Department of Minerals and Energy Pretoria

Capacity Building in Energy Efficiency and Renewable Energy

Report No. – 2.3.4-33

Energy Efficiency: Energy and Demand Efficiency for Commercial Buildings Final Report

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September 2005

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Abbreviations and Acronyms

AAAMSA	Association of Architectural Aluminium Manufacturers of South Africa
AHUs	Air Handling Units
ASHRAE	American Society for Heating, Refrigeration and Air Conditioning Engineers
AVB's	Artificially Ventilated Buildings
BCA	Building Code Australia
BEE	Black Economic Empowerment
CaBEERE	Capacity Building in Energy Efficiency and Renewable Energy
CB	Capacity Building
CBD	Central Business District
CBLA	Climate Business Leadership Action
CDD	Cooling Degree Days
CEF	Central Energy Fund
CFC	Chlorofluorocarbon
CFL	Compact Fluorescent Lighting
COP	Coefficient of Performance (dimensionless)
COWI	A Danish International Consulting Group
CSIR	Council for Scientific and Industrial Research
DANIDA	Danish International Development Assistance
DD	Degree Days
DDG	Deputy Director-General
DEAT	Department of Environmental Affairs and Tourism
DHW	Domestic Hot Water
DK	Kingdom of Denmark
DKK	Danish Kroner
DME	Department of Minerals and Energy
DOE	Depart of Energy, US
DR	Discount Rate
DRC	Democratic Republic of Congo
DSM	Demand Side Management
DTI	Department of Trade and Industry
DX	Direct expansion
ECG	Electronic Control Gear
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EDI	Electricity Distribution Industry
EI	Energy Intensity
ESETA	Energy Sector Education Training Authority
ESI	Electricity Supply Industry
EUIs	Energy Use Intensities
FIDIC	International Federation of Consulting Engineers
HDD	Heating Degree Days
HPS	High Pressure Sodium
HVAC	Heating, Ventilation and Air Conditioning

ICU	Intensive Care Units
IDC	Industrial Development Corporation of South Africa
IPD	Investment Property Databank
IPM	International Project Manager
IPP	Independent Power Producers
JHB	Johannesburg
Kva	Kilo-volt-ampere
Kw	Kilowatt
kWc	Kilowatts cooling (cooling power)
kWh	Kilowatt hour
kWi	Kilowatts input (input power)
l/s	Litres per second
L/s.m²	Litres per second per meter squared
LCC	Life Cycle Cost
LPD	Lighting Power Density in W/m²
m²	Meters Squared
mm	Millimetres
MJ	Mega joule
MNECB	Model National energy code of Canada for Buildings
MSA	Municipal systems Act
MW	Megawatt
MWh	Megawatt hour
MYPD	Multi-Year Price Determination
NER	National Electricity Regulator
NIRP2	National Integrated Resource Plan
NT	National Treasury
NER	National Electricity Regulator
NGO	Non-Governmental Organisation
OHS	Occupational Health and Safety
OMC	Old Mutual Centre
OR	Operating Room
Pa	Static pressure in Pascals
PDI	Previously Disadvantaged Individual
PM	Project Manager
PQ	Pre-qualification
PSC	Project Steering Committee
PTT	Project Task Team
QA	Quality Assurance
RE	Renewable Energy
RED	Regional Electricity Distributor
RFP	Request for Proposal
RSA	Republic of South Africa
RSI	Overall thermal resistance in metric units m² °C/W
SA IPD	South African Investment Property Databank
SA	South Africa/South African
SABS	South Africa Bureau of Standards
SADC	South Africa Development Community
SAEDES	South Africa Energy and Demand Efficiency Guidelines

SALGA	South African Local Government Association
SANS	South African National Standards
SANGOCO	South African Non-Governmental Organisations' Committee
SAPOA	South African Property Owners' Association
SAPP	South African Power Pool
SARS	South African Revenue Services
SHW	Service Hot Water
SMME	Small, Medium and Micro Enterprises
SP	Service Provider
ST	Short Term Adviser
Tavg	Average temperature
TA	Technical Assistance
TB	Balance Temperature
TC	Technical Committee
TIASA	Thermal Insulation Association of South Africa
TOR	Terms of Reference
UV	Ultra Violet
UK	United Kingdom
VAT	Value Added Tax
VAV	Variable Air Volume
Visual DOE	A Windows-based Interface to DOE 2.IE
VSDs	Variable Speed Drives
W	Watt
W/m²	Watt/metre squared
wg	static pressure in inches water column
ZAR	South African Rand

Details of Service Provider, Client and Funder

EnerWise Africa has undertaken this assignment in association with Africon Engineering International and Marbek Resource Consultants. EnerWise Africa, a South Africa based firm, has a broad based experience in energy efficiency related issues and has worked extensively in this field in South Africa. Africon Engineering International, which is one of South Africa's largest and most experienced engineering and professional service firms, has a long history of involvement in infrastructure life cycle, from policy and planning through to design, construction and operation and maintenance, in all infrastructure sectors including the energy sector. Marbek Resources Consultants is one of Canada's leading energy and environment consulting firms. Since 1983, the firm has provided consulting services to government, utility and private sector decision-makers in support of sustainable development, both in Canada and internationally.

The EnerWise team was subcontracted to the Consultant, COWI, a leading international consulting group, which operates in the engineering, environmental science and economics fields and is managing the CaBEERE programme on behalf of the Client.

The client and funder, the Danish International Development Agency (DANIDA), has been involved in South Africa in an environmental support programme since 1995, and has during this period assisted a number of activities and projects with both government and civil society structures.

The recipient of this project is the South African Department of Minerals and Energy.

Foreword

In the foreword to the March 2005 Energy Efficiency Strategy of the Republic of South Africa, former Minister of Minerals and Energy Phumzile Mlambo-Ngcuka states:

> *"In South Africa we take energy for granted, with the consequence that our energy consumption is higher than it should be. Whilst our historically low electricity price has contributed towards a competitive position, it has also meant that there has been little incentive to save electricity.*
>
> *So in many respects we start with a clean slate with little energy efficiency measures having taken place, apart from many years of work by universities and other research institutions that have pointed the way. The White Paper on Energy Policy (1998) recognized that standards and appliance labelling should be the first measures to put in place in implementing energy efficiency. Indeed such prescriptive-type measures provide the framework on which any energy efficiency strategy is based. At the same time consumers of energy also need to perceive the cost-benefits they can derive from energy efficiency measures and it is here that demonstrations are essential. In South Africa, Government is taking the lead by using Public Buildings as an example. Cabinet has approved the implementation of a programme of energy efficient measures in National Government Buildings which is currently underway and which will be extended to provincial and local governments. The Commercial Building Sector is an area for potential improvement given the rapid increase in office construction."*

The targets outlined in the Energy Efficiency Strategy include:

- Nationally - final energy demand reduction of 12% by 2015
- Commercial and public building sector – final energy demand reduction of 15% by 2015.

DME has established that commercial buildings consume as much as 4% of the country's national energy budget.

For decades, South Africans have paid among the world's lowest prices for electricity. However, the country's Electricity Supply Industry (ESI) is undergoing fundamental restructuring in order to address inequities and complexities in the pricing of electricity delivered to consumers, compounded by an impending exhaustion of excess generation capacity. This creates a timely set of opportunities for implementing energy efficiency measures

Executive Summary

Objectives

In South Africa, the Department of Minerals and Energy (DME) is responsible for the formulation of strategies and drafting of policies for the country's energy sector. The project – Capacity Building in the DME in Energy Efficiency and Renewable Energy (CaBEERE) – resulted from a dialogue between the DME and Danida between 1999 and 2001. This project aims to enhance the capacity and performance of the DME through assistance in the development of programmatic approaches through strategies and actions plans for Energy Efficiency (EE) and Renewable Energy (RE) in transparent co-operation with relevant stakeholders. The overall objective of the CaBEERE project is increased use of EE and RE throughout South Africa to maximise the contribution of the energy sector towards sustainable development.

In this assignment, the immediate objective was to undertake the necessary research for input to the development and writing of the EE standard for artificially ventilated buildings designated as SANS 204. An energy efficient building is defined as one that uses less energy than new buildings that are being built according to "current construction practices". The EE standard for artificially ventilated buildings designated as SANS 204 will provide the necessary design and relevant guidelines for use by the building industry.

Background

Whereas energy efficiency measures in South Africa have been hampered by the relatively low cost of electricity, the imminent exhaustion of the excess generating capacity in the country necessitates that resources are garnered to provide much needed additional power in the near future. This implies that electricity tariff increases henceforth may be more than the relatively marginal annual hikes that have characterised the energy sector.

