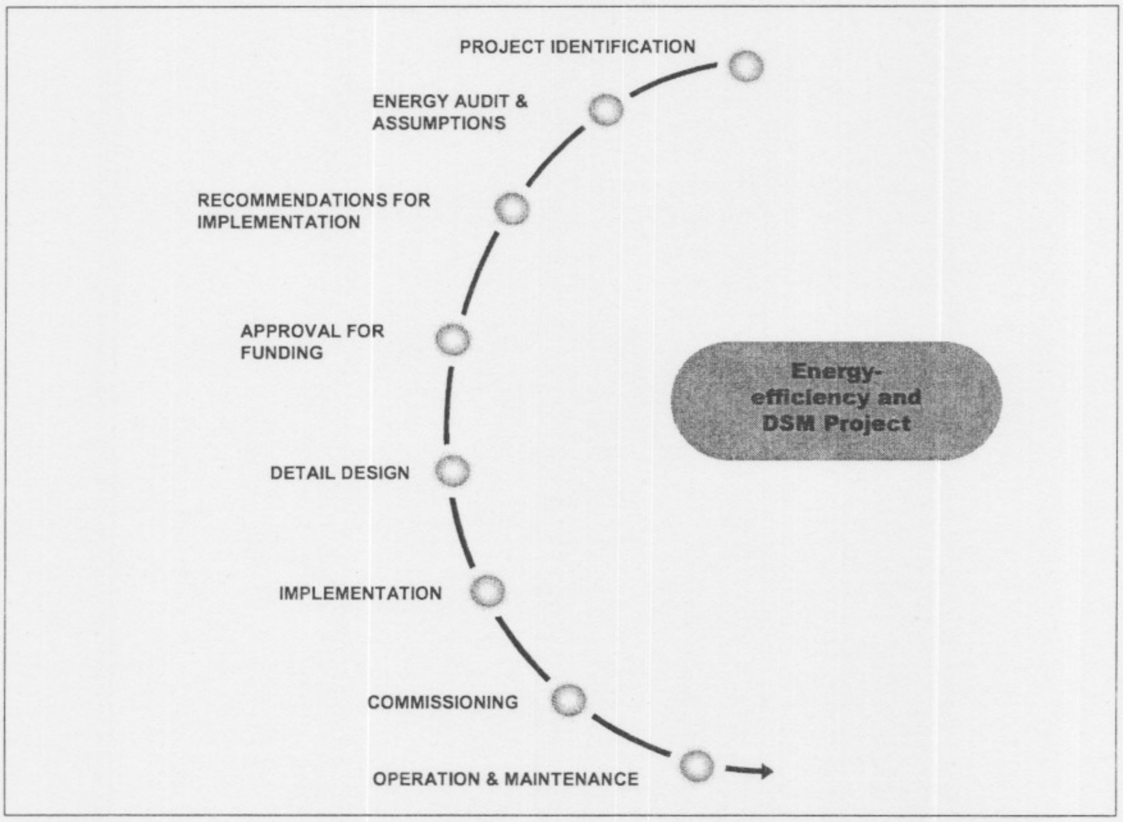

Figure 5.1: Energy-efficiency and DSM project stages.

5.3.3 Recommendations for implementation

A better estimate of the potential savings can be calculated once building and system information has been gathered. Upon evaluation of the various potential energy-efficiency and DSM activities together with a feasibility study, the energy-efficiency and DSM activities are selected that show the greatest potential, based on their individual and combined feasibility.

5.3.4 *Approval for funding*

Approval for project funding is granted (by the client or utility) once it has been established that the recommended energy-efficiency or DSM activities will deliver satisfactory results within an acceptable budget, time-frame and risk. M&V play an important role during this phase, since it will reduce the risk for stakeholders.

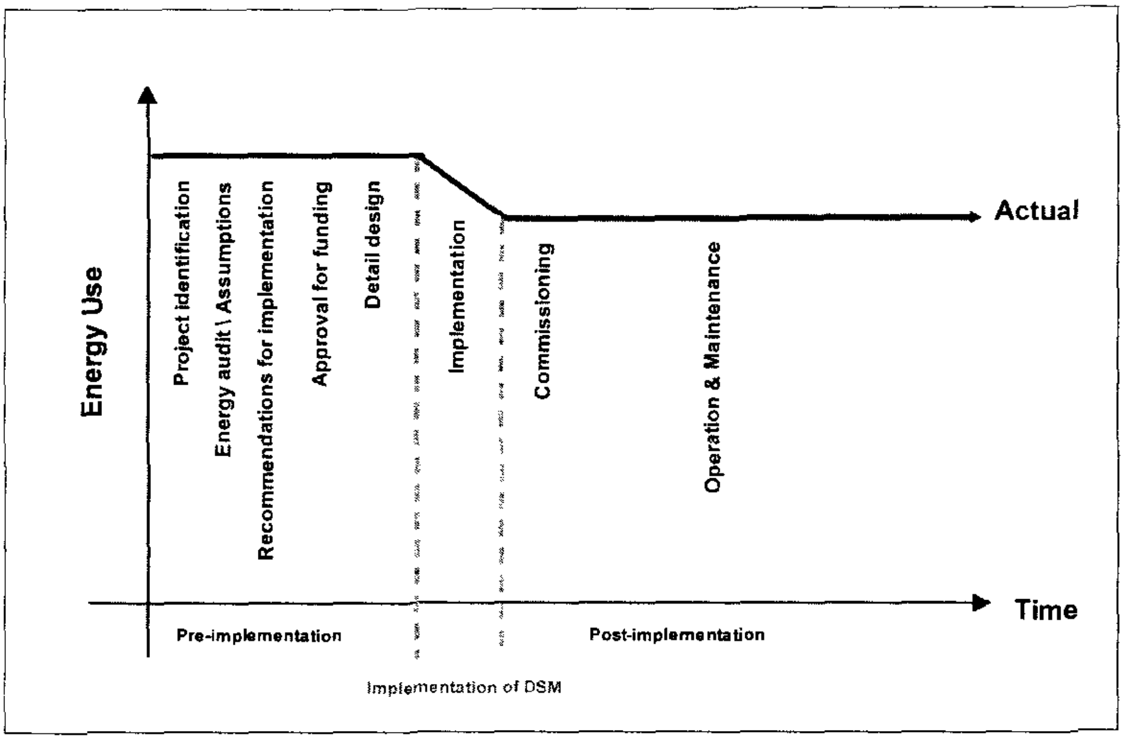

Figure 5.2: Basic energy-efficiency or DSM project stages transposed on project impacts.

5.3.5 *Detail design*

A detail design is made by the ESCO of the recommended energy-efficiency or DSM activities once project funding has been approved.

5.3.6 *Implementation*

The energy-efficiency or DSM activities are then implemented based on the detail design. This phase is characterised by fluctuations in energy usage (see Figure 5.2).

5.3.7 Commissioning

Commissioning of the installed equipment is necessary to ensure that actual implementation has been done in the correct manner and that the equipment and systems are performing to specified requirements.

5.3.8 Operation and maintenance

The systems need to be maintained to ensure that the energy-efficiency or DSM activities deliver the optimum level of performance and continue to save energy and energy costs.

5.4 Measurement and verification stages

The stakeholders in the M&V process are the M&V team, the client, the financial institution and the ESCO. These stakeholders provide valuable information on the M&V process and need to buy in for M&V to continue through its various stages.

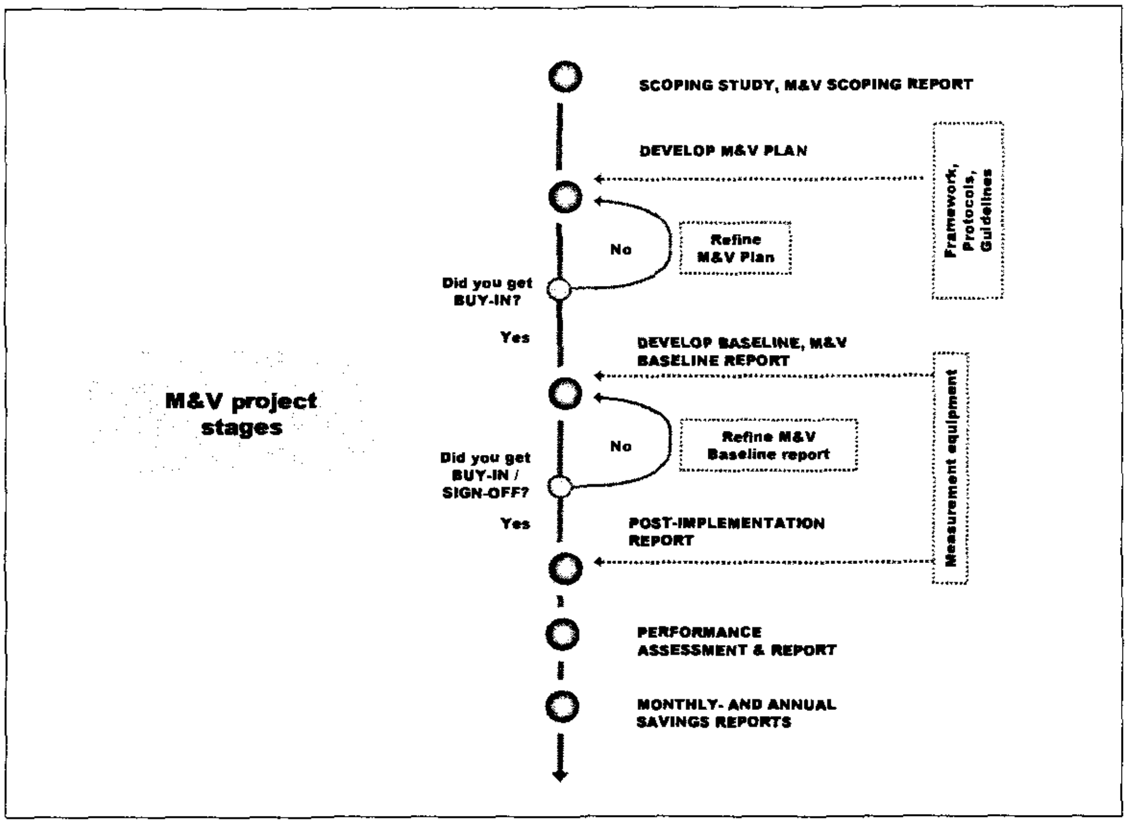

Figure 5.3: Measurement and verification project stages.

The M&V project has a total of five deliverables. They are:

- Scoping report;
- M&V plan;
- M&V baseline report;
- post-implementation M&V report;
- performance assessment report; and
- monthly and annual saving reports.

These deliverables and reports are structured in such a way as to facilitate buy-in into the M&V project procedures and provide all the project participants with a clear understanding and layout of the way in which M&V will proceed. These reports and deliverables are discussed in more detail in the sections that follow. Figure 5.3 shows the basic layout of the M&V project stages.

5.4.1 Scoping study and report

The purpose of the scoping study is to enable the M&V team to gather all relevant and available data on the project and to obtain a clear understanding of what the energy-efficiency or DSM project will entail. The scoping study starts with a kick-off meeting between the M&V team and the client and/or the ESCO. A site visit is also conducted.

The scoping report is the deliverable for this stage and needs to state the following:

- Project information – This section must contain the contact details of the involved parties and persons that represent them. The contact details of the M&V team are stated as well as those of persons representing the ESCO and the client.
- Project objective – The objective states the project impacts that the stakeholders require to be quantified and verified by the M&V team.
- Site description – The description of the site provides information on the size and utilisation of the system or facility under investigation. Also included is information on the typical annual energy consumption, maximum demand and electricity account. The control of the system / facility is described as well as the layout.
- Tariff structure – The tariff structure under which the system or facility operates needs to be stated and described in detail in this section.

- Audit of system – This section provides detailed information and data on the system(s) that is/are affected by the proposed energy-efficiency or DSM measure. It is also important to include a description of the layout of the system's electrical supply for reference from the M&V plan that would eventually contain a section on measurement of the system. If the project is concerned with a lighting retrofit, one needs to state the layout and quantities of the current lighting system, as well as the current mode of operation. This section is critical in establishing the baseyear for the system or facility.

- Proposed activities by the ESCO – This section provides a description of the activities that the ESCO proposes to implement. This information must be obtained from the ESCO.

- Expected results – The ESCO should supply the M&V team with an estimate of the expected impacts on the system. This data needs to be supplied for the monthly maximum demand, the energy consumption and the electricity cost impacts. If the project is concerned with GHG mitigation, the ESCO also needs to supply figures for expected emission reductions in terms of CO_2 equivalent. This section should also contain an estimate of the expected impacts as determined by the M&V team if the process is repeatable (which is not possible in the case of simulation models developed by the ESCO).

- Conclusions and comments – This section contains a summary of the expected results for the project and must contain comments and concerns raised by the M&V team.

The scoping study is an important document for the utility as the financing party of the projects in the sense that it provides them with the expected impacts of the project as assessed by the M&V team. Where a limited number of projects need to be selected from a large number of submittals, the selection should be made with the aid of the scoping report for each project. A case study on the selection of a number of projects that will best suit the needs of the investing party in achieving its needs is provided in Chapter 6 of this thesis. This requires that a number of scenarios be developed between the available projects to achieve the set goals.

5.4.2 M&V plan development and report

The M&V plan forms the backbone of the whole M&V process and outlines the complete process that is expected for the project. The M&V plan is the first deliverable on which all the stakeholders must give buy in before M&V activities could proceed. If the stakeholders give buy in they are agreeing with the proposed M&V activities that will be followed and are satisfied with the manner in which the baseline and savings will be determined. The M&V plan is updated with the negotiated recommendations of the stakeholders if buy-in is not obtained with the first submittal.

As mentioned, the M&V plan describes the activities and procedures that will be followed to M&V the energy-efficiency or DSM activities. The first part of the M&V plan repeats the first few sections of the scoping report. This is done to ensure that the M&V plan forms a independent report that provides a complete overview of the project. The plan should include the following sections:

- Project information – This section must contain the contact details of the involved parties and persons representing them. The contact details of the M&V team is stated as well as those of the persons representing the ESCO and the client.
- Project objective – The objective states the project impacts that the stakeholders require to be quantified and verified by the M&V team.
- Site description – The description of the site provides information on the size and utilisation of the system or facility under investigation. Also included is information on the typical annual energy consumption, maximum demand and electricity account. The control of the system / facility is described as well as the layout.
- Tariff structure – The tariff structure under which the system or facility operates need to be stated and described in detail in this section.
- Audit of system – This section provides detailed information and data on the system(s) that will be affected by the energy-efficiency or DSM measure. It is also important to include a description of the layout of the system's electrical supply for reference from the M&V plan that will eventually contain a section on measurement of the system. This section is critical in establishing the baseyear for the system or facility.
- Proposed activities by the ESCO – This section provides a description of the activities that the ESCO proposes to implement. This information must be obtained from the ESCo.
- Assumptions – This section provides the assumptions that were made by the ESCO or implementing party when it estimated/calculated the expected project impacts.
- Expected results – The project impacts as calculated by the ESCO are once again provided in the M&V plan as in the case of the scoping report.
- Evaluation – An evaluation of the expected impacts is given by the M&V team where comments and concerns are raised on the assumptions and calculation methodology of the expected project impacts.
- M&V option selection – This section is concerned with the selection of the M&V option that will be utilised to determine the project baseline and ultimately the project savings. As in the case

of the IMPVP, there are four M&V options that can be used to determine the baseline. These four options are:

Option A - Partially measured retrofit isolation: Option A involves isolation of the energy use of the equipment affected by a project from the energy use of the rest of the facility. Measurement equipment is used to isolate all relevant energy usage for the pre-implementation and post-implementation periods. Only partial measurement is used under Option A, with some parameter(s) being stipulated rather than measured. However, such stipulation could only be made where it can be shown that the combined impact of the plausible errors from all such stipulations will not significantly affect the overall reported savings.

Option B - Retrofit isolation: The savings determination techniques of Option B are identical to those of Option A, except that no stipulations are allowed under Option B. In other words, full measurement is required. Short-term or continuous metering may be used under Option B. Continuous metering provides greater certainty in reported savings and more data about equipment operation.

Option C - Whole building: Option C involves use of utility meters or whole-building sub meters to assess the energy performance of a total building. Option C assesses the impact of any type of project, but not individually if more than one were applied to an energy meter. This option determines the collective savings of all energy-efficiency / DSM activities applied to the part of the facility monitored by the energy meter. Also, since whole-building meters are used, savings reported under Option C include the impact of any other changes made in facility energy use (positive or negative). Option C may be used in cases where there is a high degree of interaction between implemented activities or between activities and the rest of the building, or the isolation and measurement of individual project activities are difficult or too costly.

Option D - Calibrated simulation: Option D involves the use of computer simulation software to predict facility energy use for one or both of the energy use terms in Equation 1. Such a simulation model must be "calibrated" so that it predicts an energy use and demand pattern that reasonably matches actual utility consumption and demand data from either the baseyear or a post-implementation year. Option D may be used to assess the performance of all project activities in a facility, similar to Option C. However, as opposed to Option C, multiple runs of the simulation tool in Option D allow estimates of the savings attributable to each project activity within a multiple activity project.

- Boundaries– This section states the boundaries of the saving impact determination. It states whether the savings will be determined to include or exclude interactive system effects.

- Baseline characterisation – A description is provided in this section on the means by which the baseline will be determined. The independent variables are stated that will be used to quantify the dependent variables (which will ultimately be the demand or energy consumption of the system). A complete description must be provided in this section whether baselines will be developed for each system or for the complete facility.
- Baseline adjustments – All the variables and situations that will necessitate adjustments to the project baseline need to be stated and described in this section.
- Pre-implementation metering plan – A complete layout and description of the electrical supply to the system or facility must be provided in this section. It is also important to state all the data requirements, variables and measurement points that will be metered, as well as the equipment that will be used. This section must state the interval of the measurements as well as the duration of the pre-implementation metering activities.
- Post-implementation metering plan – This section provides the same information as in the case of the pre-implementation metering plan, but is adjusted to describe the post-implementation data requirements, variables, metering intervals, equipment and metering positions.
- Saving calculation methodology – The methodology that will be used to determine the savings in demand, electricity consumption and cost is stated in this section with all the relevant equations describing the process. This section must also contain the methodology and emission factors to calculate the environmental impacts of the project.
- Project cost – A cost breakdown needs to be provided in this section for each of the M&V activities, together with their expected submittal dates.
- Project schedule – An M&V activity schedule needs to be included in the M&V plan to provide a detailed breakdown of all the activities associated with each M&V deliverable and its expected delivery dates. It is also important to include key project timelines such as the implementation and completion dates of the energy-efficiency or DSM project.

It is not uncommon for the scoping report and the M&V plan to be combined into a single document. An example of a combined scoping report and M&V plan can be found in Appendix A of this thesis.

5.4.3 M&V baseline report

Pre-implementation measurements need to commence once buy-in has been obtained for the M&V plan. The pre-implementation measurements will be used in the development of the baseline(s). These measurements need to be taken for an acceptable period prior to implementation (preferably 3 months) to allow for sufficient data and project buy-in for the M&V baseline.

The M&V baseline report must contain the actual baseline that will be used during the saving calculations. All other information relevant to the baseline also needs to be included in this report to ensure that the report and baseline can be determined in a repeatable manner by the stakeholders. The baseline report should include the following:

- The report should once again include the project information, the objectives and the site description;
- variables used to characterise the baseline;
- a description of the pre-implementation metering data used, as well as information on the metering period and interval;
- data used to develop the baseline;
- characterisation procedures;
- assumptions used during baseline characterisation;
- baseline adjustment procedures; and
- the actual demand baseline profile(s) and energy consumption values that will be used in the determination of the project's savings.

Upon delivery of the M&V baseline report, all parties need to review the report and state any changes that should be made. Once they are all satisfied and buy-in is obtained in the M&V baseline report, M&V can proceed to its next stage. If this were not the case, the M&V baseline report must be refined and submitted again until buy-in has been obtained. The final M&V baseline report is delivered only after all parties have come to a mutual agreement on all the issues involved regarding the development and use of the baselines.

An example of an M&V baseline report can be found in Appendix B to this thesis.

5.4.4 Post-implementation M&V report

The post-implementation audit goes hand-in-hand with the commissioning of the equipment and systems after implementation. This forms part of the M&V team's responsibility to verify that the implementation has indeed taken place according to specification. This stage usually consists of a walk-through audit. The post-implementation measurements are also taken or commenced during this stage.

The data (independent variables) obtained from the post-implementation measurement phase are used to define the baseline energy usage. The actual energy usage, also obtained from the post-implementation measurement phase, is subtracted from the baseline to obtain the savings.

The post-implementation M&V report contains all the information relevant to the M&V project. The following section needs to be included in the post-implementation report:

- Project information – This section in once again repeated for the post-implementation report.
- Project objective – The objective states the project impacts that the stakeholders require to be quantified and verified by the M&V team.
- Site description – The description of the site provides information on the size and utilisation of the system or facility under investigation. Also included is information on the typical annual energy consumption, maximum demand and electricity account. The control of the system / facility is described as well as the layout.
- Original system description – This section must contain a description of the original system as it was found to be operational during the pre-implementation phase of the project. This section needs to concur with the M&V plan.
- Proposed changes – This section needs to describe the energy-efficiency or DSM intervention as proposed by the ESCO.
- Actual changes – The actual changes to the system or facility, due to the intervention, need to be described in this section. This information needs to be obtained via a post-implementation audit.
- Deviation – The difference between the intervention that was proposed (as in the M&V plan) and the one that was actually implemented (as determined during the post-implementation audit) needs to be described in this section. If available, the M&V team can also provide the reasons for the deviation as discussed with the ESCO or client.
- Comments – Any comments on deviations need to be stated in this section. If possible, the M&V also need to state how deviations will potentially influence the estimated impacts of the project.

An example of a post-implementation report can be found in Appendix C to this thesis.

5.4.5 Post-implementation performance assessment

The post-implementation performance assessment is basically the initial or first savings report that the M&V team delivers. This report should provide the following information:

- Basic project information is provided that includes the site name, the name and contact details of the person that is responsible for the report (on the M&V team), the date that the project's implementation started and the period for which the savings are stated in the report.
- The project impacts need to be stated for the relevant period in terms of the baseline value, the actual value and the resulting savings for the energy consumption, the electricity cost and the environmental impacts (CO_2, NO_x, SO_x, particulate matter and water consumption).
- The average impact on the demand need to be stated, also in terms of the baseline, actual and savings, for all the relevant time-of-use periods, which are weekday morning peak, weekday standard, weekday afternoon peak, weekday off-peak, Saturday standard, Saturday off-peak and Sunday off-peak.
- Information on the tariff structure, the emission and environmental factors and the time-of-use periods need to be supplied.
- The accumulated impacts need to be supplied for the energy consumption, electricity cost, environmental impacts and the demand impact in the various time-of-use periods, again in terms of the baseline, actual and the savings. In the case of the post-implementation performance assessment, the impacts for the period and those for the accumulated period are exactly the same, since the period in question is the same for both cases.

Emission factors are critical for the determination of the environmental impacts of the energy-efficiency projects. A case study on the use of emission factors is provided in Chapter 6 of this thesis. An example of a post-implementation performance assessment report can be found in Appendix D to this thesis.

5.4.6 Monthly savings report

The monthly savings report provides a summary of the savings that are achieved for each month. These reports are submitted on a monthly basis to all the DSM stakeholders. The purpose of this report is to provide verified savings to the stakeholders. This report has the same structure and sections as the post-implementation performance assessment. The only difference is the fact that the first part of the report provides the project impacts for a period of one month for which the report is compiled. The accumulated section provides the impacts obtained over the total period to date of the report.

An example of a monthly savings report can be found in Appendix E to this thesis.

5.4.7 Annual savings report

An annual savings report is generated once a year. This report is generated from all the monthly data and savings reports and serves as a summary report. Both the monthly and annual savings reports are required for the duration of the energy-efficiency or DSM project. This report has the same structure as the monthly savings report. The first section, however, provides the total project impacts for a single year. The accumulated impacts are determined for the year of the report plus any additional savings obtained for additional months outside the year in question.

An example of an annual savings report can be found in Appendix F to this thesis.