Methodology

This report presents the methodology and processes used to collect the data, develop the notional buildings and carry out the analyses. In order to respond to the requirements of the Terms of Reference, a Life Cycle Costing (LCC) approach was adopted. The reasoning behind this is outlined for reference in this report. Energy use simulations using Visual DOE were undertaken in this assignment, along with development of detailed energy efficiency scenarios, and these were used to develop design guidelines. The report presents the results of the analyses and associated recommended design guidelines for the building envelope as well as lighting, HVAC and service hot water. In addition, it includes a brief scan of commercial building design practice in the UK, Europe and Australia and presents qualitative guidelines with respect to incorporating renewable energy principles in commercial building design. Furthermore, the report presents a high level assessment of energy consumption in selected existing buildings as a basis for recommendations to DME on monitoring and targeting strategies that can be adopted for existing buildings.

The analysis was undertaken using an internationally recognized building energy use simulation tool – Visual DOE – a Windows-based interface to DOE 2.1E. Once detailed building specifications are input into Visual DOE, the model provides accurate estimates of the building's annual energy use, broken out by major end use (e.g., heating, cooling, lighting, etc.,) and fuel type. Model outputs also include the life cycle cost (LCC) of capital and energy expenditures for varying energy efficiency

investment options. These outputs provide a means for DME to compare the impacts of successive levels of up-front capital investment in energy efficiency measures on the energy operating costs of the building over the life of the measures. This simulation tool has been used in several jurisdictions globally, for similar type of initiatives; and therefore provides a credible technical modelling platform for this project.

In this assignment, detailed building specifications were developed based on the project team's commercial building design expertise. These specifications were then validated through an extended stakeholder consultation process, culminating in the acceptance of six notional buildings by the project task team (PTT). The six notional buildings, also known as archetypes of the various categories of building occupancies, were defined through a detailed process and methodology. These notional buildings represent current average design and construction practice in South Africa, not best practice – nor do they represent any specific design.

Input Data

A view provided by the Department of Minerals and Energy on projected electricity tariffs in South Africa was used. Electricity was the only fuel considered in the analysis. A discount rate of 10%, based on the perspective of the South African Property Owners Association, was adopted for the LCC analysis. Climate data was obtained in compiled VisualDOE format from the South African VisualDOE Resource Centre for the three regions assessed during the course of the project, which were Johannesburg (Highveld/interior), Durban (Lowveld/Mpumalanga) and Cape Town (South Cape).

Results

This report contains base case results in Visual DOE 2 of some equipment and other temperature related processes pertaining to each of the six notional buildings, thermal performance levels beyond current construction practice, and some approaches to incorporating renewable energy into new building construction. This report includes a Visual DOE Electrical Energy Use summary for the six notional buildings. It also includes a sample output of a Large Office building energy audit. In addition, this report includes energy efficiency scenarios that were developed for the building envelope of each notional building, followed by quantification of the energy consumption impact of these scenarios. This process culminated in the tabulation of an energy efficient alternative with lowest life cycle for each notional building in all the three weather zones.

Conclusions and Recommendations

The main conclusions of the analysis are presented in the table below.

Summary of Cost Effective Thermal Performance Levels

Building	Envelope	South Cape (RSI)			Highveld/Interior (RSI)			Lowveld/Mpumalanga (RSI)		
		Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC
Hospital	Wall	0.68	0.68	2.35	0.42	0.68	2.09	0.42	0.42	2.09
	Roof	1.27	1.27	1.27	1.27	1.27	1.96	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Low Rise Campus Office	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	3.35	1.27	1.27	3.35	1.27	1.27	1.96
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Large Office	Wall	1.72	1.72	2.79	1.72	1.72	2.79	1.72	1.72	2.79
	Roof	1.67	3.75	3.75	1.67	3.05	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.39	0.17	0.17	0.39	0.17	0.17	0.17
Hotel	Wall	0.68	2.9	2.9	0.42	2.09	2.64	0.42	1.05	2.64
	Roof	1.67	1.67	3.75	1.67	1.67	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Regional Shopping Centre	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	2.65
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Strip Mall	Wall	0.68	1.75	2.9	0.42	1.49	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

The necessary inputs to the development and writing of the EE standard for artificially ventilated buildings designated as SANS 204 are compiled in recommendations made in each design guideline component. Recommendations for the treatment of existing buildings are also provided.

Summary of Recommended Inputs to SANS 204

Design/Performance Area	Recommendation
Building Air-Tightness	ASHRAE 90.1 (2004) Section 5.4.3.2 with consideration of also including Section 5.4.3.4 (vestibules)
Outdoor Air Ventilation	ASHRAE 62.1 (2004)
Lighting Systems	ASHRAE 90.1 (2004) Section 9
HVAC Equipment	ASHRAE 90.1 (2004) Table 6.81 with consideration of incorporating the entire Section 6
Service Hot Water Equipment	ASHRAE 90.1 (2004) Table 7.8 with consideration of incorporating the entire Section 7
Renewable Energy Technologies	Provided in this report

1. Introduction/Background

1.1 Background and Overall Objectives of the CaBEERE Project

In South Africa, the formulation of strategies and drafting of policies for the country's energy sector is the responsibility of the Department of Minerals and Energy (DME). The project – Capacity Building in the DME in Energy Efficiency (EE) and Renewable Energy (RE) – resulted from a dialogue between DME and Danida (formerly Danced) over the years 1999 to 2001. The aim of the project is to enhance DME's capacity and performance through assistance in the development of programmatic approaches through strategies and actions plans for EE and RE in transparent co-operation with relevant stakeholders.

The overall objective of the CaBEERE project is the increased use of EE and RE throughout South Africa to maximise the contribution of the energy sector towards sustainable development. Immediate objectives are that DME and pertinent stakeholders are resourced and capacitated to formulate and facilitate implementation of strategies and legislation promoting EE and RE production and use in both rural and urban areas.

1.1.1 Immediate Objectives of this Assignment

The objective of the Energy and Demand Efficiency for Commercial Buildings project is to undertake the necessary research for input to the development and writing of the EE standard for artificially ventilated buildings (AVBs) designated as SANS 204. This standard will provide the necessary design and relevant guidelines for use by the building industry.

1.1.2 Objectives and Structure of this Report

This report presents the methodology used to develop life cycle costing analyses of six notional buildings (archetypes representing current design and construction practice in South Africa) for three climate zones, as well as the results of these analyses and conclusions drawn, including design guidelines for specific building components and approach to incorporating renewable energy concepts into AVB design. The conclusions are expected to provide input to SANS 204.

Report Structure

Section 1 presents an introduction to the assignment and to the report, providing background and context for a focus on energy efficient AVB design in South Africa. In Section 2, the methodology for developing the notional buildings and gathering the required input data is presented, along with an explanation of the Life Cycle Costing approach and description of the software used. This section also presents a description of the consultative process adopted to gather the broadest base of viewpoints on commercial building design in South Africa in order to develop the most representative set of notional buildings. Section 3 presents the results of the analysis for each notional building and each climate zone, and a review of energy consumption in selected existing buildings. Section 4 presents a sensitivity analysis carried out on these results, as well a comparison with data collected from existing

buildings and a thorough review of renewable energy solutions for energy savings in commercial buildings. Section 5 presents conclusions and recommendations ensuing from the assignment. Section 6 provides references used during the course of the assignment, which provide the reader with further information on energy efficiency for AVB.

Several annexures are also attached to this report. Annex 1 presents the preliminary base consumption analyses on CD-ROM. Annex 2 presents a sample existing building energy audit output. Annex 3 provides the reader with AAAMSA Test Performance Criteria. Annex 4 provides energy consumption data collected during the assignment for selected existing buildings. Annex 5 presents sample "Green Building Profiles" developed under the Green Buildings for Africa programme.

1.2 Definition of an Energy Efficient Building

Although there is no "absolute" definition of an energy efficient building, the following is typically used:

An energy efficient building is one that uses less energy than new buildings that are being built according to "current construction practices" (ASHRAE).

A further refinement of the definition is that an energy efficient building provides the intended service, while at the same time minimizing/reducing the building's lifetime energy operating costs.

1.2.1 Perspectives on Electricity Price Evolution in South Africa

Ironically, energy efficiency measures to date in South Africa have been hampered by the very low cost of electricity. With the impending exhaustion of the excess capacity to supply electricity in South Africa, forecast by Eskom, the national electricity utility, for 2007, there is currently a focus on assessing the next sources of electricity supply and the tariffs at which that electricity will be supplied. Those tariffs will be influenced by the cost of new generation and the real cost of the distribution network needed to deliver electricity to consumers.

Uncertainty over Municipal Electricity Tariffs

Electricity supply to commercial buildings in South Africa is mainly through municipalities, which purchase in bulk from Eskom.

South Africa does not currently have a single tariff structure, as each of the about 190 municipal electricity distributors has its own structure. Some municipalities use electricity revenues as a means of cross-subsidising other municipal services; very few municipalities have cost reflective tariff structures. Municipalities generally purchase their electricity from Eskom, although a few do have their own generation sources. About half of South Africa's electricity customers purchase their electricity directly from Eskom.

The National Electricity Regulator (NER) has recently instigated a study to decide on a 5-year multi-tariff structure. The NER has historically decided on an Eskom tariff increase at the beginning of each year.

Under the Electricity Distribution Industry (EDI) Restructuring Bill, the Government is restructuring electricity distribution in the country into six REDs (Regional Electricity Distributors), which will incorporate the electricity distribution system of the municipalities including that of Eskom and will implement a harmonised tariff structure across the country.

Under the Municipal Systems Act (MSA) 2000, which has the force of law, municipalities must evaluate options for external service delivery. However, there is currently no legislation compelling municipalities to participate in the REDs. The Electricity Distribution Industry (EDI) Restructuring Bill does not yet have the force of law. Issues such as ownership and control, transfer instruments for assets, liabilities and staff and an equitable, acceptable compensation model present a challenge to the organisation responsible for rolling out the REDs, the EDI Holdings Company.

The REDs are not operational yet. The first RED, to be anchored by the municipality of Cape Town and with the participation of Eskom Distribution in the region, is expected to be operational in July 2005. At the time of writing of this report, it was understood that the other 39 municipalities in the Cape area (with the exception of George, which has opted out) would be phased into this first RED over a period of 18 months.

The following commentary on the MSA may assist to accentuate/clarify this uncertainty. *"Section 11(2) provides that a municipality exercises its authority by amongst others providing municipal services to the local community itself (11(2)(f)), or by appointing appropriate service providers in accordance with the criteria and process set out in Section 78. Section 78 requires a local authority to review its delivery of a service to determine whether it is more feasible to continue in-house delivery or to outsource the services in some manner. Section 77 prescribes seven situations or circumstances when the municipality is obliged to (must) consider the appropriate service delivery options. Section 76 provides that a municipality may provide a municipal service through an internal or external mechanism".*

Section 78(3) of MSA: Assessment of External Service Delivery Mechanisms states that "In view of the EDI restructuring process, it is possible that Council will explore the possibility of providing the electricity service through an external mechanism. External mechanisms under Section 76 (b) of the MSA includes (1) a Municipal entity, (2) another municipality, (3) an organ of state, (4) a community-based organisation or a legally competent NGO and (5) any other institution, entity or persons legally competent to operate a business activity.

However, there is certainty over regulation. It will be done by the NER and it is expected that all the 6 REDs will have a uniform tariff structure and (possibly) the same tariffs. EDI Holdings will work with NER to determine tariff structure before being published.

Cost of Connection and Maintenance Backlog

Much of South Africa's electricity network is old and has been operated and maintained on a "run to failure basis". The connection backlog in Gauteng province only, currently sits at about 900 000, with proportionate figures for the other provinces. The estimated maintenance backlog is even more significant. Studies commissioned by the NER and the Gauteng Provincial Government demonstrate that the cost of achieving the national target of addressing the connection and maintenance backlog by 2012 will run well into the billions of Rands.

Uncertainty over the Cost of Future Generation

South Africa's generation base is mature coal-fired plant, long since depreciated. However, the rising national peak demand is such that

> *"…the country's existing power generation capacity will be insufficient to meet [it] by 2007-2012. Energy efficiency is integral to Eskom's Demand Side Management programme, which is intended to reduce the level of load growth by a cumulative value of 4255 MW by 2025, equivalent to a saving of a six unit coal-fired power station."*

- Goal 8 of the national Energy Efficiency Strategy.

In September 2004, NER published the second National Integrated Resource Plan (NIRP2), which confirmed the need for over 2500MW of peaking capacity up to 2010 (over and above de-mothballing).

Eskom will be responsible for the supply needs up to 2008. DME will procure 1000MW of IPP capacity before 2009, and up to 30% of future capacity needs will be offered to the private sector.

DME's IPP project has several objectives:

- Meeting new generation capacity requirements
- Introducing private sector participation in the generation sector
- Enhancing security of supply through fuel diversity
- Accessing private sector financing and informing policy decisions on public versus private sector procurement
- Enhancing Black Economic Empowerment (BEE) in the energy sector
- Maintaining low cost electricity.

Many options for additional generation are being mooted in South Africa:

- Demothballing of existing coal-fired stations
- Gas-fired IPPs (open cycle gas turbine plants, developed on an independent power producer basis and using the new availability of low cost gas to national advantage)
  - Plant 1: 300 to 360MW located in Eastern Cape
  - Plant 2: 750 to 830MW located in KwaZulu Natal
  - Net output range of gas turbine units: 115-160MW
- Construction of a pumped storage plant in the Drakensberg (Braamhoek)
- Other IPPs
- Imports through the Southern African Power Pool (SAPP)
- Development of the Pebble Bed Modular Reactor
- In the very long term, imports from the Inga hydro project in DRC

While detailed studies have yet to be carried out, none of these options is expected to generate electricity at the very low costs of the existing generation park. Should the current Rate of Return methodology apply, it is expected that the South African market would see an increased marginal cost of generation, which would have to be borne either by the government, stakeholders in the ESI or by the consumer.

During the preparation of the current version of this report, the NER issued documentation on the proposed Multi-Year Price Determination (MYPD) methodology for determining Eskom's tariffs, so

that Eskom and customers can see reasonable revenue and price certainty as Eskom and other embark on the investment programme outlined above. The comment period on the proposed methodology was still open at the time of submission of the report. In short, the NER is considering replacing the current Rate of Return methodology of Eskom tariff determination (reviewed annually) with an Asset Replacement methodology which would allow for reasonable tariff stability and smoothed changes over time. This methodology envisages a three-year look ahead.

The current expectation in the market is that the introduction of this methodology would protect against price shocks and would assist South Africa in maintaining a globally competitive electricity price. While this would not immediately favour energy efficiency, the net benefit to the economy of a predictable input price regime is indisputable.

2 Methodology

2.1 Notional Building Development

In this assignment, the necessary research is undertaken for input to the development and writing of the energy efficiency standard for artificially ventilated buildings designated as SANS 204. The point of departure of this assignment is the definition of six notional buildings, which are deemed to be archetypes of the various categories.

The following process was used in the selection of the notional buildings:

1. Various tabulations of building and occupancy types were studied first in order to obtain a comprehensive overview of building types and designs. Tabulations used include Table F1 of SANS 10400-A: 2003, occupancy classes and practice guidelines of approximate building construction rates.
2. The latter type of guideline was also used to form a view of where building developers' efforts are concentrated, i.e. where the money is being spent.
3. This was followed by a process of consolidation. As a first step, building types with no or little HVAC, such as stadiums, schools and parking garages were eliminated.
4. A second round of eliminations followed, during which "question marks were placed" behind building types with very unique, non-repetitive designs, low numbers etc.
5. In a further round, a view was formed as to where significant amounts of energy are consumed in operating the buildings. This is likely also where the most can be gained in respect of energy efficiency.
6. From an expert review of the results of items 2 to 5 above, it was rather evident that the notional buildings should be picked so as to best represent the commercial building practice in offices, retail and leisure.
7. Further consultation produced the proposed set of six notional buildings.

The main characteristic sought in the combined set of notional buildings is that it should be a practical and generally recognised representation of a decent portion of present day RSA construction of buildings in which forced ventilation is employed. With this in mind and through consultation with experienced industry practitioners, the thousands of individual building designs were distilled into six notional buildings.

The six notional buildings are:

a. Regional Shopping Centres/Malls (Mix of F1&F2)

b. Suburban Strip Shopping/Value Centres (Mix of F1&F2)

c. Low rise/Campus style office park developments (G1)

d. High Rise Office Blocks (G1)

e. Hotel & Resorts (H1 & A1)

f. Hospitals (low-rise commercial style)

The occupancies shown are based on Table F1 of SANS 10400-A: 2003.

The notional buildings are then described through a set of "average" characteristics distilled through experience as follows:

- Description
- Fenestration
- Opaque wall
- Roof construction
- Building facades
- General lighting
- Office equipment and plug loads
- Occupancy
- Cooling performance characteristics and sizing
- Heating efficiency and sizing
- Air flow rates
- Supply fan size
- Fresh air requirements

It should be emphasised that these notional buildings do not represent specific building designs, and therefore site and client specific issues such as orientation are not taken into account in the development of these archetypes. Furthermore, notional buildings are not associated with specific building materials; rather, they incorporate classes of materials for the purposes of deriving estimates of capital and operating expenditure on an "increment from base case" approach.