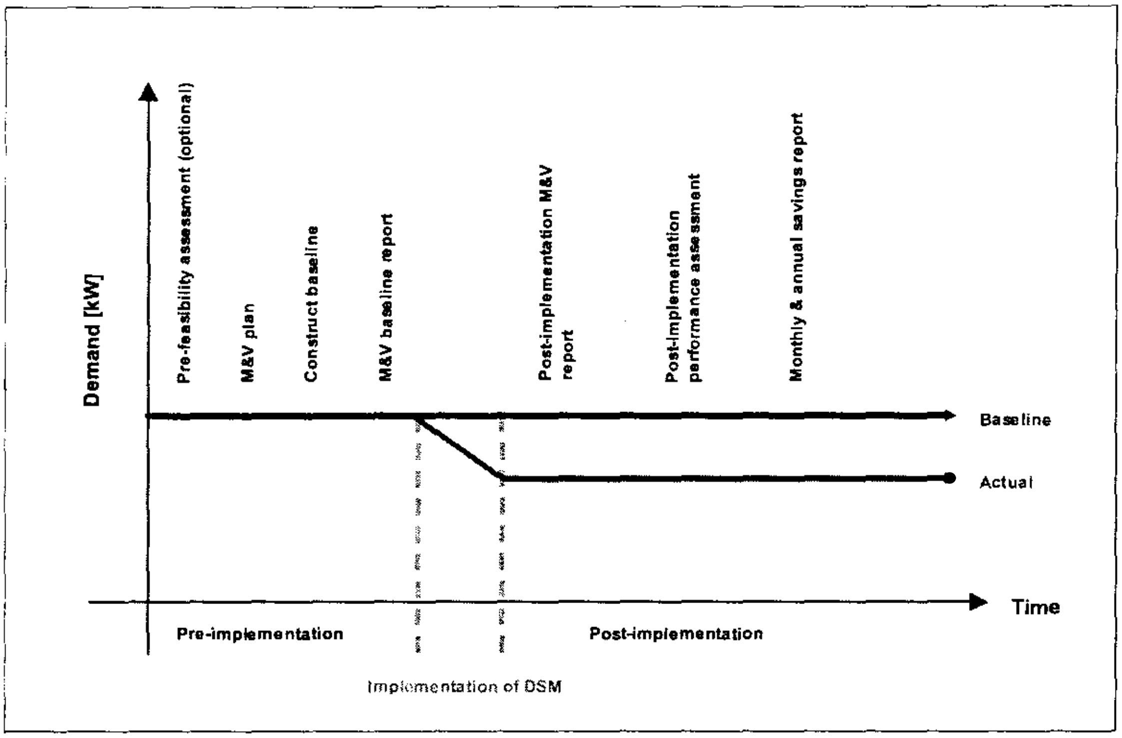

Figure 5.4: *Basic M&V project stages transposed on energy-efficiency impacts.*

The various M&V project deliverables are interposed on the energy use of a typical energy-efficiency or DSM project in Figure 5.4. It can be seen that the baseline represents the "business as usual" scenario, whilst the actual energy use was reduced due to the energy-efficiency or DSM intervention.

5.5 M&V and project implementation

The interaction between the energy-efficiency or DSM project and the M&V project can be seen in Figure 5.5. It is important to note that buy-in needs to be obtained for both the M&V plan and the M&V baseline report before any other M&V activities could continue and implementation commence.

After the M&V plan has been delivered, all parties need to review the findings. The same procedure needs to be followed for the M&V baseline report. Any queries need to be addressed by means of proof of calculation or baseline adjustments. The monthly and annual savings reports are then delivered for the duration of the M&V contract.

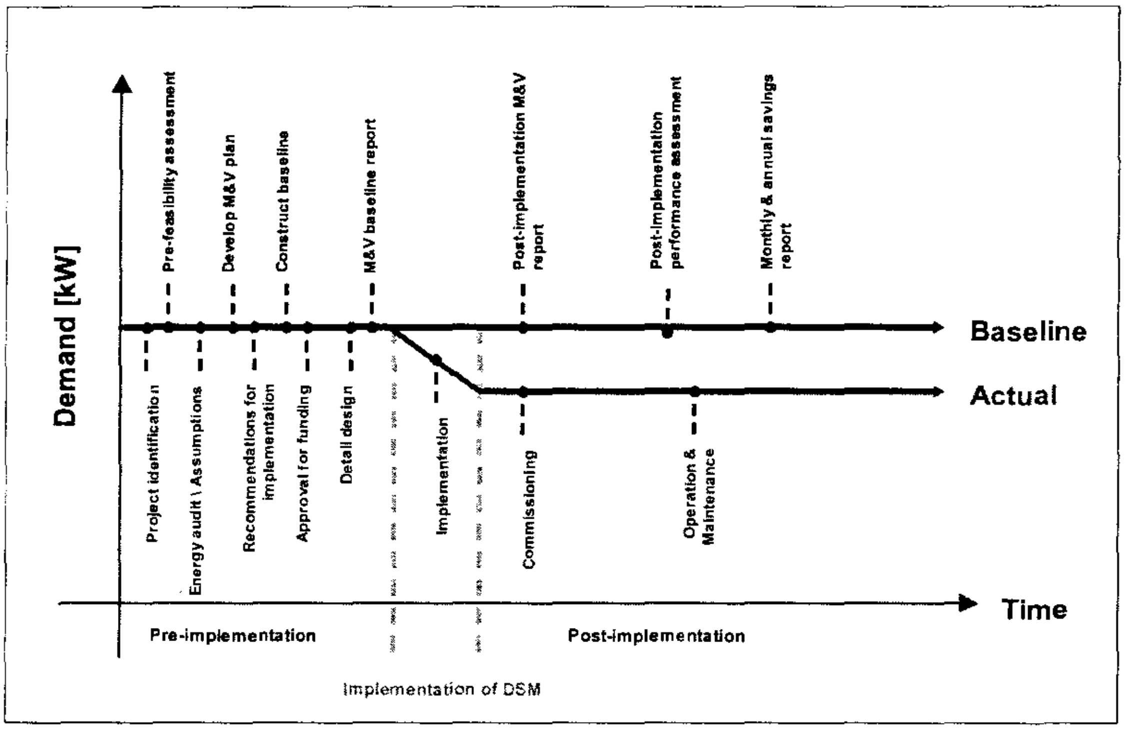

Figure 5.5: Basic energy-efficiency or DSM project interaction with M&V transposed on project impacts.

Figure 5.6 shows the position of each M&V deliverable as it fits into the energy-efficiency project's stages. As shown, a number of framework documents [3], guidelines and protocols can be used to develop the M&V plan to suit the specific needs of the stakeholders.

Metering data is also required to develop the baseline report during the calculation of the project impacts after implementation. Figure 5.6 indicates at which stages metering for M&V purposes need to be conducted. Pre-implementation metering should preferably commence three months before implementation. This data that should be used to develop the baseline report. Metering activities continue once implementation has been completed.

The above interaction is also applied during CDM projects that are concerned with energy-efficiency and DSM activities. The normal stages as outlined in Chapter 3 are followed where the project activity is designed that corresponds with the first five energy-efficiency or DSM project stages of Figure 5.6. The stages of authorisation, validation and registration are also performed for the CDM project as it is normally done.

The stage where the integrated approach plays a significant role in the CDM process is during the third CDM project activity, namely monitoring. The integrated approach can be applied by either the project participant or a third party that he appoints. The deliverables and reports from the integrated approach to M&V provide all the relevant and required results that a designated operational entity may require to perform the fourth CDM activity, namely verification and certification, which will ultimately lead to issuance of the CERs.

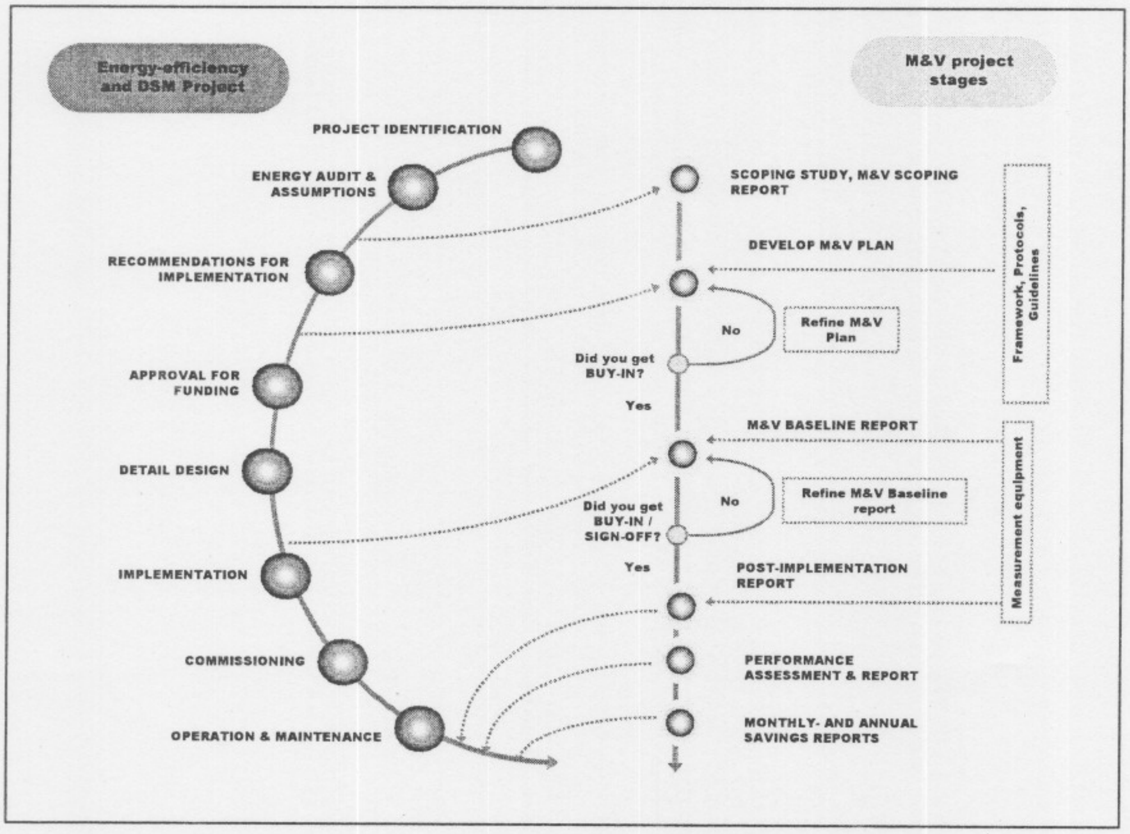

Figure 5.6: Integrated approach interaction between energy-efficiency or DSM projects and M&V.

In the case of a standard energy-efficiency or DSM project, it is preferable that the project stakeholders do not perform the M&V activities, but that a third party should do so. In the case of CDM, the project participant may perform the M&V activities, but ultimately has to provide an appointed DOE with the M&V results of the integrated approach to perform the independent verification based on the reports and data.

As mentioned, the integrated approach was originally designed for use during the M&V of DSM projects for Eskom's DSM initiative. The integrated approach has been utilised with great success since 2002, from which time it has been subjected to continuous improvement. The approach has proved to be effective, transparent and repeatable. A case study on the application of the proposed approach is provided in Chapter 6. More details on the various deliverables for the project described in the case study can be found in Appendices A to F.

5.6 Summary

This chapter provided the proposed integrated approach that should be followed during the M&V of energy-efficiency and DSM projects. The integrated approach was designed in such a manner as to facilitate agreement between the various project stakeholders on the project impacts and the processes that are followed to determine them.

The integrated approach is designed to be flexible and contains a number of deliverables that form the basis of buy-in into the M&V process, namely the M&V plan and the M&V baseline report. Saving reports are submitted to the various stakeholders on a monthly and annual basis. This has proved to increase the sustainability of the project savings and supply the ESCO and the client with valuable information of the monthly performance of their project, system and/or facility. The annual savings reports are used to show the project stakeholders what the annual cost savings of their projects were and help the utility to evaluate the project impacts against its annual DSM targets.

The integrated approach has been in use since 2002 with great success in Eskom's DSM initiative. A large number of projects that delivered accurate and repeatable results have been successfully subjected to M&V.

The integrated approach provides all deliverables and reports necessary to facilitate a repeatable and transparent process, which is also beneficial when concerned with CDM projects. In the case of a CDM project, the verification activities are performed by a DOE on the basis of information received from the project participant. The DOE is not responsible for the complete M&V process, which is the responsibility of the project participant or an independent party appointed by the project participant.

5.7 References

[1]. UNITED STATES DEPARTMENT OF ENERGY, Office of Energy Efficiency and Renewable Energy. 2000. International Performance Measurement and Verification Protocol: Concepts and options for determining energy savings. Oct.

[2]. UNITED STATES DEPARTMENT OF ENERGY, Office of Energy Efficiency and Renewable Energy. 2000. M&V Guidelines: Measurement and verification for federal energy projects. Federal Energy Management Program. Sept.

[3]. RADLOFF, F.G.T. 2001. Monitoring and verification framework document: existing / retrofit projects. Sept. Report developed for Eskom under the Measurement and Verification Steering Committee.

CHAPTER 6

Case studies

This chapter provides two case studies, of which the first describes a greenhouse gas emissions footprint model and a project selection methodology that were developed during this project for the World Summit on Sustainable Development. The second case study provides an application of the proposed integrated approach presented in the previous chapter.

Chapter 6: Case studies

6.1 Introduction

This chapter will provide two case studies. The first case study looks at the application of emission factors to establish the link between variables such as electricity consumption and the quantity of carbon dioxide emissions that are released into the atmosphere. This work culminated in the development of an emissions footprint model for the 2002 World Summit on Sustainable Development (WSSD) under a project initiated by the Johannesburg Climate Legacy (JCL). This case study also demonstrates the application of the project selection methodology that was developed during the same JCL project.

The last case study will look at the application of the integrated approach to M&V the DSM project impacts as it was applied to the lighting retrofit of the Braamfontein Civic Centre in Johannesburg, South Africa.

6.2 Case Study 1: Johannesburg Climate Legacy

The world has been taken by storm as a result of efforts to address the issue of climate change and global warming. Not only is it an issue for large developed countries, but also for developing countries such as South Africa. Climate change has a direct and very real impact on many environmental, economical and political levels. A country's actions against climate change and GHG emissions will play an ever-increasing role when participating in international trade and agreements in future. Increasingly, we will need to understand and manage our GHG emissions in order to maintain our licence to operate, to ensure long-term success in a competitive market environment and to comply with national and regional policies aimed at reducing GHG emissions.

Greenhouse gases have the function of trapping heat in the atmosphere. Climate change is caused when additional man-made GHG emissions are allowed into the atmosphere, increasing the amount of heat trapped. These additional GHG emissions are the result of years of industrial development and progress.

The combustion of fossil fuels and a number of thermal and manufacturing processes cause GHG emissions. The most common GHG emissions are carbon dioxide (CO_2) and nitrous oxides (NO_x), which result when fossil fuels are burned to produce thermal and electrical energy [1] in boilers, heaters, furnaces, kilns, ovens, driers, and any other equipment or machinery that uses fuel. Another common source of CO_2 is road and rail vehicles as well as airplanes. Methane

(CH_4), another common GHG, generally results from the anaerobic digestion of waste on landfills and waste-water sites [2].

6.2.1 Footprint model

During September 2002, Johannesburg hosted the World Summit on Sustainable Development (WSSD). Approximately 21,000 international delegates attended the Summit [3]. Each of these delegates contributed to increased GHG emissions by attending the Summit. This was due to electricity and fuel consumption and waste generated that ended up on South African landfills.

A project was launched by the Johannesburg Climate Legacy to achieve a carbon neutral WSSD, meaning that every ton of CO_2 and CO_2-equivalent emissions that was generated during the WSSD by the delegates needed to be balanced by GHG emission-reducing projects in South Africa.

The question was: How much GHG emissions were caused by the delegates attending the WSSD? A need was consequently identified for a model that could be used to link factors such as electricity and fuel consumption (together with others factors) with the resulting GHG emissions.

It was decided to develop a footprint model to provide that link in a fast and accurate manner. The function of the footprint model was to determine the quantity of CO_2 or CO_2 equivalent emissions that were caused by the 21,000 delegates. This would provide a GHG emission offset target for the JCL project. Once the target was known, JCL could start implementing a group of selected offset projects to achieve a carbon-neutral WSSD. The JCL project would attempt to fund the offset projects with Global Environmental Facility (GEF) donor funding and funds raised from emission credit sales at the WSSD.

6.2.2 The footprint and emission factors

Each and every one of us, like the WSSD delegates, contributes to GHG emissions on a daily basis. For every 1 kilowatt-hour (kWh) that South African citizens use in their homes or at work, 0.89 kilograms of CO_2 emissions are emitted on the utility supply side [4]. With every litre of fuel that we use in our cars, we emit 2.4 kilograms CO_2 emissions for a petrol vehicle and 2.8 kilograms CO_2 for a diesel vehicle [5]. These factors that link an activity to GHG emissions are called emission factors. These emission factors form the backbone of the footprint model.

The GHG emissions that were incorporated into the footprint model are the following:

- Carbon dioxide CO_2; and
- Methane CH_4.

There are a number of other GHG emissions such as nitrous oxide, hydroflourocarbons, perflourocarbons and sulphur hexaflouride not covered by the model, since these emissions were outside the scope of the footprint model or their contribution to total emissions was neglectable for this project.

In order to place the various GHG emissions on an even playing field, the factor of global warming potential (GWP) had to be incorporated into the footprint model. The GWP for the GHG emissions used in the footprint model are provided in Table 6.1 [4].

Table 6.1: Global warming potential for selected GHG emissions.

Greenhouse Gas	Global warming potential
Carbon Dioxide - CO_2	1
Methane - CH_4	21

The GWP is used to convert CH_4 emissions to CO_2-equivalent emissions. This means that 1 ton CH_4 is equivalent to 21 tons of CO_2. If we consider a case where we have 1 ton of CO_2 emissions and 1 ton of CH_4 emissions, we will have CO_2-equivalent emissions totalling 22 tons of which CH_4 contributed 21 tons.

6.2.3 Boundaries of the footprint model

The first step in the development of the footprint model was to identify the processes and activities that contributed to GHG emissions.

The following activities and processes were identified as contributing factors to the total WSSD GHG emissions for the scope of the project:

- Electricity used at hotels;
- electricity used at the WSSD venues;
- air travel to Johannesburg from international destinations, including international connecting flights;
- air travel (connecting flights) within South Africa;
- road travel between hotels and venues;
- waste;
- paper production;

- o water provision and pumping; and
- o waste-water.

The footprint model was developed only to consider CO_2 and CH_4 emissions. The N_2O emissions that were found during the project were neglectable, even with the high GWP for N_2O (310).

The footprint model was divided into three parts. The first part dealt with electricity use-related emissions, the second part with travel-related emissions and the third with emissions from sources not included in the previous two parts. Each part is described in more detail in the sections that follow.

6.2.4 Footprint model – electricity use emissions

As was mentioned in previous sections, 0.89 tons CO_2 emissions are generated on the utility supply side for every 1 kWh that is consumed by the end user. This factor was used to determine the impact of 21,000 delegates attending the WSSD for 10 days. Data was also obtained to approximate the average electricity consumption per delegate per day for their stay at the hotels. The resulting CO_2-equivalent emissions were calculated as 6,420 tons [6].

The same rationale was followed to determine the impact of electricity use at the venues. A list of venues and energy accounts was obtained and used to calculate a value for the daily electricity consumption. The total amount of energy consumed during the 10 days of the WSSD could then be calculated. The total energy consumption was then multiplied with the factor of 0.89 kg CO_2 emissions per kWh [4] to obtain a value of 930 tons CO_2 emissions over the 10-day period [6].

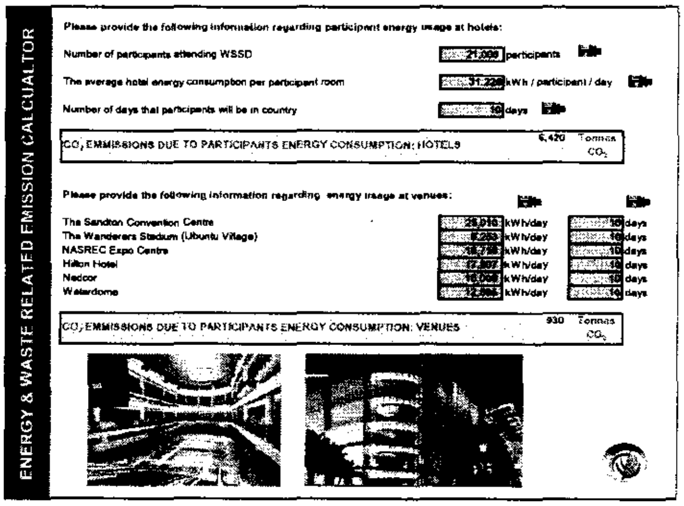

Figure 6.1: Electricity use input sheet for footprint model.

A total of 7,351 tons of CO_2-equivalent emissions was thus generated due to direct electricity consumption of the delegates [6].

6.2.5 *Footprint model – travel emissions*

The next part of the footprint model was to determine the GHG emissions that resulted from travel. The first section for travel was concerned with air travel between Johannesburg and international locations.

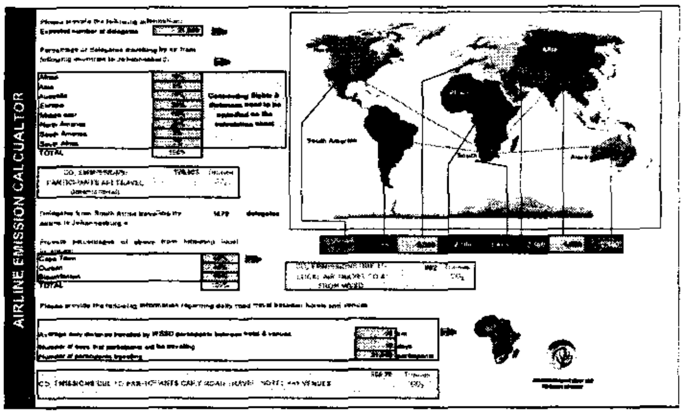

Figure 6.2: Transportation input sheet for footprint model.

The direct distances for major flights from Africa, Asia, Australia, Europe, the Middle East, North and South America was combined with average flight distances for connecting flights to these locations. The number of delegated that travelled these distances with air travel was assigned by the JCL project team and the governing body as percentages of the total 21,000 delegates attending. We thus had the number of people taking flights and the distances travelled by each group of people. The emission factor that was used to calculate the CO_2 emissions from air travel were 0.35 kg CO_2 per passenger per km travelled [5]. This resulted in a CO_2 emission estimate of 126,503 tons.

The same process was followed for delegates using flights within South Africa. It was assumed that 7% of the 21,000 delegates made use of flights within South Africa to travel to Johannesburg from various locations within the Country [6]. The JCL project team also calculated this number. The emission factor of 0.35 kg CO_2 emissions per passenger per km travelled was again used. The resulting CO_2 emissions from local flights were determined as 892 tons.

The last section of the footprint model under travel dealt with road travel of the delegates between the hotels and their venues. It was assumed that each delegate travelled 50 km by road vehicle per day [6]. This would be approximately 500 km for the 10 days of the WSSD. The emission factor use in this case was 0.0485 kg CO_2 per passenger km per day [5]. The total CO_2 emission over the 10-day period was calculated as 509 tons for all 21,000 delegates combined.

The total of 127,905 tons of CO_2-equivalent emissions was generated due to travel (air and road) of the delegates.

6.2.6 *Footprint model – other emissions*

The last part of the footprint model dealt with emissions from sources other than direct electricity consumption or fuel combustion. These sources included CH_4 emissions from the anaerobic digestion of the waste generated by the delegates. Sources estimated that the average person produce 2.04 kg waste per day that ends up on landfill sites and contribute to CH_4 emissions [6]. The problem with CH_4 is its GWP factor of 21. An emission factor of 0.13 kg CH_4 per tons of waste was used in the footprint model [6]. The waste emissions due to the 21,000 delegates attending the WSSD for 10 days was determined at 55.7 kg CH_4 which is equivalent to 1.17 tons of CO_2 emissions

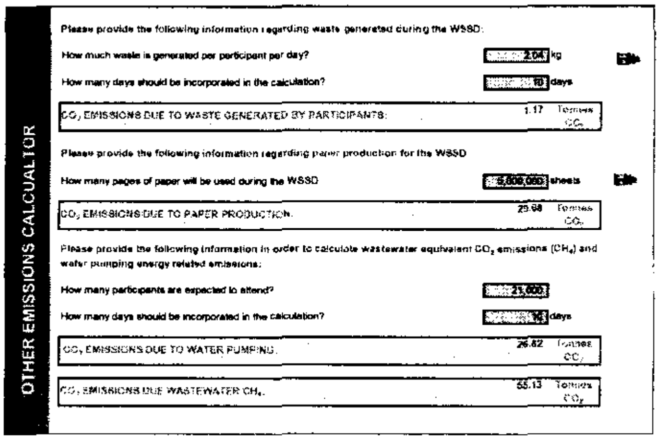

Figure 6.3: Input sheet for other emissions for footprint model.