2.2 Life Cycle Costing (LCC) Approach

The request for proposals (RFP) requested advice on the thermal levels for specific components of the building (Ref TOR item 5.1). This is the "prescriptive" approach" to setting building performance standards. Because of this requirement, the SP selected the LCC approach over the "Whole Building Method", which would not have allowed for analysis by specific component. The LCC approach allows for an assessment of energy use intensity (EUI). The LCC methodology assesses the economic impacts of differing performance levels and will, therefore, provide the DME with a basis from which it can establish the levels to be used in the standard.

2.2.1 Comparison of LCC Approach with Whole Building Analysis

A single (whole building) EUI is used for "performance-based" building standards. A performance-based standard requires that once constructed, the building must meet a "whole building" energy performance level (e.g. use 200 kWh/m2/yr or less, and it is up to the design team to achieve this performance level any way they like. In theory, it is more economically efficient than the prescriptive approach, as it leaves room for creativity and innovation on the part of the designers.

However, the method of selecting a target EUI also involves modelling notional buildings and generating LCCs; so the two methods are not mutually exclusive. The LCC, which is generated by the DOE2 model, is simply a means of quantifying the value of each successive level of additional upfront energy efficiency (EE) investment. For a new building construction, there is a trade-off between additional upfront capital costs in energy efficiency and the energy operating costs over the life of the building. Typically, investing more upfront in efficient design and equipment results in lower energy operating costs than without the EE features.

The proposal submitted by the SP responded to the requirements of the RFP in presenting a methodology based on LCC analysis, and the accepted Work Plan is based on the prescriptive approach in accordance with the Terms of Reference.

2.3 Software Used – Visual DOE

The organisation of the engineering analysis into an effective and manageable level requires the use of a simulation tool that provides accurate energy use results, whilst maintaining the simulation runs within available budget. The simulation tool being used is Visual DOE – a Windows-based front end or user interface to DOE 2.1E. This simulation tool allows users with no previous knowledge of DOEs in several jurisdictions globally for similar type of initiatives, and therefore provides a credible technical modelling platform for this project.

The analysis is being undertaken using an internationally recognized building energy use simulation tool – Visual DOE – a window-based interface to DOE 2.1E. Once detailed building specifications are input into Visual DOE, the model provides accurate estimates of the building's annual energy use, broken out by major end use (e.g., heating, cooling, lighting etc.) and fuel type. Model outputs also include the life cycle cost (LCC) of capital and energy expenditures for varying energy efficiency investment options. These outputs provide a means for the building designer to compare the impacts of successive levels of up-front capital investment in energy efficiency measures on the energy operating costs of the building over the life of the measures. This simulation tool has been used in several jurisdictions globally for similar type of initiatives and therefore provides a credible technical modelling platform for this project.

Energy Cybernetics acts as the Resource Centre for Visual DOE in South Africa.

2.4 Methodology for Addressing Existing Buildings

A qualitative, high level approach was agreed, noting that the methodology required for such an analysis is significantly different from the LCC analysis used for new buildings and would not provide a mandatory platform from which DME could address EE issues in existing buildings, but would provide a basis for benchmarking energy consumption in existing buildings based on the benchmarks developed for new buildings under the project.

It was agreed with the PTT that the possibility of older South African commercial buildings being "more" energy efficient was quite high, given that the building envelopes tend to be more thermally resistive both in terms of opaque wall and fenestration and also in terms of air conditioning volume.

The project team and the PTT agreed the hypothesis that the energy intensities in older South African buildings may be lower than those in new commercial buildings due to the increased use of glazing (windows) in modern building skin design compared to potentially more thermally resistive materials such as brick and stone, more commonly used in building design about two decades ago, a period of significant commercial building construction in South Africa. Increased use of glazing would allow increased solar radiation into buildings, with the anticipated effect of requiring increased air conditioning for occupant comfort.

It was noted that the effect of more energy efficient air conditioning systems (in new buildings) was not known, i.e. whether the effect of lower energy consumption HVAC systems would balance out the effect of increased air conditioning due to increased solar radiation.

This would provide a means to validate the energy intensities derived through the LCC analysis for “modern” buildings.

Since the project budget does not allow for extensive surveys, the energy intensities derived through the LCC analysis were compared with energy consumptions in selected older (“existing”) commercial buildings. This data was collected through personal interviews with building owners/managers.

2.5 Building Data Analysis

2.5.1 Energy Density Calculations

For buildings, energy density is expressed typically in MJ per square meter of conditioned floor area per year, MJ/m2/year. Calculating this factor very simply involves:

- Adding up all purchased and self-generated energy sources on a per year basis,
- converted to the common unit of Joules or mega-Joules, MJ;

- Dividing by the total conditioned floor area in m^2.

2.5.2 Correlating Energy Consumption to Weather

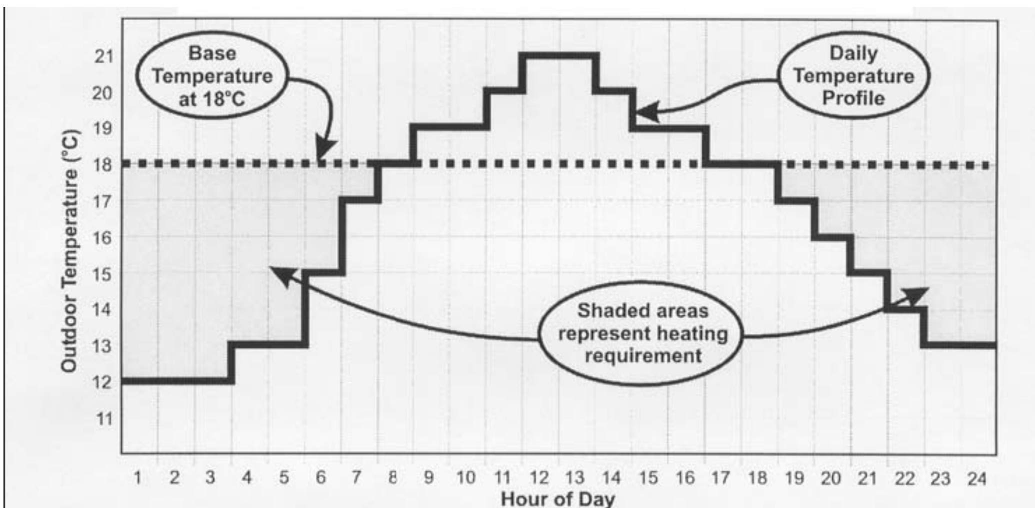
While the differences in climatic conditions from one place to another in South Africa, or from season to season, may not be as extreme as in some other parts of the world there are nevertheless seasonal and regional differences that have an impact on building energy consumption. It is important that these factors be taken into account in the assessment and benchmarking of building performance. Since the outdoor temperature is not constant, the calculation of annual heat loss involves aggregation of the heat flows at various outdoor temperatures. In a detailed audit of building energy consumption, a professional energy auditor might well use a computer to calculate the heat loss based on hourly temperature profile data. One such method uses “degree-days” and a second method uses “temperature bins”.

2.5.3 Degree-Days

The degree-day method assumes that, on a long-term average, solar and internal heat gains (people, lighting, equipment) will offset the heat loss when the outdoor temperature is 18°C. Assuming the indoor temperature is maintained at 21°C during the heating season, this means the heat loss from transmission, ventilation and infiltration loads due to a 3°C temperature difference (18 - 21) is exactly equal to the heat gain from solar and internal loads. There would be no requirement for heating or cooling energy when the outdoor temperature is 18°C.

The degree-day method also assumes that the requirement for heating or cooling energy to the building is proportional to the temperature difference between the outdoor temperature and 18°C. It is assumed, for example, that a building will require twice as much heating energy when the outdoor temperature is 10EC than when the outdoor temperature is 14°C. This is because the temperature difference at 10°EC is two times the temperature difference at 14°C. Degree-day data (base 18°C) is available from many meteorological stations throughout the SADC region. Some stations do not summarize this data, but do maintain computerized records of hourly temperature profiles. As shown in the next section, it is relatively simple to summarize hourly temperature data into degree-day values.

Figure 1 Degree-Days Calculation Process



Outdoor Temperature (°C)

12	12	12	13	13	15	17	18	19	19	20	21	21	20	19	19	18	18	17	16	15	14	13	13	
6	6	6	5	5	3	1	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	5	Total 52

Temperature Difference Below 18°C Base Temperature (Degree-Hours)

$$Degree\ Days = \frac{Degree\ Hours}{24} = \frac{52}{24} = 2.2\ DegDay$$

2.5.4 Calculating Degree-Days

Degree-days is the product of temperature difference and time, summed over a time period - usually monthly or annually. This process is illustrated in Figure 1, where the temperature difference at each hour is summed over the entire day to obtain a degree-hour value, which is then divided by 24 hours to obtain 2.2 degree-days. The required heating energy for this particular day is assumed to be the same as if the outdoor temperature was a constant 2.2°C below 18°C (i.e. 15.8°C) for the entire day. The temperature data can be summarized for an entire year in the same manner.