The delegates attending also used a large quantity of paper during the WSSD. It was assumed that the 21,000 delegates used approximately 5,000,000 sheets of paper [6]. CO_2 was generated through the electricity that was consumed during the production process of the paper. The electricity consumed for the production of the 5 million sheets was calculated and linked to the CO_2 emissions. It was determined that the CO_2 emissions resulting from paper production were 29.68 tons.

Water pumping contributed towards GHG emissions through electricity use at the water-pumping stations. It was assumed that each delegate used 250 litres of water per day [6]. Electricity consumption data for pumping stations was obtained to determine the average electricity consumption per litre of water pumped. This data was combined with the emission factors for electricity consumption to obtain a total of 26.82 tons CO_2 emissions due to water pumping.

The last section determined the CH_4 emission that resulted from waste-water and sludge in much the same manner as in the case of waste. It was determined that the delegates caused approximately 55 tons of CO_2 emissions due to waste-water and sewerage.

The last part of the footprint model estimated that all sources other than direct electricity consumption and travel emissions, contributed 113 tons of CO_2 emissions.

The total GHG emissions generated by the 21,000 delegates over the 10 days of the WSSD was estimated at 135,400 tons of CO_2-equivalent emissions, of which air travel contributed approximately 93%.

6.2.7 Footprint model summary

A large number of our every-day actions contribute to increase the amounts of GHG emissions in the atmosphere. These actions could range from something as simple as switching on a light in our homes, using a piece of paper, driving our car to work of taking a flight to an international destination.

During the WSSD, a project by JCL aimed at balancing out these GHG emissions caused by the 21,000 delegates attending. In order to balance their GHG emissions, it was important to determine how much GHG emissions the delegates were causing.

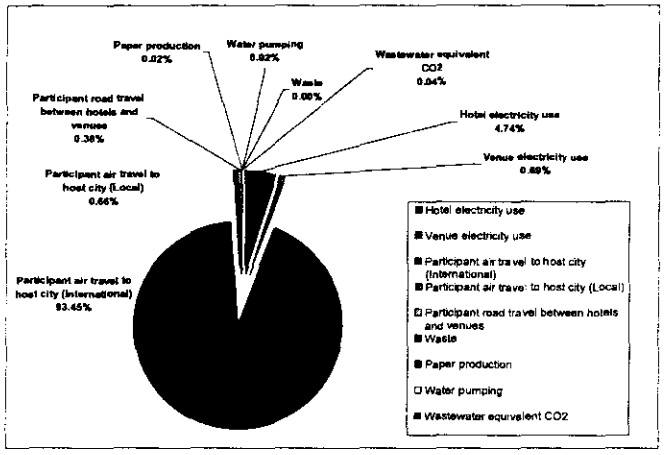

Figure 6.4: Sectional contribution towards total WSSD emissions footprint (CO_2 equivalent).

A footprint model was subsequently developed that could link activities with the GHG emissions they caused. This model incorporated a number of processes, ranging from international flights to the waste that delegates generated. The GHG emissions for each of these activities were calculated to produce a total emission footprint of 135,400 tons of CO_2-equivalent emissions. The footprint model proved to be an effective tool to determine GHG emissions.

The footprint model will play a valuable role in the development of a GHG emission target for future events similar to the WSSD. The model can be expanded to include more sources and could easily be updated to reflect more accurate emissions estimations as research provides more accurate emission factors.

6.2.8 Offsetting the WSSD emissions

As mentioned, approximately 21,000 international delegates attended the WSSD [3]. These delegates played an important part in the global actions against climate change and GHG emission reductions through the policies they put in place. Unfortunately, each of these delegates contributed in a unique and negative way towards increased GHG emissions and ultimately climate change.

An emission footprint of the WSSD was developed to estimate what the contribution towards GHG emissions (especially carbon dioxide (CO_2) and methane (CH_4)) would be due to the attendance and activities of the 21,000 delegates. The footprint estimated that 135,400 tons of CO_2-equivalent emissions were generated and released [6]. These emissions resulted from amongst others the electricity used at the hotels and venues, road travel, waste generation and paper consumption. The largest contributor, however, was the airline emissions for the delegates travelling to South Africa, comprising approximately 93% of the total emissions footprint [3].

In order to keep the WSSD in line with its principles for the ecologically sound management of the environment and the issue of climate change, it was proposed that the WSSD be made carbon-neutral. This meant that all the GHG emissions (carbon and carbon-equivalent emissions) generated by actions of the WSSD be offset over a period of 10 years.

Under the umbrella of Greening the WSSD, the JCL was created. The JCL delivered a revolutionary programme that was designed to demonstrate in a direct, practical and visible way that the WSSD had a carbon-offset responsibility and that it could be achieved in South Africa. The carbon offsets would be driven by JCL through a number of projects in the country that would reduce the current state of GHG emissions, focussing mainly on CO_2 and CH_4, whilst contributing towards sustainable development.

The JCL would, through its GEF donor fund and by means of fund-raising (sale of carbon credits to corporate and individual delegates at the WSSD), provide financial assistance to the various selected projects in order to mitigate the carbon emissions of the Summit. The JCL target was therefore to achieve a combined CO_2-equivalent emission reduction of 135,400 tons over a period of 10 years.

A technical working group (TWG) was appointed within the JCL to assess the emissions of the WSSD, produce an offset project shortlist, and calculate the emission offsets from each project. The North-West University (Potchefstroom Campus) served on the TWG and was intensively involved in the above processes. It was also responsible for the development of the various scenarios under which the JCL could achieve its target. A multi-stakeholder governing body (MSGB) was also appointed to control the process and serve as a decision-making body for the JCL project.

6.2.9 The offset projects and eligibility criteria

A call for proposals was sent out and approximately 30 project proposals were received. A brief list is provided below to give an overview of the range of projects received:

- Efficient lighting for/of buildings and mines;
- photovoltaic systems;
- commercial and residential building energy-efficiency retrofits (lighting, hot-water systems, insulation);
- bio-energy;
- fuel switching from diesel to low sulphur diesel for Spoornet locomotives;
- gasification of biomass and waste;
- thermal energy provision through anaerobic biogas generation; and
- ethanol production.

It was the responsibility of the TWG to develop the eligibility criteria on the basis of which projects would undergo the first level of screening. The eligibility criteria were the following:

- No forest and/or land-use change projects;
- projects within the boundaries of South Africa;
- legal authorisation to proceed with project;
- implementation within 3 years;
- project participant has the capacity to undertake the project;
- additionality of the emission reductions;
- no research project; and
- technology used in project must be market-ready.

The total list of offset projects was reduced to 16, based on the above eligibility criteria. These projects were then subjected to a second round of screening.

The second round of screening required a detailed proposal from the project participants where they provided technical and financial information and data concerning the following:

- Baseline used to determine the amount of GHG emission reductions;
- quantity of GHG emissions that would be reduced over the project life;
- the total cost requested from the JCL; and
- the cost required for the M&V of the GHG emission reductions.

This phase of the screening also included a rigorous evaluation of the contribution of each project towards the following sustainable development (SD) criteria:

- Contribution to job creation and economic development;

- increased access to essential services such as energy, water, health, education and transport;
- reduced local environmental impact;
- contribution to more sustainable and efficient use of non-renewable natural resources;
- the upliftment and empowerment of disadvantaged sectors; and
- additional non-direct socio-economic benefits.

The members of the TWG rated each of the offset projects for the above sustainable development criteria between 0 and 3. A rating of 0 meant a negative impact and 3 a very positive impact. These ratings were subsequently consolidated between the TWG members and for each project to obtain a single rating per offset project for sustainable development.

The result of the second screening process was a matrix containing the following data for each offset project.

- CO_2-equivalent reduction over 10 years [Tons CO_2-eq/10 years];
- required funding from JCL [JCL Rand];
- cost to JCL per ton CO_2-equivalent reduced over 10-year project life [JCL Rand / ton CO_2-eq]; and
- sustainable development rating [SD Overall].

The four above headings will be referred to as performance criteria during the remainder of this case study.

6.2.10 Scenario requirements

The MSGB reached a decision to base the scenario development on the following performance criteria:

- CO_2-equivalent reduction over 10 years [Tons CO_2-eq/10 years]; and
- cost to JCL per ton CO_2-equivalent reduced over a 10-year project life [JCL Rand / ton CO_2-eq].

All the projects performed very well under the SD criterion. It was consequently decided that the effect of sustainable development should not be incorporated into the scenario development process. The sole reason was that all the SD rankings were so close together that they would not greatly contribute to the scenario development process.

During and after the WSSD the JCL managed to raise approximately R1,000,000 for the funding of offset projects. This consequently placed a restriction of R1 million on the total projects cost.

6.2.11 Preparing the scenarios

Once the matrix was completed, the TWG could start with the process of preparing the relevant information to develop the scenarios.

This included the ranking and sorting of the projects according to their performance under the performance criteria and scenario requirements provided in the previous sections.

Table 6.2: Ranked project numbers according to performance under the individual performance criteria.

Score	CO_2 Reduction [Ton / 10 years]	JCL Rand per Ton
16	C:	P:
15	P:	F:
14	A:	L:
13	E:	D:
12	I:	J:
11	L:	C:
10	J:	E:
9	M:	N:
8	D:	I:
7	G:	M:
6	N:	G:
5	F:	A:
4	O:	O:
3	H:	H:
2	K:	K:
1	B:	B:

Table 6.2 provides the results of this process together with a brief description of each project. Note the "Score" column on the far left with a score ranging between 16 and 1. When considering the "CO_2 Reduction" column, it is evident that project C performed the best (had the highest potential CO_2 reduction), whilst project B performed the worst (least potential CO_2 reductions). Project C thus received a score of 16 and project B received a score of 1, based on their performance under CO_2 reductions. The same rationale was followed to award project C a score of 11 under JCL Rand per ton.

These individual scores per offset project were subsequently combined to result in a score out of 32. The projects were again ranked according to their combined score. The results are provided in Table 6.3.

Table 6.3: Ranked project numbers according to combined scoring under the performance criteria.

Project Number	Score out of 32
P	31
C	27
L	25
E	23
J	22
D	21
F	20
I	20
A	19
M	16
N	15
G	13
O	8
H	6
K	4
B	2

The projects that required funding less than or equal to R1 million had to be identified and isolated in order to satisfy the fourth scenario requirement. These projects are also indicated in Table 6.3 as the shaded cells (projects D, F, N, O and B).

The TWG could now proceed and develop the various scenarios under which it could attempt to achieve its target of a carbon-neutral WSSD.

6.2.12 JCL scenarios

In the previous section it was seen that only projects D, F, N, O and B satisfied the criteria set by the MSGB. Scenarios now had to be developed to determine which of the individual or combined projects would achieve the highest CO_2 emission offsets. These scenarios are provided in Table 6.4.

Table 6.4: Various JCL scenarios for combined and individual offset projects.

Scenario (10-year basis):	10.1	10.2	10.3	10.4	10.5	10.6	10.7
Projects included in scenario:	F & D	F & N	D	F	N	O	B
Total selected CO_2 emission reductions	10,610	8,271	7,291	3,319	4,952	3,214	45
Cost to JCL per ton reduced	96.23	114.19	107.39	71.71	142.66	300.82	5,692.37
Total cost to JCL for selected projects	1,021,000	944,498	783,000	238,000	706,498	966,891	255,701
Sustainable development	8.69	9.22	8.75	8.63	9.80	9.60	8.40

Scenario 10.1 comprises the joint implementation and funding of projects F and D. Under this scenario JCL would achieve the most CO_2 offsets. The only problem was that the combined implementation of those two projects would require more than R1 million from the JCL. This scenario was therefore not viable.

The next possible scenario (10.2) was the joint implementation of projects F and N. It would achieve the second highest potential offsets within the available JCL budget. This scenario was therefore deemed to be the most likely to be selected by the MSGB.

The remaining scenarios comprised of individual project implementations. These scenarios were the individual implementation of projects D, F or N.

The scenarios where projects O and B are implemented were discarded by the MSGB due to their low potential CO_2 emission reductions and their very high cost per ton CO_2 reduction.

The scenarios were submitted to the MSGB. Unfortunately the JCL project in itself did not proceed due to lack of funding. The methodologies and procedures developed during the project, however, proved to be sound. The reason for the JCL not managing to offset any emission was due to the funding mechanisms used.

6.2.13 Summary

In order to achieve a carbon-neutral WSSD, the Johannesburg Climate Legacy had to determine how much greenhouse gas emission was generated during the WSSD. The emission footprint model that was developed during the study was used to calculate that the delegates attending the WSSD contributed approximately 135,400 tons of CO_2-equivalent emissions.

The next step for the JCL project was to obtain a number of GHG emission-reducing projects that could be used to offset the WSSD emissions. It was thus important to develop scenarios of projects that could be implemented on the basis of a range of criteria and restrictions. A system had to be developed that could be used to "filter" out all the relevant data and place all the various offset projects on an even playing field.

The system allowed for the inputs of many stakeholders and isolated the available options to the JCL from which to develop its scenarios. It proved to be a valuable supporting tool where technical data and subjective information had to be incorporated into a decision-making process.

The system that was developed during this project has been streamlined to deliver quick results and would be of great use in future projects when the same procedures need to be followed for events other than the WSSD.

This case study demonstrated the use of emission factors to link variables such as electricity consumption to environmental impacts. The relevant emission factors can be utilised during the integrated approach to calculate the impact of energy efficiency on CO_2, NO_x, SO_x and particulate emissions, as well as water consumption.

The procedures followed during this case study can be applied with ease when developing scenarios that will best suit the needs of investing parties in energy-efficiency projects and CDM projects where a number of projects are available to choose from. The criteria used for this case study can easily be altered to suit the criteria that are proposed for CDM projects.

6.3 Case Study 2: Civic Centre - integrated approach

The following case study will describe the application of the proposed integrated approach towards an energy-efficiency project (lighting retrofit) that was implemented at the Braamfontein Civic Centre in Johannesburg, South Africa. The utility, Eskom, funded the DSM project. A total of 35% of the savings had to be returned to the utility, whilst the remaining 65% of the savings belonged to the ESCO and the client.

The Johannesburg Civic Centre is a large commercial building that is used by the Greater Johannesburg Metropolitan Council as offices. The building has sixteen floors used as office space, a ground floor used as an entrance foyer with offices, and three basement levels (A, B and C) used for covered parking and plant-rooms for the HVAC system. The building thus has a total of 20 levels (see Figure 6.5).

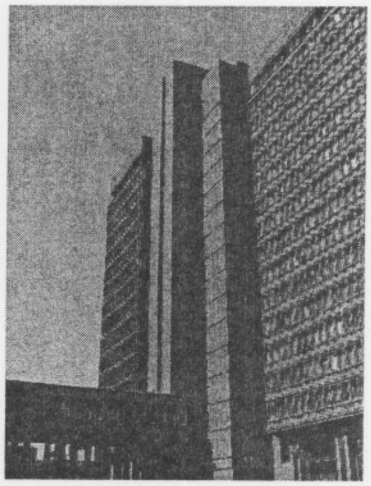

Figure 6.5: Civic Centre.

A project was proposed by Bonesa (a local ESCO specialising in lighting) that the outdated and inefficient lighting system of the Civic Centre be retrofitted. This would result in considerable electricity cost-savings and reduced maintenance costs.

Each floor in the building is divided into a head and a tail end. Each head and tail end has its own distribution board (DB). The head and tail ends have their own lighting switches (one per DB). Timers are used to control the normal hours that the lights are switched on. The switches are, however, used outside of these hours to turn the lights on. This means that individual offices cannot control their respective lights.

6.3.1 Proposed energy-efficiency activities

The ESCO proposed to replace the lighting system in the following areas of the building:

- The office areas of the building, which comprised the largest share of the total lighting retrofit project. The ESCO proposed to replace the current stock of 4830 fittings (consisting of 2 x 40 W fittings) with 2160 fittings (consisting of 2 x 36 W fittings), of which 1080 have a dimming capability. The 1080 fittings with the dimming capability would be installed next to the windows in the offices.

- The lighting in the passages consist of 467 fittings (of 2 x 40 W), which would be replaced with 467 fittings of 1 x 36 W lamps.

- Boardroom lighting would also be retrofitted from 260 fittings (mixture of 130 fittings of 4 x 75 W and 130 fittings of 4 x 65 W) with 520 fittings of 1 x 36 W lamps.

- The lighting in the various service areas would be retrofitted from 1623 fittings that are a mixture of 2 x 40 W (715 fittings), 2 x 65 W (152 fittings), 2 x 75 W (72 fittings) and 60 W recess down lighters (684 fittings) to 1591 fittings that are a mixture of 1 x 36 W lamps (665 fittings), 2 x PL 11 W (552 fittings), 1 x 18 W (118 fittings) and S1 STC 136 37 W (256 fittings).

- A total of 212 fittings that are a mixture of 2 x 65 W (30 fittings), 4 x 75 W (30 fittings) and 2 x 75 W (152 fittings) would be retrofitted in the lift lobbies for levels A, B and C to 252 fittings consisting of a mixture of 1 x 36 W LBR (72 fittings), type S STC 136 + S136 (76 fittings) and 104 fittings of S1 STC 136 37W.

- The next step was to retrofit the lighting system in the lift lobbies for levels 2–16. There are currently a total of 377 fittings that are a mixture of 2 x 65 W (160 fittings), 4 x 75W (160 fittings) and 2 x 20 W (57 fittings). It is proposed to replace all the above lighting fittings with 384 fittings of 1 x 36 W LBR.

- The entrance hall on the ground floor had a total of 216 fittings of 150 W spot-lighting lamps that would be replaced with 70 fittings of 50 W lamps.

- The lighting in the covered parking consisted of 1864 fittings that are a mixture of 2 x 40 W (1369 fittings), 2 x 65 W (9 fittings), 2 x 75 W (341 fittings) and 2 x 20 W (145 fittings). It was proposed to replace all the above covered parking lighting fittings with 1875 fittings of 2 x 36 W trifocal surface mounted (314 fittings) and 1 x 36 W trifocal surface mounted (1534 fittings).

6.3.2 Expected savings

The ESCO determined the expected cost savings from the project to be R1,054,660 per year due to the reduced demand and electricity consumption on the lighting system. The impact on the cost of maintenance was not included in the scope of the project. The M&V team also determined the savings based on similar assumptions and data as the ESCO and found the expected savings to be R1,037,913 per year. The discrepancy in the annual cost-savings was due to calculation errors found in the simulation done by the ESCO.

It was also expected that the annual electricity consumption could be reduced by as much as 3,678,364 kWh and the monthly maximum demand by 931 kVA.

6.3.3 *Savings determination*

To determine the baseline (what the energy use would have been without implementation) for this project, it was necessary to quantify the following:

- The actual lighting load (kW) before implementation; and
- the actual operational hours of all the lights before implementation.

The same parameters needed to be quantified after implementation in order to determine the impact of the retrofit. It was indicated that the project would not change the operational hours of the lighting system.

For the purposes of this project the various areas of the Civic Centre was divided into 3 groups according to their layout and usage patterns:

- Group 1 – Office area (with & without dimming devices), passages, board rooms, service areas, toilets and lift lobbies for floors 2 to 16;
- Group 2 – The 3 basement levels (A, B and C) used as covered parking; and
- Group 3 – Ground floor with entrance hall.

The groups consist of a number of identical zones (floors), each with two DBs, each feeding to the head of the tail end of each floor.

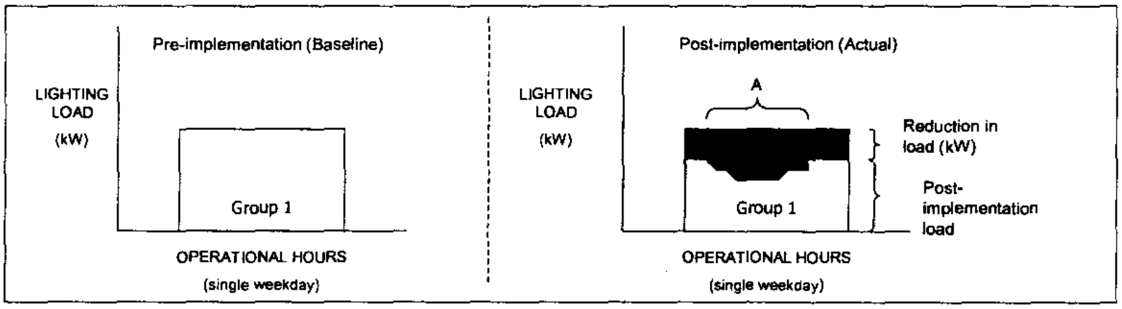

Figure 6.6: Baseline representation for Group 1 (Floors 1-16).

Each group had certain operational hours and a certain demand. Figure 6.6 is an illustration of the lighting load profile of Group 1 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 1 and will also be used as the baseline. The operational hours was expected to remain unchanged (as can be seen in Figure 6.6). The lighting load was reduced with the retrofit and the difference between the actual and the baseline profiles provided the savings achieved (the darkened section of the diagram). *The load during the post-implementation phase was no longer a straight line, but* varied during the day due to the number of office lights that was fitted with dimming equipment.

Figure 6.7 is an illustration of the lighting load profile of Group 2 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 2 and was also used as the baseline. The operational hours was expected to remain unchanged (as can be seen in Figure 6.7). The lighting load was reduced with the retrofit and the difference between the actual and the baseline profile provided the savings that was achieved (the darkened section of the diagram).

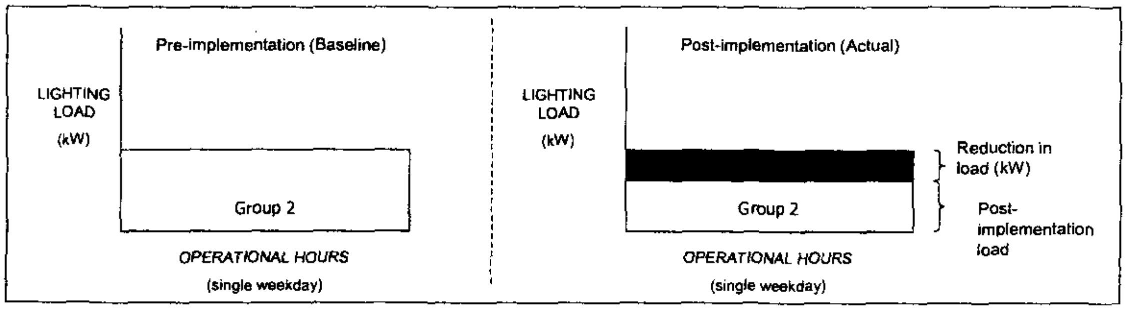

Figure 6.7: Baseline representation for Group 2 (Basement levels A, B and C).

Figure 6.8 is an illustration of the lighting load profile of Group 3 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 3 and was to be used as the baseline. The operational hours were expected to remain unchanged (as can be seen in Figure 6.8). The lighting load was reduced by the retrofit and the difference between the actual and the baseline profile provided the savings achieved (the darkened section of the diagram).

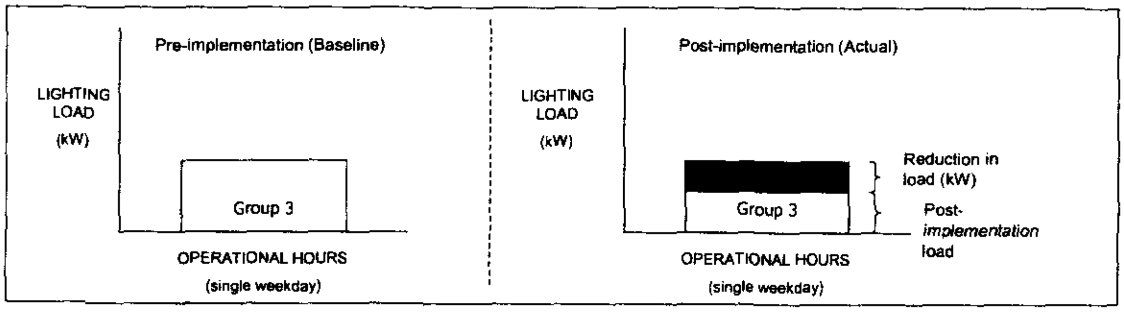

Figure 6.8: Baseline representation for Group 3 (Entrance hall on ground floor).