When hourly temperature data is not available, degree-days may be approximated by using the difference between the base temperature and the daily mean temperature. Applying this method to Figure 1, the daily mean temperature is 16.4°C, yielding 1.6 degree-days for the day (18.0 - 16.4). The difference comes because the daily mean temperature also factors in the hourly temperatures that are above the base temperature.

2.5.5 Applying Degree-day data

The rate of heat flow through the various components of a building shell is calculated from the equation:

Q = U x A x)T

The heat flow at a given temperature difference is calculated for each building component (roof, wall, glass, etc), and then summed to obtain an overall heat flow for the building shell. Using the overall heat flow value, a composite UxA value, or overall heat transfer coefficient, can then be calculated for the entire building shell. The same equation can also be applied to determine the heating energy requirement of ventilation and infiltration loads.

2.5.6 Using Degree-Days for Cooling

The degree-day method can also be used for estimating annual cooling energy usage. Instead of using a temperature difference below the base temperature as for heating, the cooling degree-day value is calculated using the temperature difference above the base temperature. Referring back to the daily temperature profile in Figure 1, there are 14 degree-hours above 18°C, or 0.6 degree-days cooling (14/24).

A different base temperature is usually used for determining cooling degree-days. Assuming the indoor building temperature is allowed to rise to 25°C during the cooling season, and assuming solar and other internal heat loads provide 3°C of heating, then cooling energy is required whenever the outdoor temperature rises above 22°C. Thus cooling degree days are often calculated using a 22°C base temperature.

One disadvantage of using the degree-day method for estimating cooling energy is that, in addition to temperature difference, humidity is also a critical factor for determining cooling energy. The degree-day method does not accommodate this factor. The “temperature-bin” method outlined in Section 2.5.8 will provide more accurate cooling energy estimates.

2.5.7 Modified Base Temperature

The standard convention of 18°C base temperature for heating assumes that the building space temperature is allowed to fall to 21°C during the heating season, and that the solar load together with the normal composition of people, lighting, and equipment provide sufficient heat gain to offset the heat

loss from 3°C temperature difference. Thus 18°C is considered the "balance temperature" at which the heat losses equal the heat gains and there is no net requirement for heating or cooling energy.

In some buildings the characteristics of the building systems and occupants may be such that the heat losses and gains balance at an outdoor temperature different than 18°C. The following procedure can be used to determine a new balance temperature. The overall heating requirement for the building is the sum of heat losses and heat gains. The various heat losses and gains can be categorized as weather-related (transmission, ventilation and infiltration) and non-weather-related (people, lights, equipment), where the weather-related factors depend upon the difference between indoor and outdoor temperatures. The balance temperature (TB) is the outdoor temperature at which the overall heating requirement for the building is zero.

2.5.8 Temperature Bin Method

Another technique for approximating annual energy usage is the temperature bin method. With the temperature bin method, the hourly temperature data for the year are sorted into groups, or bins, each bin representing a small temperature range of say, 3°C.

The building's heating/cooling performance is calculated for the outdoor temperature represented in each temperature bin, using the midpoint temperature, e.g. 19.5°C for the 18°C to 21°C range. The energy usage for each bin is calculated by multiplying the energy flow by the number of annual hours for that bin. The calculations required for the temperature bin method are longer than for the degree-day method. However, the temperature bin method can provide a more accurate assessment. There are two reasons for this:

- The temperature bin method allows the auditor to consider the building's hourly energy requirements for a particular bin and system efficiencies can be factored in accordingly. For example, the air conditioning system would operate at a much lower efficiency during low-load conditions than if it was operating near its rated capacity. The same applies to heating systems with a fuel fired heat source. The degree-day method does not allow this judgment. If a location has a given degree-day value of 1,000 DD for cooling, the auditor has no understanding of the temperature profile. The building could experience a 20°C temperature difference for 50 days, or a 4°C temperature difference for 250 days during the year. There would be a significant difference in the operating performance and system efficiencies under these two scenarios, but there is no information to assess the situation.

- The second advantage, which applies mainly to cooling requirements, is that the auditor can apply a typical wet bulb temperature to each temperature bin, and factor the effect of latent heat into the calculations. This is especially beneficial in assessing air conditioning systems.

2.5.9 Regression Analysis of Energy Consumption

As a basis for analysis, a simple but physical relationship must be established between energy use and weather in a building. In simple terms, the energy required to heat the building during the heating season is equal to the heat lost from the building into the surrounding environment, through building walls, windows, and vents; and the energy required to cool the building in the cooling season is equal to the heat gained from the surrounding environment. In each case, the internal heat load is a factor – subtracting from the heat requirements or adding to the cooling requirements.

The rate at which heat loss or gain occurs is determined mainly by two key factors:

- The temperature difference driving force, being the difference between the indoor and outdoor temperature.
- The thermal performance of the building.

Table 1 gives typical monthly average temperatures for an area in South Africa over a period of a year. From these data, the number of degree days, both HDD and CDD, can be calculated, for selected base temperatures (using 18ºC for HDD, 20ºC for CDD to illustrate.) Similarly, the CDD is defined as the sum of the differences between the average outdoors temperature and a suitable reference, such as 20ºC.

Table 1 Area Average Temperatures (Example)

Month	Days	T_{avg}	HDD18	CDD20
Jan	31	20.9	0.0	27.9
Feb	28	21.0	0.0	28.0
Mar	31	19.8	0.0	0.0
Apr	30	17.5	15.0	0.0
May	31	14.8	99.2	0.0
Jun	30	13.0	150.0	0.0
Jul	31	12.2	179.8	0.0
Aug	31	14.0	120.0	0.0
Sep	30	16.0	0.0	0.0
Oct	31	19.9	0.0	0.0
Nov	30	18.4	0.0	0.0
Dec	31	19.9	0.0	0.0
Yearly			**728.3**	**55.9**

So in July, the heating degree-days are 179.8 for the recorded average daily mean temperature of 12.2ºC. Note that the calculation yields negative answers in HDD when the average temperature is greater than 18ºC, or in CDD when the average temperature is less than 20ºC; however, negative answers are meaningless because they simply indicate that no heating was required in the first case, or no cooling was required in the second case.

Although oversimplifying a complex physical situation, the overall building can be considered to have a coefficient of heat loss (U) which relates the rate of heat loss to the temperature difference driving force. The total heat lost in a period is then the integral of the instantaneous heat loss rate. The heat lost is directly proportional to the driving force, or the HDD measure where H = U x HDD with the constant of proportion being the heat transfer coefficient of the building.

This provides a theoretical basis for the empirical expectation that energy plotted against HDD is a straight line.

2.6 Approval Processes

2.6.1 Pre-Inception Meeting

A pre-Inception Meeting was held 11 November 2004 at DME, at which the initially proposed methodology and Work Plan were accepted.

2.6.2 Inception Meeting

An Inception Meeting was held 17 January 2005 at DME/CaBEERE's offices, at which the Work Plan was further discussed and agreed. It was noted that public buildings consume 3% of South Africa's energy in comparison to the 4% consumed by commercial buildings, and the South African government was mindful of taking on a leadership role in EE, and while public buildings would not be explicitly addressed under the project, many new public building types could be considered under the notional buildings, as design practice is essentially the same for these and commercial buildings.

2.6.3 Inception Workshop

An Inception Workshop was held on 25 January 2005 at SABS, at which the following strategic considerations were presented:

- Delphi Process to confirm Notional Buildings
- Inclusion of other building energy end-uses that affect the design of the standards, especially integration of lighting or HVAC
- Isolating renewables as a separate task and guideline document. The reason is that from the viewpoint of "element perspective", renewables are not part of the building envelope.

At this workshop, the selection of LCC analysis over Energy Intensity (EI) was raised. The SP explained the selection of the LCC methodology, confirming that LCC and EI analyses are not mutually exclusive.

2.6.4 Notional Building Confirmation – Delphi Process

The Notional Buildings were circulated for review and comment in a "Delphi Process" to the PTT and the Technical Committee (TC) on 18 March. The Delphi Process is a means of gathering a quick intuitive reaction from a group of experts in a way that draws on their collective experience. The PTT managed the Delphi Process through round robin e-mail involving the full TC. The comments received over the next month and a half were incorporated into the final versions of the Notional Buildings.

2.6.5 PTT Meeting 4 May 2005 – Approvals

LCC Analysis versus EI Analysis

It was accepted that the proposed methodology was the most appropriate to respond to the TOR, despite concerns raised at the Inception Workshop. It was confirmed that an LCC analysis would yield an EI assessment, addressing the concerns raised.