The savings for each group were to be determined separately and added to obtain the total savings for the project.

6.3.4 M&V project activities

The M&V scoping report and the M&V plan for this project were developed and combined into a single document that provided all the relevant project information and the expected project impacts as they were calculated by the ESCO and the M&V team.

A detailed description of the metering activities, locations and equipment was included in the M&V plan. The M&V plan also included a detailed description of the manner in which the baselines would be developed, which data would be used and how the savings would be calculated. This combined M&C scoping report and M&V plan were submitted and buy-in was obtained from the various stakeholders (Eskom, the Greater Johannesburg Metropolitan Council and Bonesa) to proceed with the M&V activities. The combined M&V scoping report and M&V plan for the Civic Centre can be found in Appendix A of this thesis.

The M&V team continued by conducting notch tests that were required for the development of the project baseline, after which time the baseline was determined. More information on the development of the baseline can be found in the sections following this case study. Appendix B of this thesis also contains the actual M&V baseline report for this project. The M&V baseline report was submitted to the stakeholders and buy-in was obtained.

The lighting retrofit commenced and the M&V team waited for implementation to be completed during August 2003. A walk-through audit was conducted by the M&V team to assess the completeness of the implementation and to determine whether implementation was done according to the specifications provided by the ESCO. Minor discrepancies were found and noted in the post-implementation report. This served to inform all the stakeholders of the situation. This report can be found in Appendix C to this thesis.

The measurement equipment needed to record the data during the post-implementation phase was installed when the ESCO was in the process of implementation. This ensured that post-implementation data for saving calculations was available from the moment that implementation was complete. This data was utilised to develop the M&V performance assessment report, which was basically the first savings report to be submitted. The M&V performance assessment report usually do not cover a complete month.

6.3.5 Project impacts

The performance assessment report found that the project had already saved R75,800 between the period from 01 – 21 October 2003. The electricity consumption during this period was reduced by 235,066 kWh and the demand was reduced by 805 kW during the morning peak, and by 511 kW during the evening peak. The carbon dioxide emission was reduced by 209 tons for this period. The complete results for this period can be found in Appendix D of this thesis. A typical monthly savings report for the project is also included in Appendix E.

An annual savings report was generated for the project. The project did, however, not run for a whole year at the time that the annual savings report was generated. It was, however, possible to calculate the expected annual impacts for the project as the following [7]:

o Electricity consumption reduction	4 087 MWh per year;
o Electricity cost-savings	R 1 059 228 per year;
o Maximum demand reduction	0.805 MW during morning peak;
	0.511 MW during afternoon peak;
o CO_2 emission reduction	3 646 tons per year;
o NO_x emission reduction	14 511 tons per year;
o SO_x emission reduction	30 901 tons per year;
o Particulate matter emission reduction	1 185 tons per year; and
o Water consumption reduction	4 946 litres per year.

The complete annual savings report can be found in Appendix F of this thesis.

6.3.6 Conclusion

The proposed integrated approach was applied to M&V the project impacts that resulted from energy-efficiency and DSM activities at the Braamfontein Civic Centre in Johannesburg. All the proposed M&V project activities were applied with great success and proved to deliver accurate and repeatable results through methodologies and procedures that had buy-in from all the project stakeholders. Not only could the demand impact be accurately determined during the morning and evening peak periods (which was of importance to Eskom's DSM initiative), but also the monthly and annual electricity cost-savings for the project and the GHG emission reductions.

Not only did the process allow for the quantification and verification of the project impacts such as electricity cost-savings, electricity consumption reductions and maximum demand impacts, but also allowed the M&V team to determine the environmental impacts such as CO_2 emission reductions.

The process, if applied correctly, proved that it could be used with great success for energy-efficiency and DSM projects, but would also provide the same level of results that is required during CDM projects. The required deliverables and reports would be sufficient to allow a designated operational entity to effectively verify the results of energy-efficiency projects within CDM *projects*.

6.4 References

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CHAPTER 7

Closure

This chapter provides closure for this study together with recommendations for further work.

Chapter 7: Closure

7.1 Summary and conclusions

The energy industry in South Africa is under pressure due to increased load growth, which will result in this country running out of excess capacity by 2007. This in turn is placing pressure on the residential, commercial and especially the industrial end users to reduce their peak demand and increase their level of energy efficiency due to rising electricity costs. Increased energy efficiency directly leads to the reduction of GHG emissions. The drive that South Africa currently experiences for DSM and energy efficiency has the potential to assist in GHG mitigation through the clean development mechanism.

An extensive literature survey from local and international sources has shown that there are a number of barriers to the successful implementation of energy efficiency and DSM projects in South Africa. These barriers were found to be present not only for energy-efficiency projects, but also for clean development mechanism projects concerned with energy efficiency.

It was also shown that South Africa could greatly benefit from increased energy efficiency and DSM, as well as from GHG emission reductions under a CDM scenario. It is, however, important that these projects be implemented in an environment that facilitates better project design and protection of the interests of all the stakeholders. This will in turn allow the energy services industry in South Africa to grow. Measurement and verification is an important and necessary aspect of any energy efficiency, DSM or CDM project. It allows for the objective quantification of the project's impacts by a third party, thus lending credibility to the project outcomes. Its greatest benefit, if conducted correctly, is the increased sustainability of projects and their impacts.

A need was identified for an integrated approach to implement and sustain energy efficiency, DSM and greenhouse gas mitigation in South Africa. If applied correctly, the proposed integrated approach would not only help to increase the successful implementation of energy efficiency, DSM and GHG mitigation projects in South Africa, but also assist in sustaining the impacts of the projects. This approach could also be applied within the current structure of CDM projects. The integrated approach was designed in such a manner that it would provide a single flexible methodology that would enable the stakeholders in both energy and CDM projects to accurately quantify the project impacts whilst allowing for a replicable methodology that could be verified by parties outside the project. The approach would thus help with the sustainable implementation of energy-efficiency, DSM and CDM projects in South Africa.

The methodology of the new integrated approach was presented. It was designed to allow all project stakeholders to buy in on the critical project stages. This enabled the process to be transparent and independent of the energy-efficiency, DSM or CDM stakeholders. The integrated approach provides a clear methodology that may be followed to perform measurement and verification to quantify and help sustain project impacts. The proposed integrated approach has been applied, or is in the process of being applied to approximately 25 current DSM and energy-efficiency projects in the South African residential, commercial and industrial sectors. All these projects form part of the Eskom-funded DSM initiative and include a number of energy-efficiency projects that has shared DSM impacts associated with them.

The integrated methodology has been accepted as the standard by which South Africa's parastatal utility, Eskom, prefers implementation together with measurement and verification on their DSM-funded projects. The approach has proved to be flexible, transparent and replicable. It has facilitated better project implementation on a number of occasions and proved to provide accurate and verified results to all the stakeholders, which include the demand impact during each TOU period, the impact on electricity consumption, the impact on the monthly and annual electricity accounts of end users and the environmental (e.g. the GHG emissions and water consumption) impacts.

Two case studies were presented. The first case study demonstrated the use of emission factors and how they are used to establish the link between variables such as electricity consumption and CO_2 emissions. It also proposed an approach to select the most feasible scenario of project combinations from a large number of available projects that would best satisfy the needs of a funding party. The second case study demonstrated the use of the integrated approach to measure and verify the impacts of a lighting retrofit on a large commercial building.

7.2 Recommendations for further work

The integrated approach has been in use since 2002 and has been subjected to continuous improvement as new requirements were identified by industry and stakeholders. The integrates approach must, however, be updated regularly to keep it in line with new developments from sources such as the International Performance Measurement and Verification Protocol and other sources.

It is also important that developments in the requirements and procedures of CDM projects be continuously incorporated into the integrated approach.

Appendix A

M&V scoping report and M&V plan – Johannesburg Civic Centre

Measurement and Verification Team
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Noordbrug, Potchefstroom
2522
Tel: 018 299 1329
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Email: mgiljg@puk.ac.za

Measurement & Verification Plan:

Civic Centre Lighting Project

DATE OF REPORT	:	8 July, 2003
VERSION	:	Version 3, revision 0
PREPARED BY	:	W.L.R. den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

Table of Contents

Nomenclature:

AEC	Architectural Energy Corporation
c	Cent
CFL	Compact fluorescent lamp
CO_2	Carbon dioxide emissions
DB	Distribution board
ECM	Energy conservation measure
GJMC	Greater Johannesburg Metropolitan Council
HVAC	Heating, ventilation and air-conditioning
kVA	Kilovolt-ampere
kWh	Kilowatt-hour
M&V	Measurement and verification
MCS	Measurement & Control Solutions
NO_X	Nitrous oxide emissions
R	Rand
SO_X	Sulphur oxide emissions
VGD	Vangard Digital

1 OVERVIEW

The following document provides a measurement and verification (M&V)-plan for the lighting retrofit to be implemented by Bonesa at the Civic Centre in Braamfontein, Johannesburg

The purpose of the M&V-plan is to provide an overview of the project specific M&V-activities and to describe the various project stages. The plan includes a description of the energy conservation measure (ECM) to be implemented. It will also describe how these measures will result in potential energy- and cost savings, as well as a list of variables that could potentially affect the realisation of these savings.

Key assumptions about significant variables are included in the M&V-plan. The plan also includes the selection of the M&V-option and method that will be used during the M&V-process.

Information on the parties responsible for the M&V-activities of the project is also included. The methods of calculating the energy- and cost savings are briefly discussed, as well as methods of determining and adjusting the baseline energy consumption.

Planned metering activities, -equipment and -schedules are discussed.

2 PROJECT DESCRIPTION

The following sections will provide information on the parties involved in the project and the M&V-activities. The objectives of the project are stated. The energy conservation measure is discussed. A description of the system is provided and the relevant information that was gathered during the audit of the project sites is discussed.

2.1 Project information

M&V Company name:		Potchefstroom University for CHE	
M&V Contact person:		Prof. LJ Grobler and Mr. Willem Den Heijer	
Postal address:		Private Bag X6001, Potchefstroom, 2520	
Country:		South Africa	
Phone:	+27 18 299 1328 / 4025	Fax:	+27 18 299 1320
Cell:	+27 82 452 9279 +27 83 256 9640	E-mail:	Mgiljg@puknet.puk.ac.za Mgiwdh@puknet.puk.ac.za
Date of submittal of this M&V Plan:		30 April 2003	
Project Sponsor Name:		Bonesa	
Name of project site:		Civic Centre	
Address:		158 Loveday Street, Braamfontein, Johannesburg	
Country:		South Africa	
Company name (Site owner / Client):		Greater Johannesburg Metropolitan Council (GJMC)	
Contact person:		Faisel	
Phone:	011 407 7289	Fax:	011 403 1818
Cell:	082 464 9585	E-mail:	Jeffs@Joburg.org.za
Type of building(s) (office, retail, etc.):		Office building	
Contact person (Implementation / Esco):		Mr. Nad Permaul (Bonesa - Commercial programs manager)	
Phone:	+27 12 427 2797	Fax:	+27 12 427 2935
Cell:	+27 83 296 4893	E-mail:	Nperumaul@bonesa.co.za

2.2 Project Objective

The objective of the project is to measure and verify the energy consumption, demand, and energy cost savings, as well as emission impacts, due to the office lighting retrofit at the Johannesburg Civic Centre. The impacts need to be determined to verify the cost savings for the client and the ESCO, as well as the DSM-impacts obtained for Eskom.

2.3 Site description

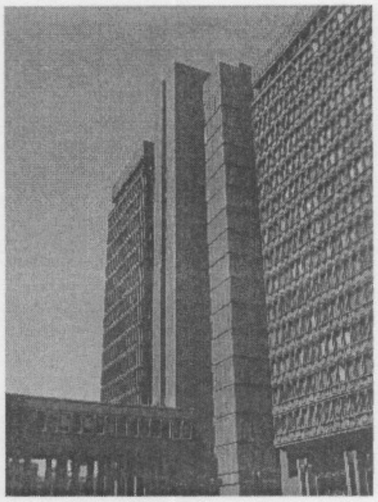
Figure 1: Civic Centre

The Civic Centre is a large commercial building that is used by the Greater Johannesburg Metropolitan Council as offices. The building has 16 floors, a ground floor and 3 basement levels. The building thus has a total of 20 levels (see Figure 1). Each floor in the building is divided into a head- and a tail end. Each head- and tail end has its own distribution board (DB). Floor 1 does not form part of the lighting retrofit project.

The head- and tail ends have their own lighting switches (one per DB). Timers are used to control the normal hours that the lights are switched on. The switches are however used outside of these hours to turn the lights on. This means that individual offices cannot control their respective lights.

2.4 Tariff structure

The Civic Centre operates under a two-part tariff structure where the GJMC pays for their monthly energy consumption (kWh) and their monthly maximum demand (kVA).

The c/kWh energy rate applicable to the active energy cost in this project is **11.84c/kWh** (R0.1184/kWh).

The R/kVA energy rate applicable to the monthly maximum demand cost in this project is **R53.9/kVA**.

2.5 Audit of Systems

A site visit was conducted on 27 March 2003. It was found that some of the efficient lamps were already installed. The present amount of lights was obtained from the Esco. A breakdown of the quantity and type of lamps in the existing system is provided in Table 1.

Table 1: Luminaires in the existing system.

Luminaire type	Watt per lamp	Watt per fitting (incl. Ballast)	Number of fittings	Installed capacity
2 X 40W Recess Mounted	40 W	101 W	6216	627.8 kW
2 X 65W Recess Mounted	65 W	175 W	351	61.4 kW
4 X 75W Recess Mounted	75 W	345 W	320	110.4 kW
4 X 65W Recess Mounted	65 W	184 W	130	23.9 kW
Recess Down Lighter - 60w Lamp	60 W	60 W	684	41.0 kW
150w Spot Lights	150 W	150 W	216	32.4 kW
2X 75W Surface Mounted	75 W	171 W	565	96.6 kW
2 X 40W Surface Mounted	40 W	101 W	1165	117.7 kW
2 X 20W Recess Mounted	20 W	46 W	202	9.3 kW
		TOTALS:	9849	1120.6 kW

These lamps are installed in offices, passages, boardrooms, service areas, lift lobbies, entrance halls, covered parking space and ancillary rooms. A breakdown of each area and the type of luminaire is provided in Table 2.

Table 2: Luminaires in the existing system (building area allocation).

Lamp type	Offices	Passages	Board rooms	Service areas & toilets	Lift lobbies A, B, C & staircase	Lift lobbies 2-16	Entrance hall	Covered parking
2 X 40W Recess Mounted	4830	467		715				204
2 X 65W Recess Mounted				152	30	160		9
4 X 75W Recess Mounted			130		30	160		
4 X 65W Recess Mounted			130					
Recess Down Lighter - 60w Lamp				684				
150w Spot Lamps							216	
2X 75W Surface Mounted				72	152			341
2 X 40W Surface Mounted								1165
2 X 20W Recess Mounted						57		145

According to the building maintenance personnel, the lights in the covered parking areas (mixture of 75W, 40W and 20W lamps) are on for 24 hours of the day, 7 days of the week.

Figure 2: Entrance hall, elevator lobbies and covered parking of the Civic Centre.

The remaining lamps (offices, passages, board rooms, service areas and toilets, lift lobbies and entrance hall) are controlled by a timer on the lighting circuits in each of the two distribution boards (head- & tail end) of each of the levels. The timer switches the lights on from 07:00 to 19:00 each weekday. The lights are on from 07:00 to 13:00 on Saturdays and off during Sundays. It is possible for people working later than 19:00 to switch on the lights for the head or tail end of a floor. The lights then remain on for 1 hour after which time they are switched off automatically. The same applies when security personnel visit a floor.

The above times will however be verified by the M&V team through metering.

2.6 Demand-side management activities

2.6.1 Description

The quantity of fittings and replacement lamps mentioned in this section was obtained from the Esco. These quantities and types will however be verified by the M&V Team with information obtained from the contractor responsible for the lighting retrofit.

Figure 3: Typical office & hallway lighting.

The project consists of the following steps:

1. **Retrofitting the Office lighting system:** The first step is to retrofit the largest portion of the lighting system, which consists of office lighting. There are currently 4830 fittings, which consist of 2 x 40W fittings.

It is proposed to replace the above 4830 fittings with 1080 fittings of 2 x 36W recess LBR and 1080 similar fittings with dimming capabilities. The lamps with the remote dimming will be installed in the office space next to the windows. These lights will dim when there is sufficient day lighting available in the offices. According to the ESCO all the fittings will be retrofitted.

2. **Retrofitting the passage lighting system:** The second step is to retrofit the lighting system in the passages. There are currently a total of 467 fittings that consist of 2 x 40W fittings.

   It is proposed to replace all the above passage fittings with 467 fittings with 1 x 36W lamps. According to the ESCO all the fittings will be retrofitted.

3. **Retrofitting the lighting system in the boardrooms:** The third step is to retrofit the lighting system in the board rooms. There are currently a total of 260 fittings that is a mixture of 4 x 75W (130 fittings) and 4 x 65W (130 fittings).

   It is proposed to replace all the above boardroom fittings with 520 fittings with 1 x 36W lamps.

4. **Retrofitting the lighting system in the service areas and toilets:** The next step is to retrofit the lighting system in the service areas and toilets. There are currently a total of 1623 fittings that is a mixture of 2 x 40W (715 fittings), 2 x 65W (152 fittings), 2 x 75W (72 fittings) and 60W recess down lighters (684 fittings).

   It is proposed to replace all the above service area and toilet lighting fittings with 1591 fittings which is a mixture of 1 x 36W lamps (665 fittings), 2 x PL 11W (552 fittings), 1 x 18W (118 fittings) and S1 STC 136 37W (256 fittings). According to the ESCO all the fittings will be retrofitted.

5. **Retrofitting the lighting system in the lift lobbies of levels A, B and C (including the staircases of these levels):** The next step is to retrofit the lighting system in the lift lobbies for levels A, B and C and their staircases. There are currently a total of 212 fittings that is a mixture of 2 x 65W (30 fittings), 4 x 75W (30 fittings) and 2 x 75W (152 fittings).

   It is proposed to replace all the above service area and toilet lighting fittings with 252 fittings consisting of a mixture of 1 x 36W LBR (72 fittings), Type S STC 136 + S136 (76 fittings) and 104 fittings of S1 STC 136 37W. According to the ESCO all the fittings will be retrofitted.

6. **Retrofitting the lighting system in the lift lobbies of levels 2-16:** The next step is to retrofit the lighting system in the lift lobbies for levels 2–16. There are currently a total of 377 fittings that is a mixture of 2 x 65W (160 fittings), 4 x 75W (160 fittings) and 2 x 20W (57 fittings).

It is proposed to replace all the above service area and toilet lighting fittings with 384 fittings of 1 x 36W LBR. According to the ESCO all the fittings will be retrofitted.

7. **Retrofitting the lighting system in the entrance hall:** Step six is to retrofit the lighting system in the entrance hall. There are currently a total of 216 fittings of 150W spot lighting lamps.

   It is proposed to replace all the above entrance hall lighting fittings with 600 x 600, 2 x PL 50W lamps (70 fittings). According to the ESCO all the fittings will be retrofitted.

8. **Retrofitting the lighting system in the covered parking and ancillary areas:** The last step is to retrofit the lighting system in the covered parking and ancillary areas. There are currently a total of 1864 fittings that is a mixture of 2 x 40W (1369 fittings), 2 x 65W (9 fittings), 2 x 75W (341 fittings) and 2 x 20W (145 fittings).

   It is proposed to replace all the above covered parking and ancillary area lighting fittings with 1875 fittings of 2 x 36W Trifocal surface mounted (314 fittings) and 1 x 36W Trifocal surface mounted (1534 fittings). According to the ESCO all the fittings will be retrofitted.

2.6.2 Assumptions

The following key assumptions have been made by the ESCO to perform the analysis:

- No other system upgrades will be performed other than the ones specified.
- No other control equipment will be installed except the dimming devices and photocells on the luminaries in the offices next to windows.
- The control equipment works correctly.
- All respective lamp and/or fittings replacements will be done according to the figures provided in the previous section.
- The operating hours of the building is from 07:00 – 19:00 during weekdays (12 hours) and from 07:00 – 15:00 (8 hours) on Saturdays and off during Sundays.
- The lights in the covered parking area remain on for 24 hours of the day for each day of the year.
- Lighting levels in the building are sufficient.

2.6.3 Expected savings

2.6.3.1 Expected savings calculated by M&V Team

The M&V team calculated the expected savings by using the fitting amounts and types of lights. It is assumed that all the lights will be retrofitted and that the lights will be retrofitted with the ones described in paragraph 2.6.1. The expected savings is shown in Table 3. It can be seen from the table that the expected total energy cost saving per year will be R 1,037,913.

Table 3: Expected annual savings (calculated by the M&V Team).

Exisiting system (BASELINE)					
Description: [N/A]	Energy consumption [kWh/yr]	Annual consumption cost [R/yr]	Max. Demand [kVA/month]	Annual demand cost [R/yr]	Total annual cost [R/yr]
Offices	1,730,821	204,929	542	350,587	555,516
Passages	167,349	19,814	52	33,897	53,711
Board Rooms	243,996	28,889	76	49,423	78,312
Service Areas & Toilets	539,889	63,923	165	106,408	170,331
Lift Lobbies	304,496	36,052	95	61,677	97,730
Entrance Hall & Offices	114,955	13,611	32	20,956	34,567
Parking,Offices,Ancilleries	2,158,613	255,580	274	177,092	432,671
Total:	5,260,118	R 622,798	1,237	R 800,041	R 1,422,839

Proposed system (RETROFIT)					
Description: [N/A]	Energy consumption [kWh/yr]	Annual consumption cost [R/yr]	Max. Demand [kVA/month]	Annual demand cost [R/yr]	Total annual cost [R/yr]
Offices	368,623	43,645	91	58,649	102,294
Passages	61,306	7,259	18	11,642	18,900
Board Rooms	68,264	8,082	20	12,963	21,045
Service Areas & Toilets	179,781	21,286	56	35,930	57,216
Lift Lobbies	50,410	5,969	15	9,573	15,541
Entrance Hall & Offices	28,810	3,411	8	5,471	8,882
Parking,Offices,Ancilleries	824,561	97,628	98	63,419	161,047
Total:	1,581,754	R 187,280	306	R 197,646	R 384,925

System savings (BASELINE - RETROFIT)					
Description: [N/A]	Energy consumption savings [kWh/yr]	Annual consumption cost savings [R/yr]	Max. Demand reduction [kVA/month]	Annual demand cost savings [R/yr]	Total annual cost savings [R/yr]
Offices	1,362,198	161,284	451	291,939	453,223
Passages	106,043	12,555	34	22,256	34,811
Board Rooms	175,732	20,807	56	36,460	57,266
Service Areas & Toilets	360,108	42,637	109	70,478	113,114
Lift Lobbies	254,086	30,084	81	52,105	82,189
Entrance Hall & Offices	86,145	10,200	24	15,485	25,685
Parking,Offices,Ancilleries	1,334,052	157,952	176	113,673	271,625
Total:	3,678,364	R 435,518	931	R 602,395	R 1,037,913
Percentage savings:	70%	70%	75%	75%	73%

2.6.3.2 Expected savings calculated by Esco

The expected savings as calculated by the M&V team based on the Esco's assumptions is shown in Table 4.

Table 4: Expected annual savings (calculated by the Esco).