Discount Rate

A discount rate (the rate required to determine the present values of future energy consumption costs in the notional buildings over the life of the building) of 10% was approved. The derivation of this discount rate (based on input from the South African Property Owners' Association - SAPOA) is presented in Section 2.6.4.

Assumptions and Inputs on Energy Tariffs

Electricity is the energy carrier for an overwhelming majority of commercial buildings in South Africa, given its current low price globally and in relation to other energy carriers. Representative prices were sought for electricity from the National Electricity Regulator (NER).

The project team experienced difficulty obtaining a realistic view on future electricity prices in South Africa from the NER, as this was the subject of a current project to develop recommendations on a new multi-year tariff structure. DME provided a view on electricity tariffs based on historical tariffs and a

perspective on escalation. This view was used as the basis for energy tariffs in the modelling. Assumptions related to the energy costs and discounts rates used in the analysis are presented in Section 2.6.2.

Notional Building Profiles
The Notional Building profiles were approved at this meeting, following the Delphi Process. These can be found in Section 0.

Methodology for Addressing Existing Buildings
The proposed methodology (presented in Section 2.4) was approved at this meeting.

2.7 Data Collection/Inputs

2.7.1 Notional Buildings

The mechanical, electrical and lighting energy data used in the LCC analysis are presented in each Notional Building in Section 3.

2.7.2 Electricity Prices

As noted in Section 2.5.5, in South Africa, electricity is the major source of energy for Commercial Buildings. In the light of this, a view was required on projected energy tariffs as a necessary input to the computation of energy costs in commercial buildings. No other energy carrier was included in the analysis.

DME View on Electricity Tariffs
DME provided a historical and future view on electricity prices in the form of a spreadsheet developed by NER, showing electricity prices from 1950 to 2055. As DME requested that this view not be published, this report presents only the conclusions in terms of electricity prices to commercial buildings.

The NER model is based on the following assumptions:

- The model does not take a view on inflation and directly calculates real future prices, leading to some distortions regarding the book value of assets, where nominal accounting practices are used.
- The model also assumes the real Rand/dollar exchange rate to stay the same, with an impact on the actual value of imported content of capital investments made.
- Fuel costs are assumed to stay fairly constant over time.
- Labour cost was escalated in direct relationship to sales.
- Return on assets at around 11.2% for existing assets and at 15.4% for new assets (2006 on). NER noted that in real terms, this may be a little high since 11.2% is the nominal return allowed for 2005.
- Real cost of debt at 10%pa, which NER also considered may be a little high.
- A no dividends policy was followed.

The future rate schedules provided show a consistent price increase of 6.12% per year over the entire study period, as well as an estimated annual inflation rate of 4.5%. Therefore, as this type of analysis should be done net of inflation, the annual electricity rate escalator should be 1.62% (real, i.e., net of inflation). This view represents DME's and NER's perspective on the future cost of generation. given the uncertainties outlined in Section 1.2.1, the project team considers this view somewhat optimistic, however in terms of energy efficiency analysis this is expected to yield a conservative output.

In other words, the higher the energy costs, the greater the energy efficiency benefits in an LCC analysis. If the future energy costs are "lowballed", this analysis will represent a floor in terms of energy efficiency benefits, rather than a ceiling.

Electricity Rates used in the LCC Analysis
Based on the view provided by the DME, the proposed energy costs used in the analysis are the following:

- Energy rate = 13.37¢/kWh
- Demand charge = R53,57/kVA
- Annual price increase = 1.62% per year (real)

2.7.3 Weather Data

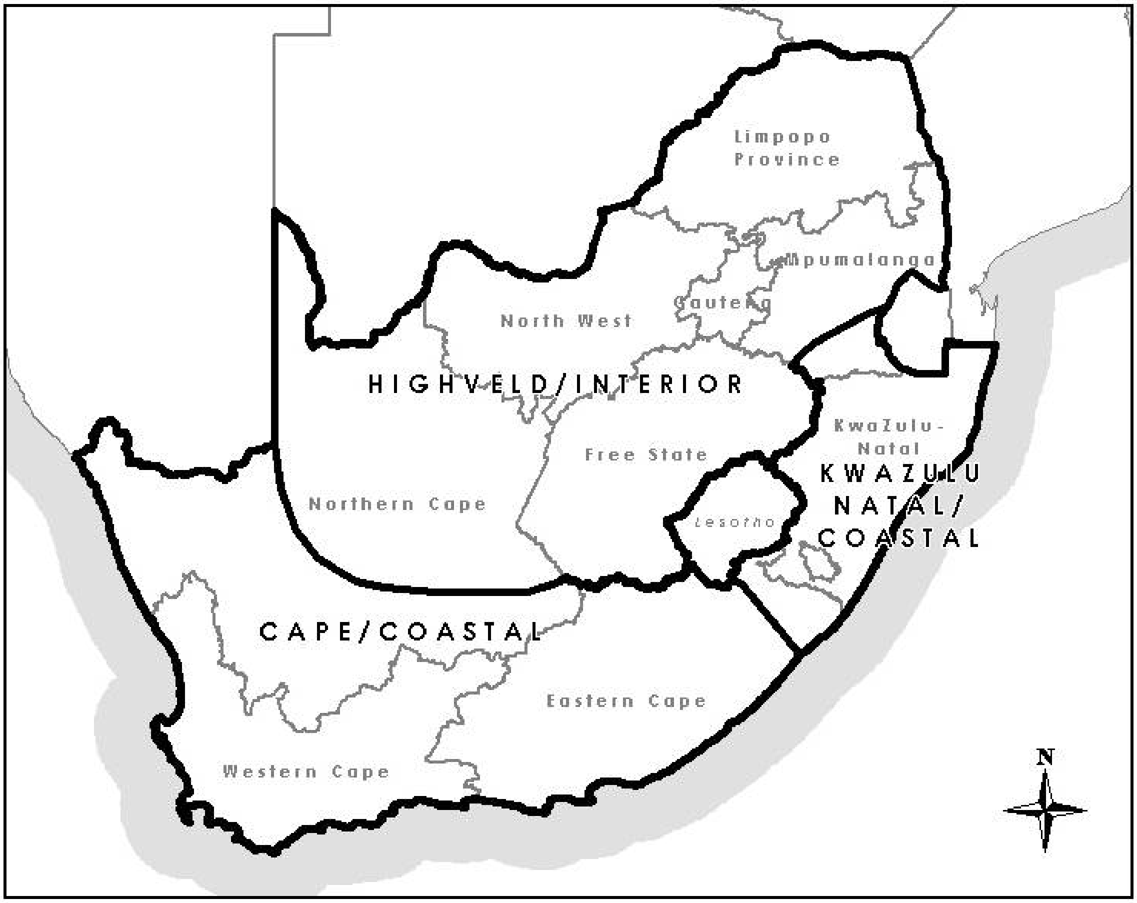
Compiled Visual DOE weather data files were obtained from the South African Visual DOE Resource Centre for the following regions:

- Highveld/Interior - Johannesburg
- Lowveld/Mpumalanga - Durban
- South Cape - Cape Town

Selection of Climate Regions
The Highveld/Interior region represents a high altitude (1700m), dry and sunny climate. The Lowveld/Mpumalanga region represents a warm, humid coastal region and the South Cape region represents a coastal region with temperatures varying from cool to hot in relatively clearly defined seasons, with more significant precipitation.

These regions are represented in Figure 2 overleaf. Note that these are indicative boundaries only and judgment should be applied based on the location of the design in comparison with the source weather data.

Figure 2 Weather Regions



2.7.4 Discount Rate

A discount rate[1] is required to determine the present values of future energy consumption costs in the notional buildings. The discount rate was selected based on the process outlined below. Used to determine the LCC of the building under analysis, the discount rate represents the building owner's perspective on the future value/cost of money.

The project team approached the South African Property Owners Association (SAPOA) for a view on the discount rate to be used. According to SAPOA, the employ of the term 'hurdle rate' in the commercial property field is one of the important financial variables influencing the investment decision around the purchase or development of property assets. There is some debate in the market as to whether or not hurdle rates/ discount rate/ required 'total return' used by the industry are at realistic levels. This in particular gives a structural move into a lower inflation environment and a general downward revision in asset return expectations.