Exisiting system (BASELINE)					
Description: [N/A]	Energy consumption [kWh/yr]	Annual consumption cost [R/yr]	Max. Demand [kVA/month]	Annual demand cost [R/yr]	Total annual cost [R/yr]
Offices	1,730,821	204,929	542	350,587	555,516
Passages	167,349	19,814	52	33,897	53,711
Board Rooms	243,996	28,889	76	49,423	78,312
Service Areas & Toilets	539,889	63,923	165	106,408	170,331
Lift Lobbies	322,347	38,166	95	61,677	99,843
Entrance Hall & Offices	283,824	33,605	32	20,956	54,561
Parking,Offices,Ancilleries	2,158,613	255,580	274	177,092	432,671
Total:	5,446,838	R 644,906	1,237	R 800,041	R 1,444,946

Proposed system (RETROFIT)					
Description: [N/A]	Energy consumption [kWh/yr]	Annual consumption cost [R/yr]	Max. Demand [kVA/month]	Annual demand cost [R/yr]	Total annual cost [R/yr]
Offices	368,623	43,645	91	58,649	102,294
Passages	61,306	7,259	18	11,642	18,900
Board Rooms	68,264	8,082	20	12,963	21,045
Service Areas & Toilets	179,781	21,286	56	35,930	57,216
Lift Lobbies	53,365	6,318	15	9,573	15,891
Entrance Hall & Offices	71,131	8,422	8	5,471	13,893
Parking,Offices,Ancilleries	824,561	97,628	98	63,419	161,047
Total:	1,627,031	R 192,640	306	R 197,646	R 390,286

System savings (BASELINE - RETROFIT)					
Description: [N/A]	Energy consumption savings [kWh/yr]	Annual consumption cost savings [R/yr]	Max. Demand reduction [kVA/month]	Annual demand cost savings [R/yr]	Total annual cost savings [R/yr]
Offices	1,362,198	161,284	451	291,939	453,223
Passages	106,043	12,555	34	22,256	34,811
Board Rooms	175,732	20,807	56	36,460	57,266
Service Areas & Toilets	360,108	42,637	109	70,478	113,114
Lift Lobbies	268,982	31,847	81	52,105	83,952
Entrance Hall & Offices	212,693	25,183	24	15,485	40,668
Parking,Offices,Ancilleries	1,334,052	157,952	176	113,673	271,625
Total:	3,819,807	R 452,265	931	R 602,395	R 1,054,660
Percentage savings:	70%	70%	75%	75%	73%

The calculated savings by the Esco is expected to be R 1,054,660 per year.

2.6.3.2 Evaluation

It can be seen from the previous sections that there is a difference between the expected annual savings as calculated by the M&V Team (R1,037,913) and the Esco (R1,054,660). The Esco expect approximately R16,747 more than the M&V Team.

From the spreadsheet received from the Esco, they expect R1,074,526 energy cost savings per year. The difference in the savings is on the energy consumption side of the calculations. The reason for the discrepancy is the fact that the Esco used different quantities of weekdays, Saturdays and Sundays per year in their calculations.

3 M&V-OPTION SELECTION

The project has been analysed and classified according to the guidelines set out in the M&V Framework document [1]. A summary of the classification is provided here. More detailed information on the option selection and project classification can be found in Appendix A of this M&V plan.

This project is classified as follows:

Project Group:	SA-A
Project ID:	41

Projects with this classification has the following characteristics:

- Both the "post" Operating Hours and the "post" Load/Requirement may be used to determine the baseline.
- The implementation of the DSM measure has resulted in a change in system efficiencies.

Based on this classification, the M&V plan should focus on the following areas:

- Determine the Operating Hours of the system - post implementation;
- Determine the Load/Requirement of the system - post implementation; and
- Quantify the change between the pre- and post system efficiencies.

3.1 Boundaries of the saving determination

Only the lighting system energy savings will be measured and verified in this project. The M&V Team will therefore be able to determine the savings obtained through the lighting system alone.

- The implementation cost will be obtained from the contractors and integrated with the energy cost savings to determine the financial feasibility and payback periods of the project.
- The hours of operation will be obtained from metering.

4 BASELINE

4.1 Characterisation

To determine the baseline (what the energy use would have been without implementation) for this project it is necessary to quantify the following:

- The actual lighting load (kW) before implementation

- The actual operational hours of all the lights before implementation

The same parameters must be quantified after implementation to determine the impact of the retrofit. The operating hours of the building before and after the retrofit will be the same.

For the purposes of this project the various areas of the Civic Centre is divided into 3 groups according to their layout and usage:

- Group 1 – Office area (with & without dimming devices), passages, board rooms, service areas, toilets and lift lobbies for floors 2 to 16;
- Group 2 – The 3 basement levels (A, B and C) used as covered parking; and
- Group 3 – Ground floor with Entrance hall.

The groups consist of a number of identical zones (floors) each with two DBs, each feeding to the head of the tail end of each floor.

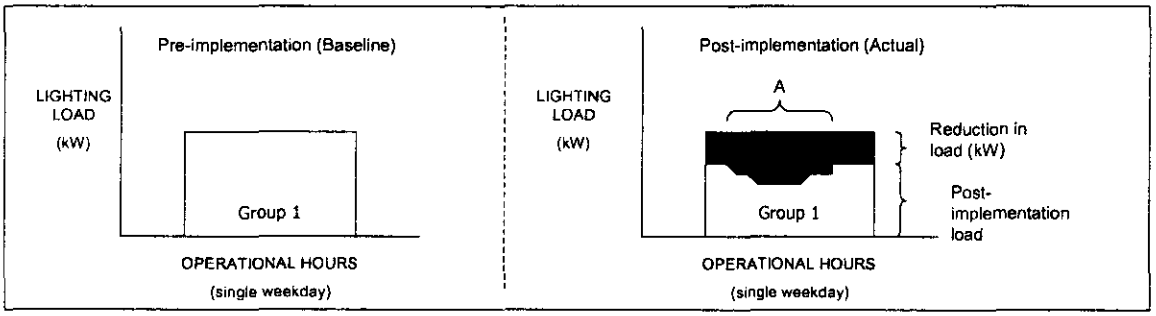

Figure 4: Baseline representation for Group 1 (Floors 1-16).

Each group has a certain operational hours and a certain demand. Figure 4 is an illustration of the lighting load profile of Group 1 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 1 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 4). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile

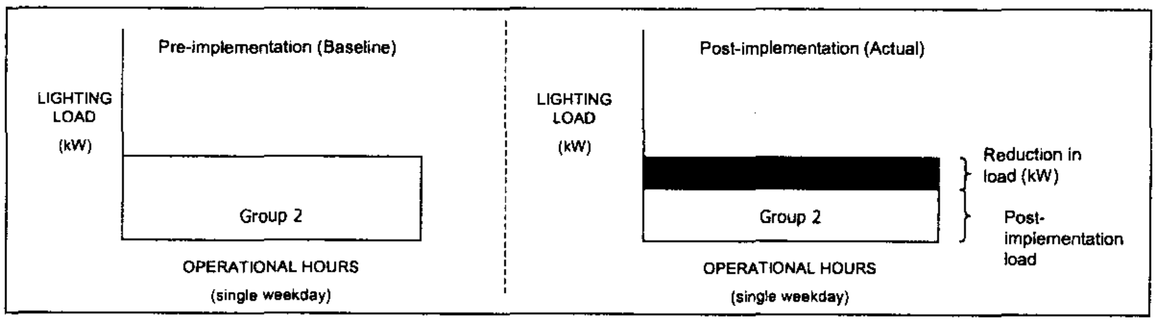

Figure 5: Baseline representation for Group 2 (Basement levels A, B and C).

provides the savings achieved (the darkened section of the diagram). The load during the post-implementation phase is no longer a straight line, but varies during the day due to the number of office lights fitted with dimming equipment.

Figure 5 is an illustration of the lighting load profile of Group 2 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 2 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 5). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile provides the savings achieved (the darkened section of the diagram).

Figure 6 is again an illustration of the lighting load profile of Group 3 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 3 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 6). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile provides the savings achieved (the darkened section of the diagram).

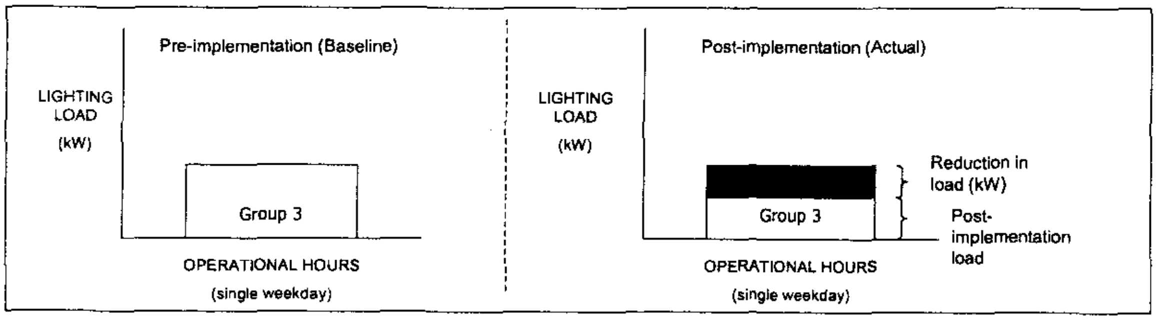

Figure 6: Baseline representation for Group 3 (Entrance hall on ground floor).

The savings for each group will be determined separately and summed to obtain the total savings.

The detailed method for the determination of the baseline for this project will be given in the baseline report.

4.2 Baseline adjustments

Baseline adjustments will be needed when:

- The operating hours of the lighting system change.
- The quantity of lamps is changed after the development of the baseline.

5 METERING PLAN

The building consists of groups as described in section 4.1. Each group consists of a certain number of floors. There are two distribution boards on each floor (including the parking areas) containing the three phases for the head end and the three phases for the tail end of the building (Figure 7). Therefore each floor can be divided into two zones. There is a total of 38 measurement points (38 DB boards) in the building.

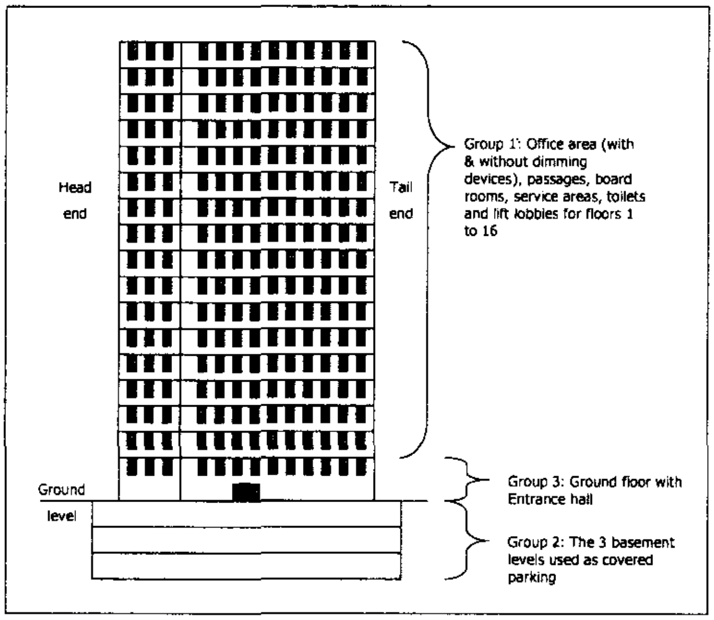

Figure 7: Basic building layout and grouping.

To obtain the load profile of the lighting system it is necessary to determine the lighting load of all the different zones. For the purposes of constructing a baseline only a representative amount of the zones on each floor have to be measured. Statistical sampling will be used to determine the size of the sample that need to be measured. These procedures can be found in Appendix B of this M&V plan.

These measurements will be used to calculate a ratio between the measured load and calculated load of the representative zones. This ratio can then be used to calculate the load for all the other zones and obtain the actual load for the whole group. A total of 8 loggers will thus be required to conduct the measurements.

Continuous metering will be performed during this project after implementation. Additional information on the selection of the number of loggers and the metering layout can be obtained in Appendix C of this M&V plan.

5.1 Pre-implementation

A notch test will be done on each group in order to determine the lighting current (Ampere), lighting load (Watts), power factor and volts. A hand-held digital power meter will be used to perform the notch tests. Table 5 provides a breakdown of the various measurement locations and equipment required for this phase of the M&V process.

Table 5: Pre-implementation measurement groups, locations, equipment and measurement breakdown.

Group:	Location	Distribution board	Equipment	Circuit	Type of measurement	Measure
Group 1:	Floor 3	Head-end DB	Hand-held power meter	Red	Notch test A	Ampere, Watts, Power factor, Volts
				White	Notch test A	
				Blue	Notch test A	
		Tail-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
	Floor 9	Head-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
		Tail-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
	Floor 15	Head-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
		Tail-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
Group 2:	Basement level A	Plant room	Hand-held power meter	30	Notch test A	
				31	Notch test A	
				32	Notch test A	
Group 3:	Entrance hall	Tail-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	
Notch test A: Switch circuit on and off 3 times at 1-minute intervals. To be conducted during normal operational hours.						

5.1.1 Data requirements

The following pre-implementation data will be required to M&V the lighting retrofit and calculate the savings:

- The number and type of existing lights in the Civic Centre;
- Ampere of lighting circuits;
- Watts of lighting circuits;
- Volts of lighting circuits; and

- Power factor.

5.1.2 Metering period

Time to complete a notch test and to verify the number and types of lights in the building.

5.1.3 Summary of required pre-implementation metering equipment

The following type of metering equipment will be required:

- One (1) handheld power meter.

5.2 Post-implementation

After implementation it will be necessary to measure the lighting current, lighting load, volts and power factor. A notch test will again be done to determine the new ratio between the measured and actual load of the retrofitted lights. The operational hours will then be determined through metering of the lighting system of each group. See Table 6 for a breakdown.

Table 6: Initial post-implementation measurement groups, locations, equipment and measurement breakdown.

Group:	Location	Distribution board	Equipment	Circuit	Type of measurement	Measure
Group 1:	Floor 3	Head-end DB	Hand-held power meter	Red	Notch test B	Ampere, Watts, Power factor, Volts
				White	Notch test B	
				Blue	Notch test B	
		Tail-end DB	Hand-held power meter	Red	Notch test B	
				White	Notch test B	
				Blue	Notch test B	
	Floor 9	Head-end DB	Hand-held power meter	Red	Notch test B	
				White	Notch test B	
				Blue	Notch test B	
		Tail-end DB	Hand-held power meter	Red	Notch test B	
				White	Notch test B	
				Blue	Notch test B	
	Floor 15	Head-end DB	Hand-held power meter	Red	Notch test B	
				White	Notch test B	
				Blue	Notch test B	
		Tail-end DB	Hand-held power meter	Red	Notch test B	
				White	Notch test B	
				Blue	Notch test B	
Group 2:	Basement level A	Plant room	Hand-held power meter	30	Notch test A	
				31	Notch test A	
				32	Notch test A	
Group 3:	Entrance hall	Tail-end DB	Hand-held power meter	Red	Notch test A	
				White	Notch test A	
				Blue	Notch test A	

Notch test A: Switch circuit on and off 3 times at 1-minute intervals. To be conducted during normal operational hours.

Notch test B: Switch circuit on and off 3 times at 1-minute intervals. To be conducted during the night to capture full load of all lights, including the office lights with dimming capabilities when they are NOT dimmed.

After the completion of the notch testing, permanent metering will be installed for the duration of the project. A breakdown of the permanent post-implementation measurement groups, locations, equipment and measurements can be obtained from Table 7

Table 7: Permanent post-implementation measurement groups, locations, equipment and measurement breakdown.

Group:	Location	Distribution board	Equipment		Circuit	Type of measurement	Measure
Group 1:	Floor 3	Head-end DB	Logger 1	CT 1 (50 Amp)	Red	Permanent	Ampere
				CT 2 (50 Amp)	White	Permanent	
				CT 3 (50 Amp)	Blue	Permanent	
		Tail-end DB	Logger 2	CT 4 (50 Amp)	Red	Permanent	
				CT 5 (50 Amp)	White	Permanent	
				CT 6 (50 Amp)	Blue	Permanent	
	Floor 9	Head-end DB	Logger 3	CT 7 (50 Amp)	Red	Permanent	
				CT 8 (50 Amp)	White	Permanent	
				CT 9 (50 Amp)	Blue	Permanent	
		Tail-end DB	Logger 4	CT 10 (50 Amp)	Red	Permanent	
				CT 11 (50 Amp)	White	Permanent	
				CT 12 (50 Amp)	Blue	Permanent	
	Floor 15	Head-end DB	Logger 5	CT 13 (50 Amp)	Red	Permanent	
				CT 14 (50 Amp)	White	Permanent	
				CT 15 (50 Amp)	Blue	Permanent	
		Tail-end DB	Logger 6	CT 16 (50 Amp)	Red	Permanent	
				CT 17 (50 Amp)	White	Permanent	
				CT 18 (50 Amp)	Blue	Permanent	
Group 2:	Basement level A	Plant room	Logger 7	CT 19 (50 Amp)	30	Permanent	
				CT 20 (50 Amp)	31	Permanent	
				CT 21 (50 Amp)	32	Permanent	
Group 3:	Entrance hall	Tail-end DB	Logger 8	CT 22 (50 Amp)	Red	Permanent	
				CT 23 (50 Amp)	White	Permanent	
				CT 24 (50 Amp)	Blue	Permanent	
Permanent: Permanent installation of metering equipment for the duration of the project. Measurement at 5-minute intervals. The data will be downloaded manually from each logger once a month.							

5.2.1 Metering System Layout

Additional information on the metering system layout can be obtained from Appendix C of this M&V plan.

5.2.2 Data requirements

The following data will be required to M&V the lighting retrofit and calculate the savings:

- The number and type of lights replaced in the Civic Centre;
- Ampere of lighting circuits;
- Watts of lighting circuits;
- Volts of lighting circuits; and
- Power factor.

5.2.3 Summary of required post-implementation metering equipment

The following type of metering equipment will be required:

- One (1) hand-held power meter
- Eight (8) 12-bit resolution 4 channel loggers.
- Twenty-four (24) 50 Amp Clamp-on Current Transducers (CT).
- One (1) handheld data download unit.
- Connection cable between handheld-data-download-unit and desktop computer and corresponding software.

5.3 Metering equipment acquisition

The following metering equipment needs to be acquired for this project:

- Eight (8) 12-bit resolution 4 channel loggers.
- Twenty-four (24) 50 Amp Clamp-on Current Transducers (CT).
- One (1) handheld data download unit.
- Connection cable between handheld-data-download-unit and desktop computer and corresponding software.

The contact information on the supplier as well as the prices for the received quotation is given in Appendix D.

6 SAVINGS CALCULATION METHODOLOGY

This section describes the methodology and/or equations that will be used to estimate the annual savings for lighting efficiency measures.

6.1 Demand

The impacts of the lighting retrofit on the monthly maximum demand will be determined by making use of the logged data and the stipulated parameters. The baseline maximum demand for a 30-min interval i will be calculated as follows:

$$kW_{bl,i} = \sum_{n=1,..,x}^{n} \left(kW_{lamp,bl,i} \times Quantity\right)_n \qquad \text{(Eq. 1)}$$

Where:

$kW_{bl,i}$ = Baseline maximum demand at 30-min interval i for lamp type n, including ballast load per lamp.

Quantity = Quantity of lamps of type n.

i = Time interval (30-min).

n = Type of lamp (pre-implementation) with n = 1 to x.

x = Total types of lamps prior to retrofit.

The actual post-implementation maximum demand will be:

$$kW_{act,i} = \sum_{n'=1,..,y}^{n'} \left(kW_{lamp,act,i} \times Quantity\right)_{n'} \qquad \text{(Eq. 2)}$$

Where:

$kW_{act,\,i}$ = Actual post-implementation maximum demand at 30-min interval i for lamp type n, including ballast load per lamp.

Quantity = Quantity of lamps of type n.

i = Time interval (30-min).

n' = Type of lamp (post-implementation) to replace type n with n' = 1 to Y.

y = Total types of lamps after retrofit.

The maximum demand savings at any specific 30-min time interval i will be quantified by calculating the following:

$$kW_{savigs,i} = kW_{bl,i} - kW_{act,i} \qquad \text{(Eq. 3)}$$

Where:

$kW_{savings,i}$ = Maximum demand savings realised in this project for all lamps types over 30-minute time interval i.

6.2 Electricity consumption

The reduction in energy consumption will be calculated through engineering calculation methods incorporating metered data. The savings will be the difference between the baseline electricity consumption and the electricity consumption of the post-implementation system. The savings will be calculated in kilowatt-hours (kWh) on a monthly and annual basis.

The following equation will be used for each different luminaire type and added together to determine the baseline electricity consumption:

$$kWh_{bl,i} = kW_{bl,i} \times 0.5 \qquad \text{(Eq. 4)}$$

Where:

$kWh_{bl,i}$ = Baseline electricity consumption for 30-min time interval i.

$kW_{bl,i}$ = The installed electrical capacity of the lamps used in the baseline for the 30-minute time interval i (from Equation 1).

The following equation will be used in determining of the actual electricity consumption for each different luminaire type and added:

$$kWh_{act,i} = kW_{act,i} \times 0.5 \qquad \text{(Eq. 5)}$$

Where:

$kWh_{act,i}$ = Actual (post-implementation) electricity consumption for 30-min time interval i.

$kW_{act,i}$ = The actual installed electrical capacity of the lamps after implementation for the 30-minute time interval i (from Equation 2).

The electricity consumption savings per 30-minute time interval i can then be determined by subtracting the actual post-implementation consumption (Equation 5) from the baseline consumption (Equation 4). Thus:

$$kWh_{savings,i} = kWh_{bl,i} - kWh_{act,i} \qquad \text{(Eq. 6)}$$

The monthly savings in energy consumption (kWh) can then be obtained by adding all the values from Equation 6 that fall in the period of one month.

$$kWh_{savings} = \sum_{i=1,\ldots,z}^{i} \left(kWh_{savings,i} \right) \qquad \text{(Eq. 7)}$$

Where:

$kWh_{savings}$ = Monthly savings in energy consumption.

$kWh_{savings,i}$ = Incremental savings in energy consumption per 30-minute time interval i (Equation 6).

i = 30-minute time interval.

z = Total number of 30-minute time intervals in specific month.

6.3 Electricity cost

Electricity cost is calculated by using the electricity consumption and monthly maximum demand. Details about the tariffs ($Tariff_{kWh}$ and $Tariff_{kW}$) are stated in section 2.4 of this M&V plan. The cost savings can be calculated by using the following formula in combination with the results of Equations 7 and 3:

$$R_{savings} = (kWh_{savings} \times Tariff_{kWh}) + (kW_{savings} \times Tariff_{kW}) \qquad \text{(Eq. 8)}$$

6.4 Emissions

The emission reductions due to reduced energy consumption will be calculated through the use of established and trusted emission factors linked to energy consumption savings. The emission reductions will be calculated for carbon dioxide (CO_2), Nitrous oxides (NO_X), Sulphide oxides (SO_X) and particulate matter [2].

$$\text{Emission Impact}_X = (EF_X) \cdot \left(\frac{kWh_{savings,annual}}{1000}\right) \qquad \text{(Eq. 9)}$$

Where:

Emission Impact $_X$ = The impacts of emission X, which can be CO_2, NO_X, SO_X or particulate matter.

EF_X = Emission factor X for CO_2, NO_X, SO_X or particulate matter (provided below).

$kWh_{savings, annual}$ = Annual energy consumption savings calculated in equation 7 and added for all the months of the year.

In order to calculate the reductions in the above emissions, one need to know what the total number of megawatt-hours was that was saved due to the implementation of the DSM option. The emission factors used are the following [2]:

Carbon dioxide (CO_2)	EF_{CO2}	=	892 kg /MWh
Nitrous oxides (NO_X)	EF_{NOX}	=	3.55 kg/MWh
Sulphide oxides (SO_X)	EF_{SOX}	=	7.56 kg/MWh
Particulate matter	EF_{PAR}	=	0.29 kg/MWh

7 PROJECT SCHEDULES AND COST

Table 8 provides the completion dates and respective costs of each project deliverable. The total M&V cost for this project is R195,000 excluding VAT. For more detail on project schedules see Appendix E.

Table 8: Project deliverables and invoice amounts.

	Deliverable	Date	Invoice
1	Project Scoping, M&V Development and M&V plan	28 May 2003	R25,000
	M&V plan development	28 May 2003	R30,000
2	Baseline Development and Baseline Report	16 June 2003	R22,500
3	Implementation Assessment and M&V Post-Implementation Report	27 August 2003	R25,000
4	M&V Metering Installation and Commissioning	15 September 2003	R35,000
5	Performance Assessment and First Monthly Savings Report	7 October 2003	R35,000
6	Monthly Savings Analysis and Report	12 November 2003	R12,500
7	Annual Savings Analysis and Report	15 January 2004	R10,000
	Total		R195,000 (excl. VAT)

8 BIBLIOGRAPHY

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[4]. Moore, David. S., The basic practice of statistics. Freeman. 1995. pp 680.