Erwin Rode, speaking at the recently held SA IPD Valuation Conference approached the debate from a 'market's view' on expected or implied inflation. Using the conventional long bond yield less that of inflation-hedged bonds, the inferred **expected inflation** could be understood to be:

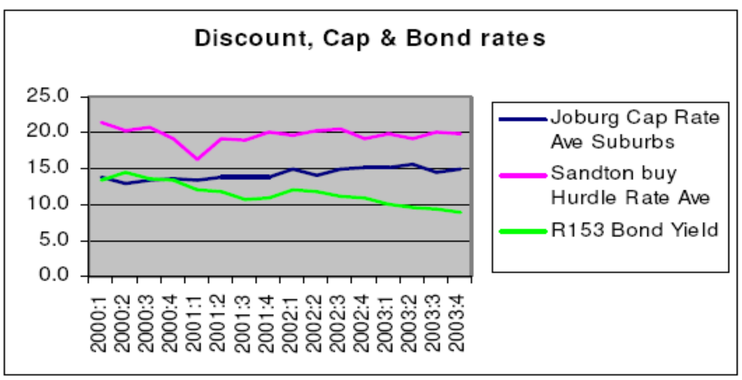
[1] The rate of return used to convert future projected net income flows into a present value. This largely determines the required return to induce an investor to invest in a property as opposed to an alternative property or even asset class.

- 5.6% for 4-year term
- 5.9% for 9-year term
- 4.7% for 30 years (assume perpetuity)

Based on the **perpetuity scenario** and assuming that annual income growth is depreciated by an ageing factor of 0.75%; using a current cap rate of 12% adjusted upwards by 1% per decade and a re-rating through structurally lower inflation, one can get to a total return (discount rate) of 15%. For a **5-year view**, assuming a neutral cap rate of 12% and an implied rental inflation rate corresponding with the 'market' income yield above, one could expect a discount rate to be around 17.8%. On the face of it, this would suggest that the property market's view of around 19% for prime offices may be too high. In particular, there is some concern whether the required future property rental growth of 7-9% can be achieved against the income growth derived from the markets (though net income growth in 2003 for office property was 7.8% according to SA IPD).

Discount rates as utilized for valuation purposes in the SA IPD database suggest that for non-CBD primary and secondary office markets, the achieved median was 18% and 18.5% respectively; with a surveyed range of 15.5%-19% and 16.5%-20% as obtained from a valuer survey in early 2004. Approaching the discount rate argument from the perspective of a **long bond rate and risk** perspective, a similar result is achieved: A long bond yield of say 10% + a risk premium for property of 6-8% depending on circumstances gives a discount rate (DR) of around 16%-18% as shown in Figure 3 below.

Figure 3 Discount, Cap and Bond Rates



Alternatively, from the **Cap Rate** perspective, one applies the formula DR = Cap Rate + Gross Market Rental Growth: As such, DR = 12% +6% = 18%. The cap rate could be adjusted downwards to reflect the improved outlook of commercial property, and a rental growth scenario that is at the lower end of market expected inflation growth, say 5%, to get the same result: i.e. 11% +5% = 16%. Rode suggests that on a 5-year term, a hurdle rate of around 19% applies; and that on a longer 15-year plus term, a rate of 15% applies. It still seems that a slight downward revision to the short-medium term discount rate needs to take place. Perhaps serving as a good benchmark is the 16-18% range reflected by the IPD survey.

In order to come to an informed discount rate for application in a discount cash flow scenario, one should give due consideration - preferably in combination - to the three approaches; i.e. the long bond/risk perspective; the cap rate/rental growth perspective; as well as the cap rate/implied market inflation growth rate.

Based on the SAPOA report, a conservative view of a nominal discount rate of 15% can be applied for a long-term commercial property investment. To adjust this nominal discount rate to a real discount rate, the following simplistic formula should be applied:

(1 + real rate) = (1 + nominal rate)/(1 + inflation rate).

Since the long-term nominal discount rate is being applied, it is germane to also apply the long-term inflation rate as per the same report. The simple formula

(1 + real rate) = (1 + 15%)/(1 + 4.7%)

gives a real discount rate of approximately 10%.

3 Results

This section presents the notional building derived for each building occupancy examined and the thermal building shell energy efficiency options considered for each notional building and for each climate region. It also provides the modelling results by end use (annual energy consumption, in kWh/year) and End Use Intensity (in kWh/m^2-yr). Demand intensity (in kW/m^2-yr) for each notional building can be found in the Visual DOE outputs included in Annex 1.

3.1 Medium Sized, Single Storey Hospital

3.1.1 Introduction

This section describes the medium-sized, single storey hospital notional building and the thermal building shell energy efficiency options considered for this building.

3.1.2 Building Profile

A medium-sized hospital is defined as an 86 bed, 14 examination room, single storey facility – 8 080 m² building with a varying footprint. Facilities such as long and short stay wards, consultation rooms, theatres, administration etc., would generally be housed in separate wings of the building leading off a central spine. A U-shaped single storey form with a centre courtyard has been used to emulate the wings.

A ward wing is assumed to consist of 4-bed hospital wards along the periphery of the building with all services located in a central corridor. Where theatres are located against an external wall, the façade would be of solid construction.

A typical layout of the wing of consultation rooms shows a corridor along one façade, leading into waiting rooms with the consultation room against the opposite façade. Examination rooms are located in the centre.

Auxiliary services, such as reception, lounges, cafeteria, admission, pharmacy and administration offices are housed in a separate block.

The building is served by constant volume and low pressure VAV air handling systems, as indicated. Heating is provided by electric heaters. The cooling load is met by central screw chillers rated at 5.5kW_c/kW_i.

Floor areas in m² of the different facilities are shown in Table 2.

Table 2 Hospital Floor Areas and HVAC Systems

Facility	Area (m²)	HVAC Air System
Reception, admission and administrative offices	700	VAV
Wards	2000	Individual CV AHU's
Consulting rooms, including waiting areas	1000	VAV
Theatre suite total o Theatres – 160 o Passages – 105 o Other – 270	535	Individual VC AHU's Full fresh air VAV
ICU total o ICU beds and isolation – 115 o Other – 310	425	Individual VC AHU's Full fresh air VAV
Radiology and CCS	620	Individual CV AHU's
Pharmacy and medicine store	230	VAV
Mortuary	50	CV Refrigerated
Technical services	400	VAV
Primary circulation area	990	VAV
Auxiliary areas without forced ventilation	1130	VAV

Building and Plenum Heights: Floor to floor height is assumed to be 4m with a plenum height of 790 mm. Drywall ceilings are assumed throughout except reception, admission, administration, doctors consulting rooms, pharmacy and primary circulation.

Fenestration: Glazing is assumed to be single pane windows with opening sections. The most popular glazing is clear glass with a shading coefficient of 1.0 – U=5.8W/m²K RSI 0.17. Interior shading is assumed.

Wall: The walls are assumed to be masonry unit cavity wall with construction characteristics shown in Table 3. As shown, construction in the South Cape region assumes a masonry wall with a 50 mm air cavity and an overall thermal performance of RSI 0.68. Other locations typically use a masonry wall with no air cavity.

Roof Construction: Roof construction is assumed to be a pitched roof with profiled, coloured steel roof sheets on timber trusses as shown in Table 4. This configuration results in an overall thermal performance of RSI 1.27.

Table 4**Building Facades:** Bay width is assumed to be between 3.5 m and 7.0 m long. The overall length of glazing per 3.5 m bay is 2.4 m. Window height is 1.2 m and sill height is 900 mm. This would apply to all of the building facades containing hospital wards.

- 1 mm profiled steel roof sheets
- Prefabricated timber trusses
- 50 mm foil backed fibre glass installed over the piurlins and derated by 10% due to the over the purlins installation

(RSI=1.27)

Table 3 Hospital Opaque Wall Construction Detail (Brick Cavity Wall)

Highveld/Interior and Lowveld/Mpumalanga Regions o 10 mm cement/sand plaster o 180 mm cement brick o 10 mm cement/sand plaster (RSI =0.42) Or South Cape Region o 10 mm cement/sand plaster o 90 mm cement brick o 50 mm cavity o 90 mm cement brick o 10 mm cement/sand plaster (RSI = 0.68)

Table 4 Hospital Roof Construction Detail

o 1 mm profiled steel roof sheets o Prefabricated timber trusses o 50 mm foil backed fibre glass installed over the piurlins and derated by 10% due to the over the purlins installation (RSI=1.27)

General Lighting: Hospitals, regardless of size, share similar requirements regarding lighting levels. The areas covered would generally be:

- Wards
- Offices
- Theatres
- Foyers
- Circulation areas
- Parking (Basement)
- Plant Rooms

General lighting is based on linear T8 fluorescent lamps with electronic control gear (ECG) or electronic ballasts. Table 5 lists the assumed lighting power densities (LPDs) per area.

Table 5 Hospital LPD, Plug Load and Occupant Densities Assumed

Area	LPD (W/m²)	Plug Load Density (W/m²)	Occ. Density (m²/occupant)
Main (admission and admin, technical and circulation	20	8	25
Reception	20	1	25
Pharmacy	20	2	25
Consulting and radiology	20	7	20
Wards	10	1	25
OR, Recovery and ICU	30	10	20
Mortuary	20	8	25

Exterior Lighting: Exterior lighting has been assumed with a total connected load of 1.5 kW. This is based on provision of 10 -150 HPS lamps for the building perimeter.