[5]. Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison. California's 2000 Large Non-Residential Standard Performance Contract Program: Procedures Manual. Appendix G – Sampling, Version 1.0, May 1, 2000

[6]. Montgomery, Douglas C., Runger, George C., Applied statistics and probability for engineers. John Wiley & Sons, Inc. 1994. pp 895.

Appendix A

M&V Option Selection

A.1. Project classification according to M&V Framework document.

The detailed project classification according to the M&V Framework document is presented here.

A.1.1. *ECM or Pricing Response*

This project is classified as an energy conservation measure.

1	2	3	4		5	6	7
ECM	Fuel Switching	Load Shifting	Load Shedding	Now use Flow Chart B	Whole Facility	Sub-system WITH interactive effects	Sub-system WITHOUT interactive effects
●							

The objective of this project is to improve the energy efficiency of the lighting system under the same operational conditions.

A.1.2. Definition of Boundaries

A sub-system is considered for the development of the baseline. The system boundary is defined as a sub-system without interactive effects.

1	2	3	4		5	6	7
ECM	Fuel Switching	Load Shifting	Load Shedding	Now use Flow Chart B	Whole Facility	Sub-system WITH interactive effects	Sub-system WITHOUT interactive effects
●							●

A detailed description of the sub-system can be found in the main document of the M&V plan.

A.2. Analysis of Standard Elements

A completed project classification sheet is presented below.

COLUMNS												
A	B	C	D	E	F	G	H	I	J	K	L	M
BEFORE				AFTER								
Operating Hours		Requirement/Load		Operating Hours	Requirement/ Load	Efficiency	Operating Hours	Requirement/ Load	Operating Hours		Requirement/Load	
Fixed pattern(s)	No Pattern (variable)	Fixed value or fixed pattern(s)	Variable value or no pattern(s)	Does the measure change the operating hours?	Does the measure change the Requirement/ load?	Does the measure change component efficiencies?	Can the post-operating hours be used for the baseline?	Can the post-requirement/ load be used for the baseline?	Fixed pattern(s)	No Pattern (variable)	Fixed value or fixed pattern(s)	Variable value or no pattern(s)
●		●				●	●	●	●		●	

The rest of this section provides the rationale/reasons/justification as to why these choices have been made.

A.2.1. Operating hours – fixed or variable

The system operates on a fixed operational schedule. This is considered to be the case both before and after the intervention. The "Post" operating hours can consequently be used for the baseline development and the saving calculations.

A.2.2. The "Load/Requirement" – fixed or variable

The load/requirement of the lighting system was fixed before the retrofit, and it would vary according to a pattern after the retrofit of the lighting system.

A.2.3. Efficiency

Although the efficiency of the system may be slightly improved (through reduced standing losses during controlled periods), this impact is considered to be small enough to be disregarded.

A.2.4. Operating hours

The operating for the post-implementation stage can be used for the development of the baseline since they will remain unchanged after the lighting retrofit. It is controlled according to a fixed pattern.

A.2.5. Load/Requirement

The load/requirement for the post-implementation stage can be used for the development of the baseline since it will remain unchanged after the lighting retrofit. It is controlled according to a fixed pattern.

A.3. Identification of the Parameters that can influence the savings

A.3.1. Saving mechanisms and associated risks

Prior to listing the various parameters that can influence savings, it is useful to define how and why savings occur. At the same time, it is also necessary to highlight some of the conditions/risks that may influence the savings. The table and subsequent discussion below provides the reason for the savings and a list of things that can go wrong.

What causes savings?		Why does this cause savings?		What can go wrong?	
1.	Changing the requirement (efficiency) of the system – in other words changing how much electricity the system uses when it is using electricity.	1.	The system used less electricity in term or energy consumption (kWh) and monthly maximum demand (kVA).	1.	The tariff can change. If the tariff change, the monthly and annual electricity accounts will increase accordingly, but in the absence of the retrofit, the increase in cost would have been greater.
				2.	The operational hours may change. If they decrease from the current situation, the electricity accounts would show increased savings. If the operational hours increase, the system would result in increase electricity accounts. The savings would thus be reduced. In the absence of the retrofit, the increase in electricity accounts would have been greater.
				3.	More lights might be installed that fall outside the scope of this project. This would change the load/requirement and increase the electricity accounts accordingly.
				4.	Poor maintenance may result in the replacement of the efficient lamps with less efficient ones. This would result in decreased savings.

A.4. Responsibilities

For the purposes of assigning responsibilities the parties are defined as follows.

1. The Esco: Bonesa.
2. The client: Greater Johannesburg Metropolitan Council.

Standard Element		Responsibility			
		ESCO	Client	Jointly	Outside
Load/Requirement					
Parameters that can influence this standard element					
1.	Natural day light				✓
2.	Time of day				✓
3.	Type of day				✓
4.	Usage pattern required from the system		✓		
5.	Control strategy/algorithm		✓		
6.	Duration of control		✓		
7.	Degree of control		✓		
Hours of operation					
Parameters that can influence this standard element					
1.	Power failures		✓		
2.	Installation of individual control switched		✓		
System Efficiency					
Parameters that can influence this standard element					
1.	Maintenance		✓		

Appendix B

Statistical Sampling

B.1. Statistical Sampling.

B.1.1. Definition of Parameters

This section will provide a brief description and definition of the terms, parameters and variables used in the process of determining the sample sizes for an M&V project's measurement campaign. The sample size for the measurement campaign of this M&V project will also be calculated in this appendix.

B.1.2. Usage Groups

It is often the case that subsets with similar characteristics can be found inside a population. If we consider a lighting system in one or more buildings, we can assume that lights in all the hallways will be used in a similar manner or schedule. The same can be assumed for offices lighting, lights in bathrooms, stair lighting, etc. This means that subsets can be grouped together to facilitate easier measurement

Usage groups [3] are subsets of the entire population of affected equipment at the project site that have similar operating characteristics. Combining the affected equipment into homogeneous groups reduces the sample size required to obtain a reliable estimate. The proper designation of usage groups therefore critical for maintaining small sample sizes while still obtaining statistically valid results within specified confidence bounds.

There are 3 usage groups in this project. They are:

- Group 1 – Office area (with & without dimming devices), passages, board rooms, service areas, toilets and lift lobbies for floors 2 to 16;
- Group 2 – The 3 basement levels used as covered parking;
- Group 3 – Ground floor with Entrance hall

B.1.3. Confidence Level

The confidence (or also called the confidence level) states the probability that the sample will give an accurate representation of the behaviour of the population in terms of the measured parameter of characteristic. The confidence tells you how sure you can be. It is expressed as a percentage and represents how often the true percentage of the population, which would behave in a certain manner, lies within the confidence interval. The 95% confidence level means you can be 95% certain; the 99% confidence level means you can be 99% certain.

A confidence level of 80% will be used during this M&V project.

B.1.4. 2.3 Precision

The precision [6] or margin of error [4] of the confidence interval is expressed as a percentage. If a precision of 10% is used and 60% percent of your sample behaves in a certain manner (has a certain energy usage profile), one can be "confidant" that if one had monitored the entire relevant population the results would be that between 50% (60%-10%) and 70% (60%+10%) would have behaved in the same manner (or had the same profile).

The wider the confidence interval you are willing to accept, the more certain you can be that the whole population's behaviour would be within that range. For example, if you measured a sample of 1000 lights to determine their hours of operation, and 60% resulted in a same number of operating hours, you can be very certain that between 40% and 80% of all the lights in the population have the same operational hours, but you cannot be so sure that between 59% and 61% of the lights have the same operational hours. Due to the methods used, halving the precision from 20% to 10% will result in a sample size four times larger per usage group [3].

A precision of 20% will be used during this M&V project

B.1.5. Reliability

The reliability [3] of a sample refers to the likelihood or probability with which one can state that the estimate produced by the sample falls within a specified range of the true value or characteristic of the population. The reliability is expressed in terms of the confidence and the precision. When you put the confidence and the precision together, you can say the following (consider a case where the measurements resulted that 60% of the sample gave the same operational hours):

- Reliability level (90/10) – 90% confidence at 10% precision: You can be 90% sure that between 50% and 70% of the population has the same operational hours as the sample.
- Reliability level (80/20) – 80% confidence at 20% precision: You can be 80 sure that between 40% and 80% of the population has the same operational hours as the sample.

Generally, for a fixed sample size n and standard deviation σ (discussed in next sections), the higher the confidence, the longer the resulting precision (or confidence interval) becomes [4].

B.1.6. Z-Statistic (Standard Normal Critical Value) [z*]

The manner in which the Z-statistic is calculated is beyond the scope of this document. The Z-statistic is dependent on the confidence, but independent of the precision. You simply need to specify the confidence level required for your sample measurement campaign and read the corresponding value for the Z-statistic from Table B1 provided below.

Table B1: Selection of Z-statistic.

Confidence level [5]	z* (Z-statistic) [5]
50.0 %	0.674
60.0 %	0.841
70.0 %	1.036
80.0 %	1.282
90.0 %	1.645
95.0 %	1.960
96.0 %	2.054
98.0 %	2.326
99.0 %	2.576
99.5 %	2.807
99.8 %	3.091
99.9 %	3.291

A reliability of (90/10) specify a confidence of 90% and a precision level of 10%. The selected Z-statistic from Table B1 is 3.291.

B.1.6. Standard Deviation

The standard deviation is a term that describes the measure of variability of the parameter that will be measured during the coarse of the M&V project [5]. This can be the lighting intensity, hours of operation or the operational profile, etc. This value is typically drawn from previous studies that have metered the operation of systems with similar operational characteristics. A default value of 0.5 or 50% is however used.

B.2. Calculating the Sample Size

This section provides the statistical equations used to calculate the size of the measurement sample. It gives a breakdown of the data that need to be specified, as well as the steps involved in the calculation of the sample sizes.

B.2.1. Equations

The size of the sample for a usage group or the entire population can be calculated with Equation 1. The equation requires the specification of the Z-statistic (which is obtained from Table B1 with the help of a specified confidence), the standard deviation (with a default value of 0.5 or 50%, unless specified otherwise), and lastly the precision or margin of error (also expressed as 0.1 or 10% corresponding to σ)

$$n_k = \left(\frac{z^* \cdot \sigma}{m} \right)^2 \quad \text{(Eq. B1)}$$

The above equation determines the size of the sample that needs to be measured. It is however clear that the size of the sample is independent of the size of the population. In order to take the size of the population into consideration, a population adjustment need to be made. The population adjustment is done with Equation B2.

$$n^* = \left(\frac{n \cdot N}{n + N} \right) \quad \text{(Eq. B2)}$$

Although the effect of the population size is now include din the sample size, the impact is still extremely small.

B.2.2. Steps in Sample Size Calculations

The following steps need to be followed to calculate the size of the measurement sample:

1. Compile information on the energy conservation measure to be implemented on the lighting system. This is done to determine the manner in which lights are controlled and if they can be grouped together in similar groups in terms of control.

2. Assign usage groups based on similarities such as area type, operating hours, and timing of operating hours, variability of operating hours, similar functional use. Three usage groups has been assigned. Group 1 has 30 DBs, Group 2 has 6 and Group 3 has 2 DBs.

3. Specify a standard deviation. The default value used is 0.5 or 50%, unless another value is specified based on experience from previously monitoring projects. Note must be take to remain consistent in the use of Equation 1. If the standard deviation is used as 0.5, the margin of error needs to be used in the same format.

4. Specify the level of confidence that is required for the sample. It usually ranges between 90% and 80% for lighting projects, but can vary. Table B1 provides the various confidence levels available. A confidence level of 80% has been selected for this project.

5. Obtain the Z-statistic from Table B1 that corresponds to the selected confidence. This value is 1.282.

6. Specify the margin of error or the precision of your confidence interval. It is usually specified as 10% or 20% for lighting retrofit projects. A precision of 20% has been selected for this project.

7. Calculate the sample size n_k. The sample size is always rounded up, whether it is calculated as 10.2 or 10.9, it should become 11. Make the adjustment for population size N with Equation B2. The resulting number of measurement points in the building is calculated as 8 DBs. Fro Group 1 we need to measure 6 DBs (or 3 floors). For Group 2 we only need to measure 1 DB (or 1 halve of a floor), and for Group 3 we only need to measure 1 DB (half of the ground floor).

8. With the known sample size, select the appropriate measurement points in a random manner.

Appendix C

Metering Layout

C.1. Metering layout

The building consists of groups as described in section 4.1. The groups are assigned according to layout and usage. They are:

- Group 1 – Office area (with & without dimming devices), passages, board rooms, service areas, toilets and lift lobbies for floors 2 to 16;
- Group 2 – The 3 basement levels used as covered parking;
- Group 3 – Ground floor with Entrance hall

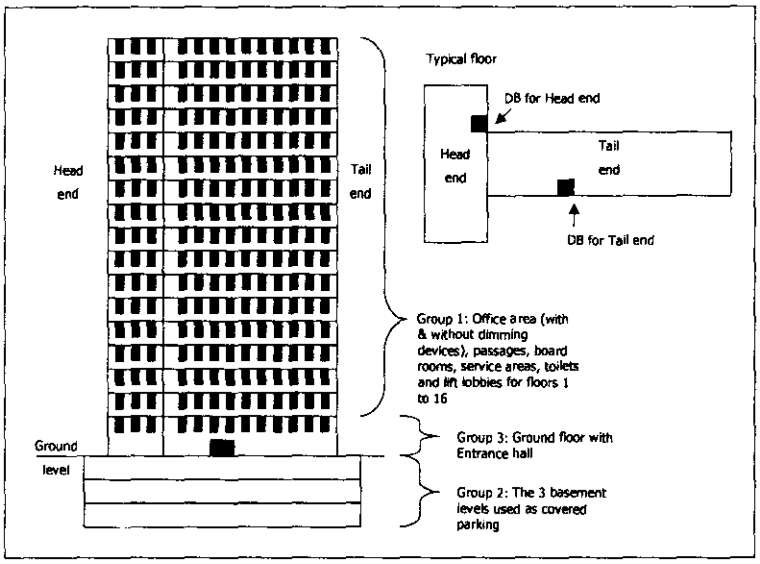

Figure C1: Basic building layout, grouping and location of DBs

Group 1 consist of 16 levels, used mainly as office space. The three covered parking levels are on a different operational schedule than the rest of the building. The Entrance hall on the ground floor is also assigned to its own group due to its difference in usage. According the building maintenance personnel, the entrance hall is operated on the same schedules than the office levels.

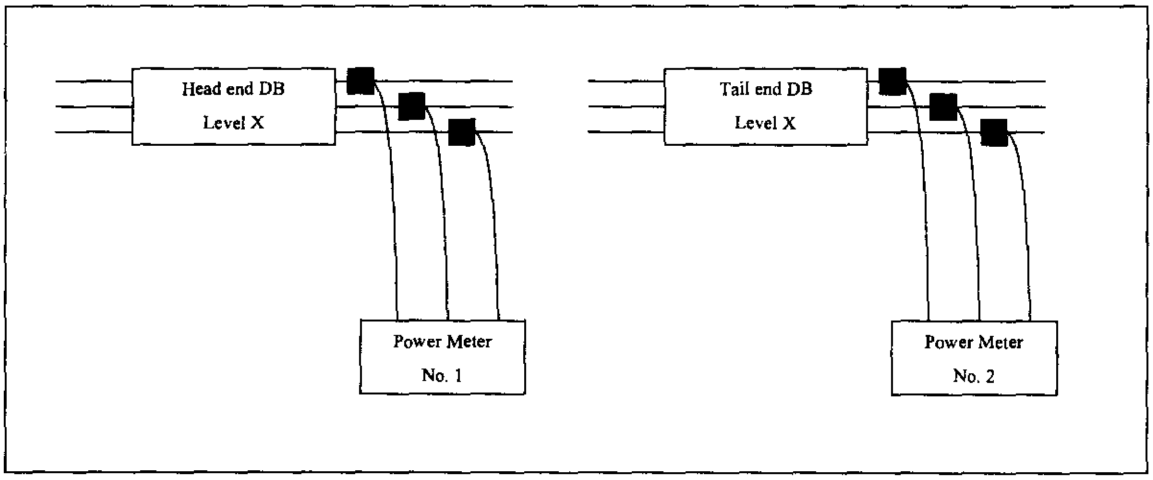

Figure C2: Metering Layout for a typical floor

There are two distribution boards on each floor (including the parking areas) containing the three phases for the head end and the three phases for the tail end of the building (Figure A1). Therefore each floor can be divided into two zones. There is a total of 38 measurement points (38 DB boards) in the building (including all 3 Groups).

To obtain the load profile of the lighting system it is necessary to determine the lighting load of all the different zones. For the purposes of constructing a baseline only a representative amount (15%) of the zones on each floor have to be measured. These measurements will be used to calculate a ratio between the measured load and calculated load of the representative zones. This ratio can then be used to calculate the load for all the other zones and obtain the actual load for the whole group.

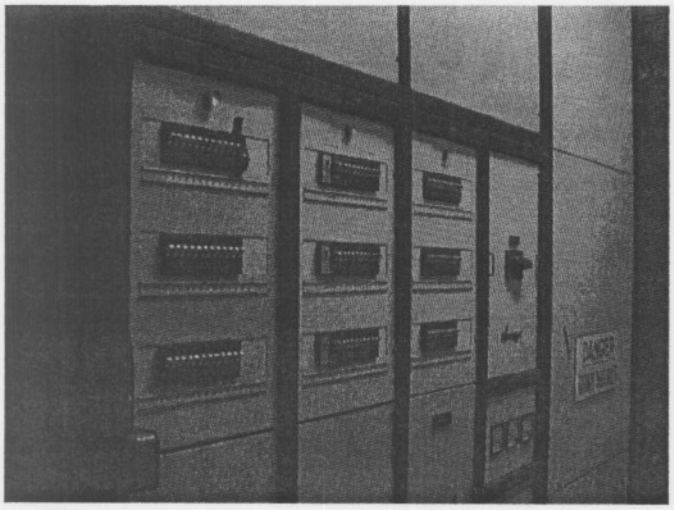

Figure C3: Typical DB (1 of 2) per level.

Group 1 (the 2-16 office floors) will thus require that three floors be measured (6 DBs = 6 loggers). Group 2 (the basement levels) will require the measurement of one DB (one half of a level) on the covered parking levels, and Group 3 (the ground floor) will require that one DB (one half of a level) be measured on the floor. A total of 8 loggers will be required to conduct the measurements.

The locations of the DBs are indicated on Figure C1.

Continuous metering will be performed during this project after implementation.

Appendix D

Metering Equipment Quotations & Evaluation

D.1. Executive Summary

Three quotations have been obtained for the hardware required to carry out the M&V of the Civic Centre lighting retrofit project in Johannesburg. The minimum hardware requirements of this project are the following:

- Eight (8) loggers with at least 3 channels.
- Twenty-four (24) 50 Amp Clamp-on Current Transducers (CT).
- Connection cable between handheld-data-download-unit and desktop computer and corresponding software.

The system recommended by the M&V Team is discussed in section D.2.1 and could be obtained from **Vangard Digital** (VGD). The quoted system costs R56,102.00 (excl. VAT). This system met the requirements of the system specified by the M&V team, at the lowest cost of the three quotations.

D.2. Metering equipment quotations

Three quotations were received. They were obtained from:

- Vangard Digital (VGD)
- Architectural Energy Corporation (AEC)
- Measurement & Control Solutions (MCS)

The sections that follow contain more detailed information on the various quotes received.

D.2.1. Quote 1: Vangard Digital

Contact information: Raymond Jooste

6 Du Raan Rd., Sunward Park, Boksburg

P.O. Box 19939, Sunward Park, RSA, 1470

E-mail: dirk@vangard.co.za

Web: www.vangard.co.za

Tel: (011) 913 3199

Fax: (011) 913 1261

Number	Description	Quantity required	Cost
1	VGD-400 4 ch data logger 0-25 mA input (R3,905.00 ea.)	8	R31,240.00
2	50A –1A current transformers (R125.00 ea.)	24	R3,000.00
3	1A AC to 4-20mA transducers (R608.00 ea.)	24	R14,592.00
4	800mAh rechargeable batteries (R115.00 ea.)	8	R920.00
5	Extended memory from 5,000 to 20,000 readings (R250.00 ea.)	8	R2,000
6	VGD Handheld communicator (download 15 loggers)	1	R4,350
	Sub-Total		**R56,102.00**
	VAT		**R7,854.28**
	Total		**R63,956.28**

The official quote of this system is attached on the following page.

D.2.2. Quote 2: Architectural Energy Corporation

Contact information: 2540 Frontier Avenue, Suite 201, Boulder, Colorado 80301

E-mail: MDLinfo@archenergy.com

Web: www.archenergy.com

Number	Description	Quantity required	Cost
1	Microdataloggers: MDL-202	8	US$ 5,560.00
2	Serial Cable interface: Cable-serial	1	US$ 25.00
3	Battery charger: Charge-02	2	US$ 60.00
4	50A current transducers: CT-0750-050	24	US$ 1,008.00
5	333mV module: VAC-17-3	24	US$ 1,200
6	Shipment		US$ 200
	Sub-Total		**US$ 8,053.00**
	Rand total (exchange rate = R7.5 to US$ 1.		**R60,397.00**
	VAT		**R8,455.58**
	Total		**R68,852.58**

The exchange rate used in the above table was obtained for 13 May 2003. The quote of this system is attached on the following page.

D.2.3. Quote 3: Measurement & Control Solutions

Contact information: Raymond Phillips

9 Lands End, Constantia Kloof, 1725, South Africa

P.O. Box 1479, Cresta, 2118, South Africa

Tel: (011) 475 1014

Fax: (011) 475 1654

Cell: 083 226 9539

Number	Description	Quantity required	Cost
1	XR440, Pace scientific XR440 precision batt powered, 12 Bit 4 channel data logger (R5,943.00 ea.)	8	R47.544.00
2	IC209, IC209 computer connection cable (R238.00 ea.)	1	R238.00
3	CT, Miniring CT with 32mm ID-Ration, 50/A AC C/W converter (R810.00 ea.)	24	R19,440.00
4	Freight		R0.00
	Sub-Total		**R67.222.00**
	VAT		**R9,411.08**
	Total		**R76,633.08**

The official quote of this system is attached on the following page.

Appendix B

M&V baseline report – Johannesburg Civic Centre

Measurement and Verification
Team
Potchefstroom University for CHE
PO Box 19139
Noordbrug, Potchefstroom
2522
Tel: 018 299 1329
Fax: 018 299 1320
Email: mgiljg@puk.ac.za

Baseline Report:

Civic Centre

DATE OF REPORT	:	09 July, 2003
VERSION	:	Version 1, revision 0
PREPARED BY	:	W.I.R den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

Table of Contents

Nomenclature:

A	Ampere
CFL	Compact fluorescent lamp
CT	Current transducer
DB	Distribution board
DSM	Demand side management
ESCO	Energy service company
GJMC	Greater Johannesburg Metropolitan Council
kVA	Kilovolt ampere
kW	Kilowatt
LBR	Low brightness reflector
M&V	Measurement and verification
PF	Power factor
V	Volt

1 OVERVIEW

The following document provides a measurement and verification (M&V) baseline report for the lighting retrofit to be implemented by Bonesa at the Civic Centre in Braamfontein, Johannesburg.

The purpose of the M&V baseline report is to provide a baseline for the electricity demand and electricity consumption of the lighting system. After implementation of the demand side management (DSM) activity, the baseline will represent the pre-implementation electricity demand and – consumption for the lighting system, since these value cannot be measured after implementation, only the actual post-implementation demand and consumption can be measured.

Once the DSM measure has been implemented, the savings can be determined as the difference between the actual energy demand and consumption (as measured during the post-implementation stage) and the inferred baseline demand and consumption.

This M&V baseline report provides:

- A description of the project, its activities and the stakeholders;
- The baseline methodology applicable to this project;
- The necessary measurements that were taken to determine the lighting system baseline electricity demand and -consumption; and
- The baseline values that represent the baseline demand and electricity consumption of the lighting system.

2 PROJECT DESCRIPTION

This section provides information on the parties involved in the project and the M&V-activities as well as the objectives of the project and the DSM measures that will be implemented. A short description of the site is also provided.

2.1 Project information

M&V Company name:		Potchefstroom University for CHE	
M&V Contact person:		Prof. LJ Grobler and Mr. Willem Den Heijer	
Postal address:		Private Bag X6001, Potchefstroom, 2520	
Country:		South Africa	
Phone:	+27 18 299 1328 / 4025	Fax:	+27 18 299 1320
Cell:	+27 82 452 9279 +27 83 256 9640	E-mail:	Mgiljg@puknet.puk.ac.za Mgiwdh@puknet.puk.ac.za
Date of submittal of M&V baseline report:		16 July 2003	
Project Sponsor Name:		Eskom - DSM	
Name of project site:		Civic Centre	
Address:		158 Loveday Street, Braamfontein, Johannesburg	
Country:		South Africa	
Company name (Site owner / Client):		Greater Johannesburg Metropolitan Council (GJMC)	
Contact person:		Faisel	
Phone:	011 407 7289	Fax:	011 403 1818
Cell:	082 464 9585	E-mail:	Jeffs@Joburg.org.za
Type of building(s) (office, retail, etc.):		Office building	
Contact person (Implementation / Esco):		Mr. Nad Permaul (Bonesa - Commercial programs manager)	
Phone:	+27 12 427 2797	Fax:	+27 12 427 2935
Cell:	+27 83 296 4893	E-mail:	Nperumaul@bonesa.co.za

2.2 Project Objective

The objective of the project is to measure and verify the energy consumption, demand, and energy cost savings, as well as emission impacts, due to the office lighting retrofit at the Johannesburg Civic

Centre. The impacts need to be determined to verify the cost savings for the client and the ESCO, as well as the DSM-impacts obtained for Eskom.

2.3 Report Objective

The objective of this report is to establish the lighting system baseline conditions (demand and electricity consumption) and baseline values of the DSM project before implementation of the lighting retrofit.

2.4 Site description

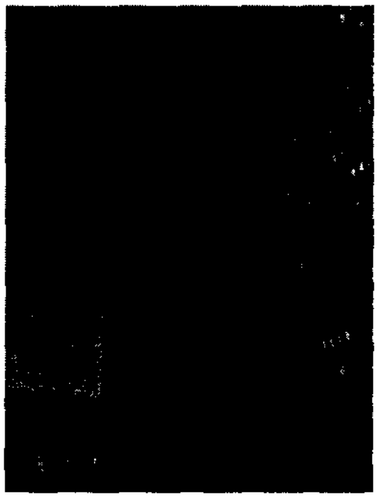

Figure 1: Civic Centre

The Civic Centre is a large commercial building that is used by the Greater Johannesburg Metropolitan Council (GJMC) as offices. The building has 16 floors (of which floor 1 does not form part of this project), a ground floor and 3 basement levels used as covered parking. The building thus has a total of 20 levels (see Figure 1). Each floor in the building is divided into a head- and a tail end. Each head- and tail end has its own distribution board (DB).

The head- and tail ends have their own lighting switches (one per DB). Timers are used to control the normal hours that the lights are switched on. The switches are however used outside of these hours to turn the lights on. This means that individual offices cannot control their respective lights.

3 BASELINE

The following process as stipulated in the M&V Plan for the Civic Centre[1] was followed to establish the baseline and its conditions.

3.1 Characterisation

To determine the baseline (what the energy use would have been without implementation) for this project it is necessary to quantify the following:

- The actual lighting load (kW) before implementation
- The actual operational hours of all the lights before implementation

[1] Measurement and Verification Plan: Civic Centre lighting project, 14 May 2003

The same parameters must be quantified after implementation to determine the impact of the retrofit. The operating hours of the building before and after the retrofit will be the same.

For the purposes of this project the various areas of the Civic Centre is divided into 3 groups according to their layout and usage:

- Group 1 – Office area (with & without dimming devices after implementation), passages, board rooms, service areas, toilets and lift lobbies for floors 2 to 16;
- Group 2 – The 3 basement levels (A, B and C) used as covered parking; and
- Group 3 – Ground floor with Entrance hall.

The groups consist of a number of identical zones (floors) each with two DBs, each feeding to the head of the tail end of each floor.

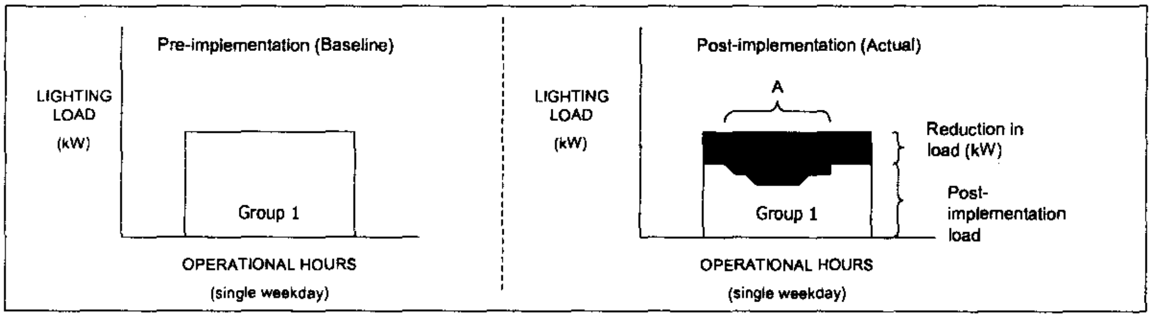

Figure 2: Baseline representation for Group 1 (Floors 1-16).

Each group has a certain operational hours and a certain demand. Figure 2 is an illustration of the lighting load profile of Group 1 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 1 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 2). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile provides the savings achieved (the darkened section of the diagram). The load during the post-implementation phase is no longer a straight line, but varies during the day due to the number of office lights fitted with dimming equipment.

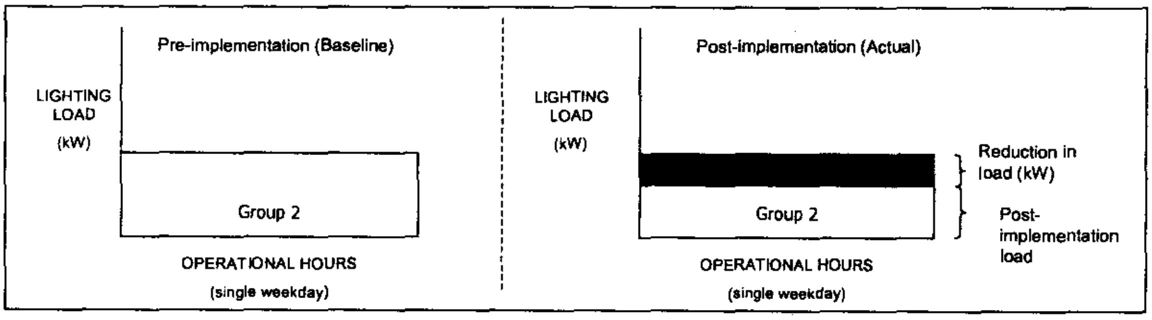

Figure 3: Baseline representation for Group 2 (Basement levels A, B and C).

Figure 3 is an illustration of the lighting load profile of Group 2 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 2 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 3). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile provides the savings achieved (the darkened section of the diagram).

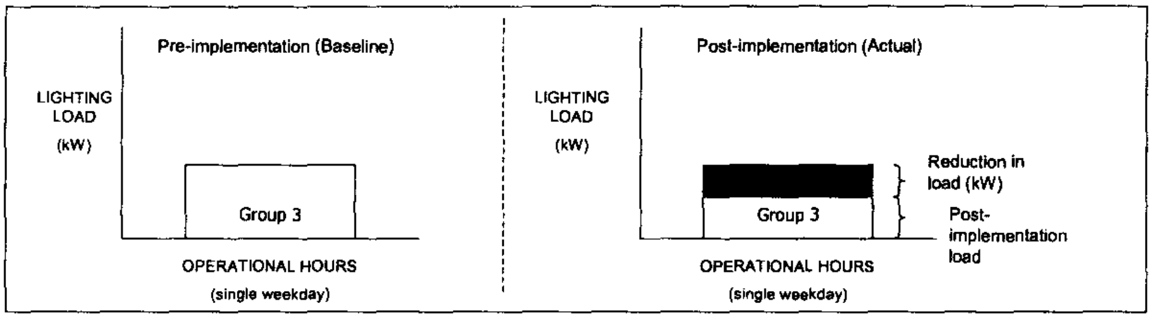

Figure 4: Baseline representation for Group 3 (Entrance hall on ground floor).

Figure 4 is again an illustration of the lighting load profile of Group 3 over a typical weekday (24-hour period). The pre-implementation profile represents the current system before the retrofit for Group 3 and will also be used as the baseline. The operational hours are expected to remain unchanged (as can be seen in Figure 4). The lighting load is reduced with the retrofit and the difference between the actual and the baseline profile provides the savings achieved (the darkened section of the diagram).

The savings for each group will be determined separately and summed to obtain the total savings.

3.2 Baseline adjustments

Baseline adjustments will be needed when:

- The operating hours of the lighting system change.
- The quantity of lamps is changed after the development of the baseline.

4 BASELINE METERING

The building consists of groups as described in section 3.1. Each group consists of a certain number of floors. There are two distribution boards on each floor (including the parking areas) containing the three phases for the head end and the three phases for the tail end of the building (Figure 5). Therefore each floor can be divided into two zones. There is a total of 38 measurement points (38 DB boards) in the building.

To obtain the load profile of the lighting system it is necessary to determine the lighting load of all the different zones. For the purposes of constructing a baseline only a representative amount of the zones on each floor have to be measured. Statistical sampling was be used to determine the size of the sample that need to be measured. These procedures can be found in the M&V plan for the Civic Centre lighting retrofit project.

These measurements will be used to calculate a ratio between the measured load and calculated load of the representative zones. This ratio can then be used to calculate the load for all the other zones and obtain the actual load for the whole group. A total of 8 loggers will thus be required to conduct the measurements after implementation.

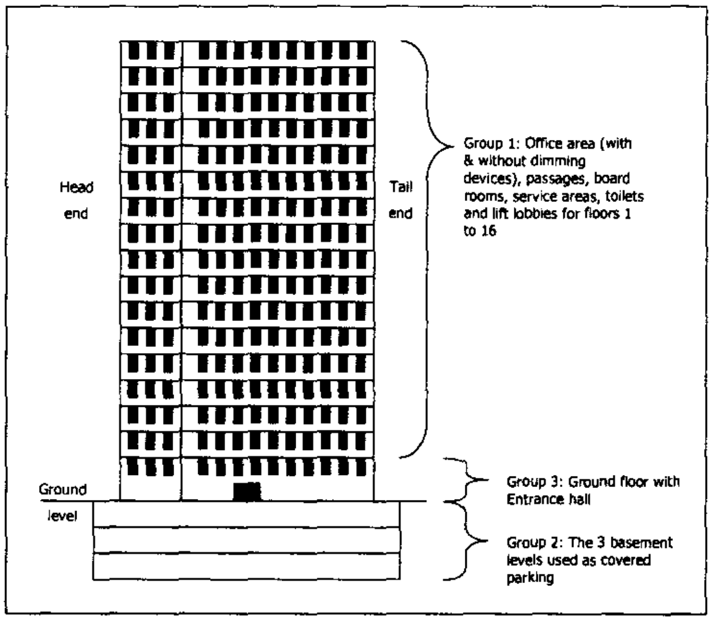

Figure 5: Basic building layout and grouping.

Continuous metering will be performed during this project after implementation. Additional information on the selection of the number of loggers and the metering layout can be obtained in the M&V plan.

4.1 Summary of pre-implementation metering equipment used

The following type of metering equipment was used:

- One (1) handheld power meter.

4.2 Metering period

During the week of 11 April notch tests were performed on floor 15, the ground floor and on the Basement level A of the Civic Centre.

4.3 Data acquired

Table 1 shows the measurements obtained from the Civic Centre. These measurements were used to determine the baseline for the Civic Centre lighting system.

Table 1: Data from pre-implementation metering.

Group:	Location	Distribution board	Equipment	Circuit	Amps	Volts
Group 1:	Floor 15	Head-end DB	Hand-held power meter	Red	35.5 A	226 V
				White	44.2 A	226 V
				Blue	41.0 A	226 V
		Tail-end DB	Hand-held power meter	Red	18.9 A	226 V
				White	30.8 A	226 V
				Blue	12.3 A	226 V
Group 2:	Basement level A	Plant room	Hand-held power meter	Red	38.5 A	224 V
				White	27.5 A	224 V
				Blue	12.3 A	224 V
Group 3:	Entrance hall	Tail-end DB	Hand-held power meter	Red	29.4 A	226 V
				White	27.8 A	226 V
				Blue	31.6 A	226 V
		Tail-end DB	Hand-held power meter	Red	27.4 A	226 V
				White	29.3 A	226 V
				Blue	28.3 A	226 V

Table 1 shows the number and type of the lights of the lighting system of Civic Centre before the DSM project started.

The following lighting types were identified for the three groups:

- 2 x 40W Recess mounted (101W per fitting);
- 2 x 65W Recess mounted (175W per fitting);
- 4 x 75W Recess mounted (345W per fitting);

- 4 x 65W Recess mounted (184W per fitting);
- 60W Recess down lighter (60W per fitting);
- 150W spot lights (150W per fitting);
- 2 x 75W Diachroics (171W per fitting);
- 2 x 40W surface mounted (101W per fitting); and
- 2 x 20W Recess mounted (46W per fitting).

In order to determine the baseline, a correction factor for each group was determined in Table 2. The correction factors in Table 2 are used to determine the calculated actual load of all the remaining lights of the lighting system. The calculations for the complete lighting system are shown in Table 3.

Table 3: Notch test data and calculation of group extrapolation ratios.

Group	Location	Fitting description	Measured			Calculated (theoretical)						Ratio
		Type	Ampere [A]	Volts [V]	Actual Load [kVA]	Fitting Volt Ampere [VA]	# Fittings	# Fittings not working	# Total	Calculated installed load [kVA]	Calculated installed load [kVA]	Actual / Calculated
Group 1 (Office floors)	Head- & Tail end	2x40W	183.0	226	41.29	112	303	39	264	29.57	40.97	1.01
		2x65W				194	16	0	16	3.10		
		4x75W				383	14	7	7	2.68		
		4x65W				204	0	0	0	0.00		
		1x60W				60	45	2	43	2.58		
		2x75W				190	16	0	16	3.04		
		2x20W				51	0	0	0	0.00		
Group 2 (Basement / Covered parking)	Parking	2x40W	78.2	224	17.52	112	124	10	114	12.77	15.93	1.10
		2x65W				194	0	0	0	0.00		
		4x75W				383	0	0	0	0.00		
		4x65W				204	0	0	0	0.00		
		1x60W				60	0	0	0	0.00		
		2x75W				190	0	0	0	0.00		
		2x20W				51	72	10	62	3.16		
Group 3 (Entrance hall)	Head- & Tail end	2x40W	173.5	226	39.21	112	38	0	38	4.26	40.03	0.98
		2x65W				194	10	0	10	1.94		
		1x60W				60	36	0	36	2.16		
		1x150W				150	216	15	201	30.15		
		2x75W				190	8	0	8	1.52		

Table 4: Use group extrapolation ratios to calculate whole building electricity demand.

Group	Location	Fitting description	Calculated (theoretical)				Ratio	Calculated actual load [kVA]
		Type	Fitting Volt Ampere [VA]	# Fittings	Calculated installed load [kVA]	Calculated installed load [kVA]	Actual / Calculated	Actual / Calculated
Group 1 (Office floors)	Head- & Tail end	2x40W	112	5860	656.32	917.54	1.01	924.65
		2x65W	194	279	54.13			
		4x75W	383	290	111.07			
		4x65W	204	130	26.52			
		1x60W	60	540	32.40			
		2x75W	190	180	34.20			
		2x20W	51	57	2.91			
Group 2 (Basement / Covered parking)	Parking	2x40W	112	1369	153.33	160.72	1.10	176.73
		2x20W	51	145	7.40			
	Other [2]	2x40W	112	114	12.77	114.59	1.01	115.48
		2x65W	194	63	12.22			
		4x75W	383	30	11.49			
		1x60W	60	108	6.48			
		2x75W	190	377	71.63			
Group 3 (Entrance hall)	Head- & Tail end	2x40W	112	38	4.26	42.28	0.98	41.42
		2x65W	194	10	1.94			
		1x60W	60	36	2.16			
		1x150W	150	216	32.40			
		2x75W	190	8	1.52			
Totals				**9850**	**1235**	**1235**	**N/A**	**1258**

[2] The other section of the basement / parking levels behave in a similar manner as the offices of group 1, thus the ratio of group 1 was used on this section of group 2.

5 PROJECT BASELINE

5.1 Baseline Lighting load (Demand)

The ratios determined in section 4.3 were calculated by dividing the calculated installed load (or theoretical load) with the measured actual load. Therefore, the calculated installed load for each assigned group (section 3.1) must be multiplied by the respective ratio to obtain the calculated actual load for the whole building.

A summary of the calculated actual load for all the lights in the lighting system is shown in Table 5.

Table 5: Baseline for the lighting system.

Group	Location	Calculated actual load [kW]
Group 1	Floor 2-16	924.65 kVA
Group 2	Covered parking	292.21 kVA
Group 3	Entrance hall	41.42 kVA
Building total		1258.28 kVA

The baseline electricity demand for the Civic Centre's lighting system is calculated at 1258 kVA.

We were unable to measure the power factor at the time when the pre-implementation measurements were taken due to equipment limitations. Based on the original calculations submitted by the Esco, a power factor of 0.93 can be assumed to convert the above value of 1258 kVA to 1170 kW.

5.2 Baseline Energy Consumption

The operating hours of the building will be determined after installation as mentioned in paragraph 3.1. Therefore the baseline annual energy consumption will be determined after finalisation of the DSM project.

5.3 Comments

The implementation of the Civic Centre's lighting retrofit will be completed in full by the end of July 2003.

The baseline demand for the Civic Centre is 1258 kVA (or 1170 kW). After the completion of the DSM project another set of notch tests will be conducted to establish the lighting power demand for the retrofitted lighting system. The new load will be compared to that of the baseline demand to determine the savings.

The operating hours will be determined after completion of the retrofit. Therefore the baseline energy consumption will be calculated after the retrofit.

Appendix C

M&V post-implementation report – Johannesburg Civic Centre

Measurement and Verification Team
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Post Implementation Report:

Civic Centre

PROJECT NUMBER	:	N/A (Bonesa Project)
DATE OF REPORT	:	25 August, 2003
FILENAME	:	Civic Centre Implementation v1r2.doc
PREPARED BY	:	WLR den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

Table of Contents

Nomenclature:

DSM	Demand Side Management
LBR	Low brightness reflector
M&V	Measurement and verification

1 OVERVIEW

The following document provides a post implementation report for the demand side management (DSM) measure that was implemented at the Civic Centre in Braamfontein, Johannesburg. The DSM measure consisted of a lighting retrofit.

The purpose of the post implementation report is to provide feedback to DSM stakeholders on the implementation of the DSM measures, and whether implementation took place as intended according to the specifications of the project. Relevant information on the lighting retrofit was gathered and meetings were held with involved parties.

This report provides a description of:

- the original system prior to the lighting retrofit;
- the DSM project as it was originally intended;
- the project as it was ultimately implemented; and
- any deviations from the original project design as described in the M&V plan for the Civic Centre.

2 PROJECT DESCRIPTION

The following sections will provide information on the parties involved in the project and the M&V-activities. The objectives of the project are stated together with a short description of the project site.

2.1 Project information

M&V Company name:		Potchefstroom University for CHE	
M&V Contact person:		Prof. LJ Grobler and Mr. Willem Den Heijer	
Postal address:		Private Bag X6001, Potchefstroom, 2520	
Country:		South Africa	
Phone:	+27 18 299 1328 / 4025	Fax:	+27 18 299 1320
Cell:	+27 82 452 9279 +27 83 256 9640	E-mail:	Mgiljg@puknet.puk.ac.za Mgiwdh@puknet.puk.ac.za
Date of submittal of this report:		22 August 2003	
Project Sponsor Name:		Eskom DSM	
Name of project site:		Civic Centre	
Address:		158 Loveday Street, Braamfontein, Johannesburg	
Country:		South Africa	
Company name (Site owner / Client):		Greater Johannesburg Metropolitan Council (GJMC)	
Contact person:		Faisel	
Phone:	011 407 7289	Fax:	011 403 1818
Cell:	082 464 9585	E-mail:	Jeffs@Joburg.org.za
Type of building(s) (office, retail, etc.):		Office building	
Contact person (Implementation / Esco):		Mr. Nad Permaul (Bonesa - Commercial programs manager)	
Phone:	+27 12 427 2797	Fax:	+27 12 427 2935
Cell:	+27 83 296 4893	E-mail:	Nperumaul@bonesa.co.za

2.2 Project Objective

The objective of the DSM measure at the Civic Centre is to reduce electricity cost of the building through the installation of energy efficient lighting.

The objective of the M&V project is to measure and verify the energy consumption, demand, and energy cost savings, as well as emission impacts, due to the office lighting retrofit at the Civic Centre.

The impacts need to be determined to verify the cost savings for the client and the ESCO, as well as the DSM-impacts obtained for Eskom.

2.3 Site description

The Civic Centre is a large commercial building that is used by the Greater Johannesburg Metropolitan Council as offices. The building has 16 floors, a ground floor and 3 basement levels. The building thus has a total of 20 levels (see Figure 1). Each floor in the building is divided into a head- and a tail end. Each head- and tail end has its own distribution board (DB). Floor 1 does not form part of the lighting retrofit project.

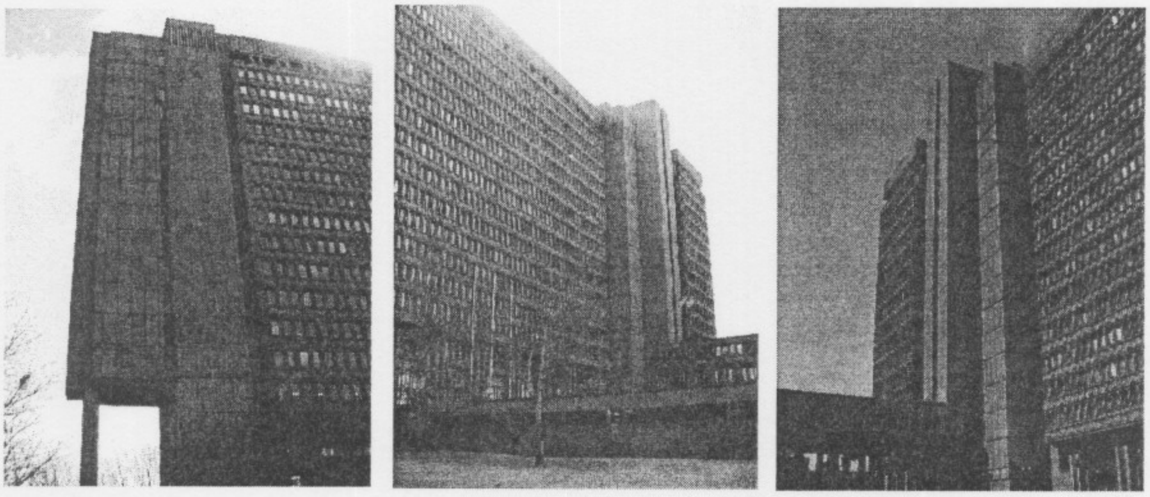

Figure 1: Civic Centre showing the tail-end (far left and center) and the head-end (right).

The head- and tail ends have their own lighting switches (one per DB). Timers are used to control the normal hours that the lights are switched on. The switches are however used outside of these hours to turn the lights on. This means that individual offices cannot control their respective lights.

6. **Retrofitting the lighting system in the lift lobbies of levels 2-16:** There were a total of 377 luminaires in the lift lobbies for levels 2–16. They were a mixture of 2 x 65W (160 fittings), 4 x 75W (160 fittings) and 2 x 20W (57 fittings).

7. **Retrofitting the lighting system in the entrance hall:** The entrance hall (ground floor) contained a total of 216 fittings made up of 1 x 150W spot lighting lamps.

8. **Retrofitting the lighting system in the covered parking and ancillary areas:** A total of 1864 luminaires could be found in the covered parking and ancillary areas. They were a mixture of 2 x 40W (1369 fittings), 2 x 65W (9 fittings), 2 x 75W (341 fittings) and 2 x 20W (145 fittings).

Table 2: Luminaires (fittings) found in the existing system (allocation per building area).

Lamp type	Offices	Passages	Board rooms	Service areas & toilets	Lift lobbies A, B, C & staircase	Lift lobbies 2-16	Entrance hall	Covered parking
2 X 40W Recess Mounted	4830	467		715				204
2 X 65W Recess Mounted				152	30	160		9
4 X 75W Recess Mounted			130		30	160		
4 X 65W Recess Mounted			130					
Recess Down Lighter - 60w Lamp				684				
150w Spot Lamps							216	
2X 75W Surface Mounted				72	152			341
2 X 40W Surface Mounted								1165
2 X 20W Recess Mounted						57		145

3.2 Proposed changes to the original system

The following changes were proposed to the original system and are summarised in Table 3.

1. **Retrofitting the Office lighting system:** It was proposed to replace the original 4830 luminaires with 1080 luminaires of 2 x 36W lamps and 1080 similar luminaires with dimming capabilities. The lamps with the remote dimming would be installed in the office space next to the windows. These lights would dim when there was sufficient day lighting available in the offices.

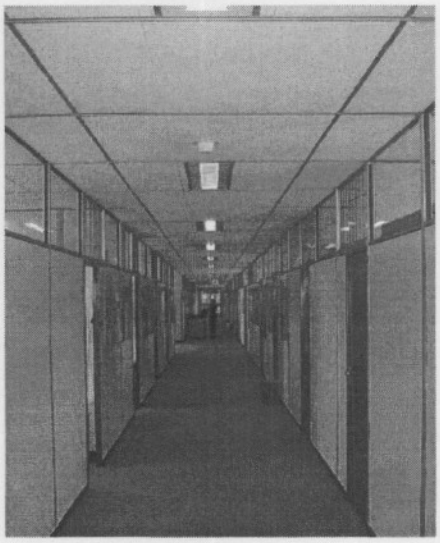

Figure 3: Passage luminaires (1x36W).

2. **Retrofitting the passage lighting system:** It was proposed to replace the original 467 passage luminaires with 467 luminaires of 1 x 36W lamps.

3. **Retrofitting the lighting system in the boardrooms:** It was proposed to replace the 260 boardroom luminaires with 520 luminaires of 1 x 36W lamps.

4. **Retrofitting the lighting system in the service areas and toilets:** It was proposed to replace the 1623 luminaires in the service areas and toilets with 1591 luminaires which are a mixture of 1 x 36W lamps (665 fittings), 2 x PL 11W (552 fittings), 1 x 18W (118 fittings) and S1 STC 136 36W (256 fittings).

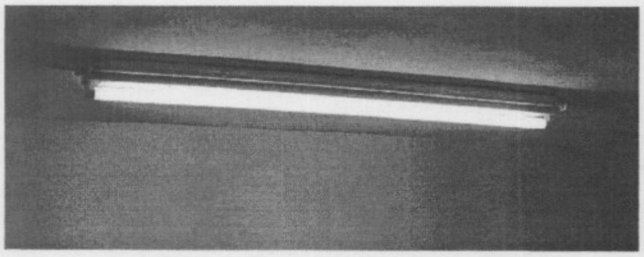

Figure 3: Staircase luminaire (on) with single emergency lamp (off).

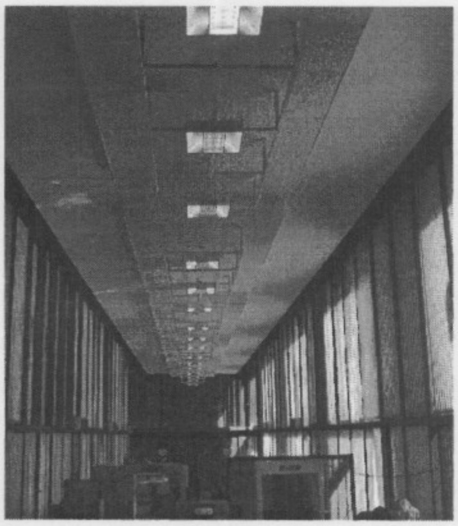

Figure 2: Ground floor entrance hall.

5. **Retrofitting the lighting system in the lift lobbies of levels A, B and C (including the staircases of these levels):** It was proposed to replace the 212 luminaires in the service areas and toilets with 252 luminaires consisting of a mixture of 1 x 36W LBR (72 fittings), Type S STC 136 + S136 (76 fittings) and 104 fittings of S1 STC 136 36W.

6. **Retrofitting the lighting system in the lift lobbies of levels 2-16:** The 377 service area and toilet luminaires would be replaced with 384 luminaires of 1 x 36W lamps.

7. **Retrofitting the lighting system in the entrance hall:** All 216 luminaires in the entrance hall would be replaced with 600 x 600, 2 x PL 55W luminaires (70 fittings).

8. **Retrofitting the lighting system in the covered parking and ancillary areas:** It was lastly proposed to replace all 1864 luminaires in the covered parking and ancillary areas with 1875 luminaires of 2 x 36W Trifocal surface mounted (314 fittings) and 1 x 36W Trifocal surface mounted (1534 fittings). According to the ESCO all the fittings will be retrofitted.

Table 3: Proposed Luminaires (fittings) for the retrofitted system (allocated per building area).

Lamp type	Offices	Passages	Board rooms	Service areas & toilets	Lift lobbies A, B, C & staircase	Lift lobbies 2-16	Entrance hall	Covered parking
2 X 36W Recess LBR	1080							
2 X 36W Recess LBR + remote dimming	1080							
1 X 36W Recess LBR		467	520	665	72	384		
2 X PL 11W Recess Mounted				552				
1 X 18W Recess Mounted				118				
600 X 600: 2 X PL 55W							70	
Type S STC 136 + S136					76			
Type S STC 136				256	104			
2 X 36W Trifocal surface mounted								341
1 X 36W Trifocal surface mounted								1534

3.3 Actual changes to the original system

A site visit was made to the Civic Centre upon completion of the lighting retrofit. A number of floors was counted to confirm that implementation took place and that all the luminaries has been replaced. The following measures were implemented in the Civic Centre:

Table 4: Luminaires actually implemented.

Luminaire type	Actual	Allocated area(s)
	Quantity of luminaires	
2 X 36W Recess LBR	2501	Offices, covered parking.
2 X 36W Recess LBR + remote dimming		
2 X 36W Trifocal surface mounted		
1 X 36W Recess LBR	3996	Passages, boardrooms, service areas and toilets, lift lobbies and staircases, covered parking.
1 X 36W Trifocal surface mounted		
Type S STC 136		
+ S136 (emergency lights)	50	Lift lobbies for level A, B, C and staircases.
2 X PL 11W Recess Mounted	552	Service areas and toilets.
1 X 18W Recess Mounted	160	Service areas and toilets.
600 X 600: 2 X PL 55W	41	Ground floor entrance hall.

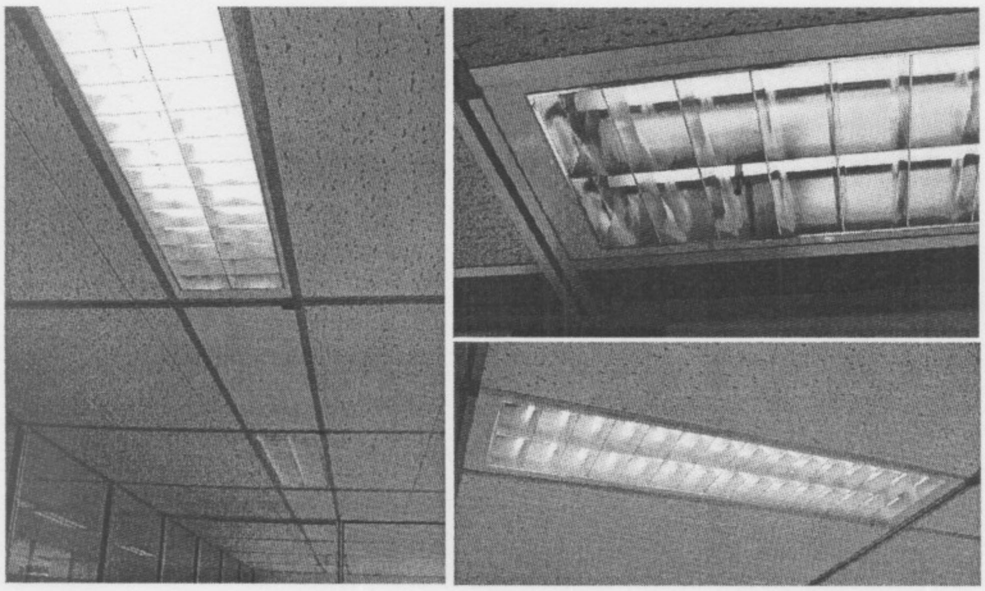

Figure 2: Office luminaires (2 x 36W) with top-right frame showing dimming sensor of luminaires next to office windows.

3.4 Deviations from original project proposal

Some discrepancies were found between the quantity of lights that was proposed and what was actually implemented. Table 5 gives an overview of the actual and proposed quantities for the luminaires, as well as the identified deviations relative to the proposed system.

Table 5: Deviation between actual and proposed luminaires implemented.

Luminaire type	Actual	Proposed	Deviation from Actual
	Quantity of luminaires	Quantity of luminaires	Quantity of luminaires
2 X 36W Recess LBR 2 X 36W Recess LBR + remote dimming 2 X 36W Trifocal surface mounted	2501	2501	0
1 X 36W Recess LBR 1 X 36W Trifocal surface mounted Type S STC 136	3996	4078	- 82
+ S136 (emergency lights)	50	76	- 26
2 X PL 11W Recess Mounted	552	552	0
1 X 18W Recess Mounted	160	118	+ 42
600 X 600: 2 X PL 55W	41	70	- 29

The number of single lamp 36W luminaires has been reduced by 82 luminaires (from 4078 to 3996). These luminaires are the most commonly used and can be found in the following areas: Passages; boardrooms; service areas and toilets; lift lobbies; staircases and covered parking.

The emergency lights, found in the lift lobbies of basement levels A, B, C and the staircases, has been reduced from 76 luminaires to 50 luminaires.

The 18W recess mounted luminaires has been increased by 42 from what was originally proposed. They are used in the service areas and toilets of each floor.

The 2 x 55W luminaires used on exclusively on the ground floor and the entrance hall has been reduced with 29 luminaires from what was originally proposed.

3.5 Completion date

The retrofit of the lighting system was completed by the end of August 2003. Only minor work remained at the time this report was compiled, which included removal of the old fittings (not working anymore), etc. This work would however not influence the project itself in terms of the energy use.

4 CONCLUSIONS AND COMMENTS

The lighting retrofit was completed in the Civic Centre in Braamfontein, Johannesburg. All the luminaires was replaced and only minor deviations were found between the proposed number of luminaires and what was actually implemented.

Appendix D

M&V post-implementation performance assessment report – Johannesburg Civic Centre

Measurement and Verification Team

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Performance Assessment Report: Civic Centre Lighting Project

PROJECT NUMBER	:	Bonesa
DATE OF REPORT	:	24 October 2003
SAVINGS REPORT	:	01 October to 21 October 2003
PREPARED BY	:	W.L.R den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

1. PROJECT INFORMATION

Site name:	Johannesburg Civic Centre, Braamfontein, Johannesburg	
Project number:	Bonesa	
M&V Team:	Potchefstroom University for CHE	
Report Compiled by:	W.L.R den Heijer	**Tel:** (018) 299-4025
Savings report for:	01 October to 21 October 2003	
Implementation date:	June 2003	

2. TOTAL IMPACT IN PERIOD

Period: 01 October to 21 October 2003

The following table shows the total actual Measured and Verified impact of the DSM measures implementated in this project.

Table 1: Total impact of the project for the month

	E/Cons	**Cost**	**Emissions (kg)**				
	kWh	*Rand*	*CO2*	*Nox*	*SOx*	*Particles*	*Water*
Baseline	337,928	R 107,521	301,432	1,200	2,555	98	409
Actual	102,862	R 31,750	91,753	365	778	30	124
Savings	235,066	R 75,771	209,679	834	1,777	68	284

3. AVERAGE DEMAND IMPACT

Period: 01 October to 21 October 2003

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods.

Table 2: Average impacts in the different TOU periods

	Weekday (kW)				**Saturday (kW)**		**Sunday**
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1,140	988	722	357	618	476	304
Actual	335	290	211	120	171	155	108
Savings	805	698	511	237	447	322	196

COMMENTS:

The costs were calculated using the tariff applicable to the Civic Centre: 11.84 cents/kWh and R53.90/kVA

Emission factors used are: CO_2: 892kg/MWh, NO_X: 3.55kg/MWh, SO_X: 7.56kg/MWh, Particles: 0.29kg/MWh, Water: 1.21litre/MWh.

The standard TOU times of Eskom were used for the TOU period calculations.

> Current TOU periods during weekdays are: Morning Peak: 7:00 to 10:00, Afternoon Peak: 18:00 to 20:00. Standard times: 6:00 to 7:00 & 10:00 to 18:00 & 20:00 to 22:00. OffPeak: 22:00 to 6:00.

> Current TOU periods for Saturdays are: Standard: 7:00 to 12:00 & 18:00 to 20:00. Off-Peak: 12:00 to 18:00 & 20:00 to 7:00.

> All day Sunday is off-peak.

> Note that certain public holidays are set as Saturdays and the rest are set as Sundays.

Filelist:

Civic Centre - Perf ass Oct v1r1.xls

4. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R den Heijer **Tel:** (018) 299-4025
Accumulated savings for: 01 October 2003 to 21 October 2003
Implementation date: June, 2003

5. ACCUMULATED IMPACT

The following table shows the accumulated Measured and Verified impact since the implementation of the DSM measures of this project.

Table 3: Total accumulated impact of the project

	E/Cons	Cost	Emissions (kg)				
	kWh	*Rand*	*CO2*	*Nox*	*Sox*	*Particles*	*Water*
Baseline	337,928	R 107,521	301,432	1,200	2,555	98	409
Actual	102,862	R 31,750	91,753	365	778	30	124
Savings	235,066	R 75,771	209,679	834	1,777	68	284

6. AVERAGE ELECTRICITY CONSUMPTION IN DIFFERENT PERIODS

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods since the implementation of the project.

Table 4: Average impacts in the different TOU periods during the accumulated period

	Weekday (kW)				Saturday (kW)		Sunday
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1,140	988	722	357	618	476	304
Actual	335	290	211	120	171	155	108
Savings	805	698	511	237	447	322	196

COMMENTS:
The costs were calculated using the tariff applicable to the Civic Centre: 11.84 cents/kWh and R53.90/kVA

Emission factors used are: CO2: 892kg/MWh, NOX: 3.55kg/MWh, SOX: 7.56kg/MWh, Particles: 0.29kg/MWh, Water: 1.21litre/MWh.

The standard TOU times of Eskom were used for the TOU period calculations.
> Current TOU periods during weekdays are: Morning Peak: 7:00 to 10:00, Afternoon Peak: 18:00 to 20:00. Standard times: 6:00 to 7:00 & 10:00 to 18:00 & 20:00 to 22:00. OffPeak: 22:00 to 6:00.
> Current TOU periods for Saturdays are: Standard: 7:00 to 12:00 & 18:00 to 20:00. Off-Peak: 12:00 to 18:00 & 20:00 to 7:00.
> All day Sunday is off-peak.
> Note that certain public holidays are set as Saturdays and the rest are set as Sundays.

Filelist:
Civic Centre - Perf ass Oct v1r1.xls

Appendix E

Monthly savings report–
Johannesburg Civic Centre

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Monthly Savings Report
Civic Centre Lighting Project

PROJECT NUMBER	:	Bonesa
DATE OF REPORT	:	29 April 2004
SAVINGS REPORT	:	01 February 2004 to 31 March 2004
PREPARED BY	:	W.L.R den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

1. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R den Heijer **Tel:** (018) 299-4025
Savings report for: 01 February 2004 to 31 March 2004
Implementation date: June 2003

2. TOTAL IMPACT IN PERIOD

Period: 01 February 2004 to 31 March 2004
The following table shows the total actual Measured and Verified impact of the DSM measures implementated in this project.

Table 1: Total impact of the project for the month

	E/Cons	Cost	Emissions (kg)				
	MWh	*Rand*	*CO2*	*Nox*	*SOx*	*Particles*	*Water*
Baseline	964	R 249,181	860,060	3,423	7,289	280	1,167
Actual	294	R 73,906	261,900	1,042	2,220	85	355
Savings	671	R 175,275	598,159	2,381	5,070	194	811

3. AVERAGE DEMAND IMPACT

Period: 01 February 2004 to 31 March 2004

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods.

Table 2: Average impacts in the different TOU periods

	Weekday (MW)				Saturday (MW)		Sunday (MW)
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1.140	0.988	0.722	0.357	0.618	0.476	0.304
Actual	0.335	0.290	0.211	0.120	0.171	0.155	0.108
Savings	0.805	0.698	0.511	0.237	0.447	0.322	0.196

COMMENTS:

The costs were calculated using the tariff applicable to the Civic Centre: 11.84 cents/kWh and R53.90/kVA

Emission factors used are: CO_2: 892kg/MWh, NO_X: 3.55kg/MWh, SO_X: 7.56kg/MWh, Particles: 0.29kg/MWh, Water: 1.21litre/MWh.

The standard TOU times of Eskom were used for the TOU period calculations.
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> Current TOU periods for Saturdays are: Standard: 7:00 to 12:00 & 18:00 to 20:00. Off-Peak: 12:00 to 18:00 & 20:00 to 7:00.
> All day Sunday is off-peak.
> Note that certain public holidays are set as Saturdays and the rest are set as Sundays.

Filelist:
Civic Centre - 1Feb to 31March v1r1.xls

4. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R den Heijer **Tel:** (018) 299-4025
Accumulated savings for: 01 October 2003 to 31 January 2003
Implementation date: June, 2003

5. ACCUMULATED IMPACT

The following table shows the accumulated Measured and Verified impact since the implementation of the DSM measures of this project.

Table 3: Total accumulated impact of the project

	E/Cons	**Cost**	**Emissions (kg)**				
	kWh	*Rand*	*CO2*	*Nox*	*Sox*	*Particles*	*Water*
Baseline	2,947	R 754,021	2,628,982	10,463	22,282	855	3,566
Actual	897	R 223,637	800,161	3,184	6,782	260	1,085
Savings	2,050	R 530,384	1,828,821	7,278	15,500	595	2,481

6. AVERAGE ELECTRICITY CONSUMPTION IN DIFFERENT PERIODS

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods since the implementation of the project.

Table 4: Average impacts in the different TOU periods during the accumulated period

	Weekday (MW)				**Saturday (MW)**		**Sunday (MW)**
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1.140	0.988	0.722	0.357	0.618	0.476	0.304
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The costs were calculated using the tariff applicable to the Civic Centre: 11.84 cents/kWh and R53.90/kVA

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> All day Sunday is off-peak.
> Note that certain public holidays are set as Saturdays and the rest are set as Sundays.

Filelist:
Civic Centre - 1Feb to 31March v1r1.xls

Appendix F

Annual savings report –
Johannesburg Civic Centre

Measurement and Verification Team
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Savings Summary Report
Civic Centre Lighting Project

PROJECT NUMBER	:	Bonesa
DATE OF REPORT	:	12 December 2003
SAVINGS REPORT	:	22 October 2003 to 30 November 2003 - Monthly 01 October 2003 - 30 November 2003 - Accumulated 01 January 2003 to 31 December 2003 - Annual extrapolated
PREPARED BY	:	W.L.R. den Heijer
M&V LEADER	:	LJ Grobler
ISSUED FOR	:	Eskom

1. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R. den Heijer **Tel:** (018) 299-4025
Savings report for: 22 October 2003 to 30 November 2003 - Monthly
Implementation date: June 2003

2. TOTAL IMPACT IN PERIOD

Period: 22 October 2003 to 30 November 2003 - Monthly

The following table shows the total actual Measured and Verified impact of the DSM measures implemented in this project.

Table 1: Total impact of the project for the month

	E/Cons	Cost	Emissions (kg)				
	MWh	*Rand*	*CO2*	*NOx*	*SOx*	*Particles*	*Water*
Baseline	639	R 143,131	569,712	2,267	4,828	185	773
Actual	195	R 42,609	173,561	691	1,471	56	235
Savings	444	R 100,522	396,150	1,577	3,358	129	537

3. AVERAGE DEMAND IMPACT

Period: 22 October 2003 to 30 November 2003 - Monthly

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods.

Table 2: Average impacts in the different TOU periods

	Weekday (MW)				Saturday (MW)		Sunday
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1.140	0.988	0.722	0.357	0.618	0.476	0.304
Actual	0.335	0.290	0.211	0.120	0.171	0.155	0.108
Savings	0.805	0.698	0.511	0.237	0.447	0.322	0.196

COMMENTS:

The costs were calculated using the tariff applicable to the Civic Centre: 11.84 cents/kWh and R53.90/kVA

Emission factors used are: CO_2: 892kg/MWh, NO_X: 3.55kg/MWh, SO_X: 7.56kg/MWh, Particles: 0.29kg/MWh, Water: 1.21litre/MWh.

The standard TOU times of Eskom were used for the TOU period calculations.
> Current TOU periods during weekdays are: Morning Peak: 7:00 to 10:00, Afternoon Peak: 18:00 to 20:00. Standard times: 6:00 to 7:00 & 10:00 to 18:00 & 20:00 to 22:00. Off-Peak: 22:00 to 6:00.
> Current TOU periods for Saturdays are: Standard: 7:00 to 12:00 & 18:00 to 20:00. Off-Peak: 12:00 to 18:00 & 20:00 to 7:00.

> All day Sunday is off-peak.
> Note that certain public holidays are set as Saturdays and the rest are set as Sundays.

File list:
Civic Centre - Annual sav v1r1.xls

4. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R. den Heijer **Tel:** (018) 299-4025
Accumulated savings for: 01 October 2003 - 30 November 2003 - Accumulated
Implementation date: June, 2003

5. ACCUMULATED IMPACT

The following table shows the accumulated Measured and Verified impact since the implementation of the DSM measures of this project.

Table 3: Total accumulated impact of the project

	E/Cons	Cost	Emissions (kg)				
	kWh	*Rand*	*CO2*	*NOx*	*SOx*	*Particles*	*Water*
Baseline	977	R 250,652	871,143	3,467	7,383	283	1,182
Actual	297	R 74,359	265,314	1,056	2,249	86	360
Savings	679	R 176,293	605,829	2,411	5,135	197	822

6. AVERAGE DEMAND IMPACT

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods since the implementation of the project.

Table 4: Average impacts in the different TOU periods during the accumulated period

	Weekday (MW)				Saturday (MW)		Sunday
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1.140	0.988	0.722	0.357	0.618	0.476	0.304
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File list:
Civic Centre - 1st sav Oct v1r1.xls
Civic Centre - 2st sav Nov v1r1.xls

7. PROJECT INFORMATION

Site name: Johannesburg Civic Centre, Braamfontein, Johannesburg
Project number: Bonesa
M&V Team: Potchefstroom University for CHE
Report Compiled by: W.L.R. den Heijer **Tel:** (018) 299-4025
Accumulated savings for: 01 January 2003 to 31 December 2003 - Annual extrapolated
Implementation date: June, 2003

8. EXTRAPOLATED ANNUAL IMPACT

The following table shows the accumulated Measured and Verified impact since the implementation of the DSM measures of this project.

Table 5: Total accumulated impact of the project

	E/Cons	Cost	Emissions (kg)				
	MWh	*Rand*	*CO2*	*NOx*	*SOx*	*Particles*	*Water*
Baseline	5,876	R 1,505,841	5,241,389	20,860	44,423	1,704	7,110
Actual	1,789	R 446,613	1,595,350	6,349	13,521	519	2,164
Savings	4,087	R 1,059,228	3,646,039	14,511	30,901	1,185	4,946

9. AVERAGE DEMAND IMPACT - ANNUAL EXTRAPOLATION

This paragraph shows the baseline, actual and electricity consumption savings in the different TOU periods since the implementation of the project.

Table 6: Average impacts in the different TOU periods during the accumulated annual period

	Weekday (MW)				Saturday (MW)		Sunday
	Morning Peak	*Standard*	*Afternoon Peak*	*Off-Peak*	*Standard*	*Off-Peak*	*Off-Peak*
Baseline	1.140	0.988	0.722	0.357	0.618	0.476	0.304
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