Plug Load Requirements: For the general requirements, 16 amp 3 pin round switched socket outlets are provided through power skirting run along the walls or floor channels recessed into the floor slab / screeding.

For specialised areas such as Operating Theatres, dedicated power points with special earthing requirements (to prevent static electricity) are provided.

Operating of small power would include the use of essential equipment at patient bed and for cleaning purposes. Equipment supplied from small power would operate at 100% (Hospital ICU and High Care). General wards would depend on the number of occupied beds. Table 5, above, lists the typical plug load densities assumed.

Occupancy: Occupancy densities are shown in Table 5 above.

Cooling Performance Characteristics: The cooling load is met with a central screw chiller rated at a coefficient of performance (COP) of 5.5 at full load.

Economizer Cycle: All air handling units have been assumed to have a fixed outside air volume with no damper modulation and no economizer cycle.

Air Flow Rates: Design air flow rates are 8 l/s.m² at summer design conditions. All areas have been designed at this level plus the air handling serving the OR, Recovery and ICU has been assumed to be 100% OA.

Supply Fan Size: Supply fan size is based on a total static pressure of 150 Pa. No return fan is present.

Fresh Air Requirements: Fresh air ventilation rates have been assumed based on 7.5 l/s. person.

Exhaust Fans: Washroom exhaust was assumed based on an exhaust rate of 15 l/s-m² in the wards. A total building exhaust of 1 500 L/s was assumed based on 25 washrooms serving the 86 beds.

Domestic Hot Water: Hot water (electric heating and 60°C), is estimated as 200 l/capita/day.

Weather Data: The weather data used is shown in Table 6 overleaf.

Table 6 Weather Data and Elevations (Hospital)

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

Regional Variations: As stated in the description of the opaque wall, hospitals in the South Cape region are built with a masonry wall containing a 50 mm air cavity. Buildings in all other regions use masonry wall with no cavity.

Operating Schedules: As hospitals run on a 24hr basis, it is assumed that operation of the lights runs at nearly 100%. This would exclude the wards at night were lighting would be reduced to essential areas and only operate at patients' bedheads as required. It can therefore be assumed that an operating level of 30% would be acceptable.

3.2 Medium Sized, Single Storey Hospital Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.2.1 Wall Construction

Because the base case wall construction varies by region, two different sets of energy efficiency wall constructions are presented. For South Cape region, four alternatives were analyzed. These constructions and their associated costs, together with the base case information, are summarized in Table 7. For the other two regions, four alternatives are analyzed. Their constructions, the associated costs, and the base case information, are summarized in Table 7.

Table 7 EE Alternatives for Wall Insulation (Hospital – South Cape Region)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[2] (R/m façade)
Base Case	None	0		50			
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	25	R 12.78	R 17.00	
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	25	R 15.49	R 17.00	R 25.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	25	R 19.36	R 17.00	R 50.00

* Additional is in reference to the Base Case.

[2] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

Table 8 EE Alternatives for Wall Insulation (Hospital - Highveld/Interior and Lowveld/Mpumalanga Regions

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[3] (R/m façade)
Base Case	None	0		0			
EE Level-0	None	Base + 0	Base + 0.26	50			R 50.00
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	0	R 12.78	R 17.00	R 25.00
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	0	R 15.49	R 17.00	R 50.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	0	R 19.36	R 17.00	R 75.00

* Additional is in reference to the Base Case.

3.2.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 9.

Table 9 EE Alternatives for Roof Insulation (Hospital)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	None	0			
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

* Additional is in reference to the Base Case.

3.2.3 Windows

Three energy efficiency alternative window glazings were analyzed. The descriptions and costs are summarized in Table 10 overleaf.

[3] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

Table 10 EE Alternatives for Window Glazing (Hospital)

EE Level	Glazing Description	Shading Coefficient	Overall RSI Value	Material Cost (R/m² window)	Additional Labour Cost (R/m² window)	Incremental Cost (R/m² window)
Base Case	Single 6.38 mm clear	1	0.17	R 200.00	-	
EE Level-1	Single 6mm Grey Low E (e=0.1)	0.4	0.22	R 440.00	-	R 240.00
EE Level-2	Double 6/12/6 mm Grey	0.4	0.31	R 680.00	R 100.00	R 580.00
EE Level-3	Double 6/12/6 mm Low E	0.4	0.5	R 820.00	R 100.00	R 720.00

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4, remain virtually unchanged.

3.2.4 Modelling Results

Energy efficiency alternatives were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 11, Table 12, and Figure 4.

Table 11 Annual Electricity Consumption by End-Use and End Use Intensity (Hospital - South Cape)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps/Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	459,738	146,727	1,020,226	602,857	100,277	31,451	420,127	805,920	3,587,323	444.0
Wall (EE-1)	459,738	146,727	1,010,445	603,182	100,146	31,298	419,728	805,920	3,577,184	442.7
Wall (EE-2)	459,738	146,727	1,007,124	603,330	100,103	31,249	419,583	805,920	3,573,774	442.3
Wall (EE-3)	459,738	146,727	1,005,112	603,420	100,072	31,212	419,486	805,920	3,571,687	442.0
Roof (EE-1)	459,738	146,727	1,018,194	596,898	98,978	30,995	419,341	805,920	3,576,791	442.7
Roof (EE-2)	459,738	146,727	1,017,179	593,021	98,156	30,701	418,814	805,920	3,570,256	441.9
Roof (EE-3)	459,738	146,727	1,016,781	590,628	97,650	30,524	418,397	805,920	3,566,365	441.4
Window (EE-1)	459,738	146,727	1,089,536	580,468	97,302	30,412	420,116	805,920	3,630,219	449.3
Window (EE-2)	459,738	146,727	1,079,214	581,022	97,059	30,291	419,952	805,920	3,619,923	448.0
Window (EE-3)	459,738	146,727	1,068,498	582,264	97,085	30,255	419,668	805,920	3,610,155	446.8

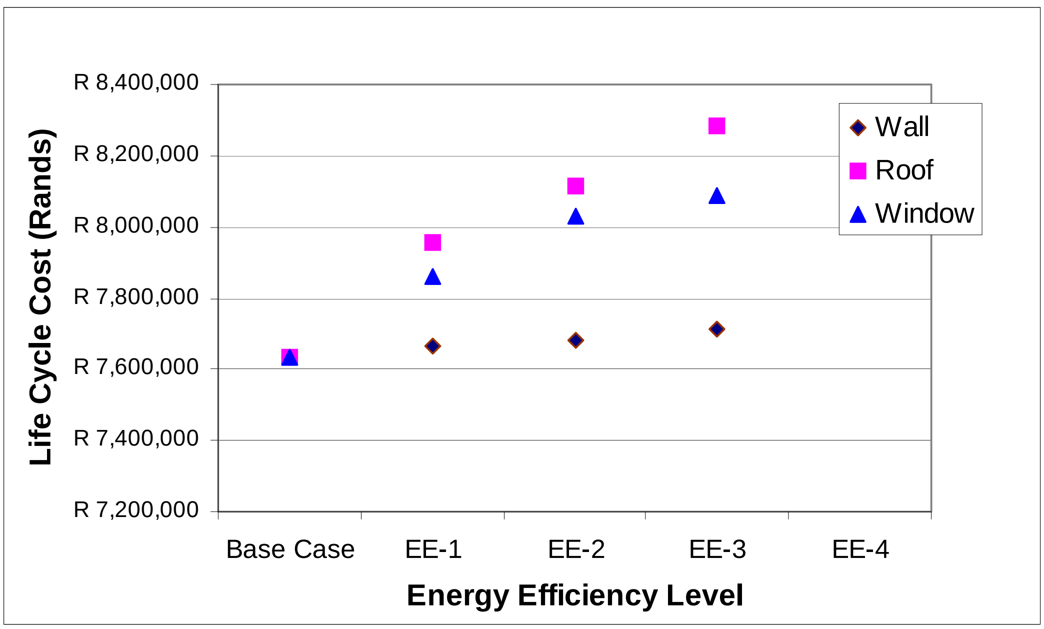
Table 12 EE Alternative LCC Comparison (Hospital – South Cape)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 810,850	R 0	R 7,631,036	
Wall (EE-1)	R 807,555	R 66,052	R 7,666,078	0.46%
Wall (EE-2)	R 806,484	R 88,563	R 7,678,510	0.62%
Wall (EE-3)	R 805,844	R 130,146	R 7,714,069	1.09%
Base Case	R 810,850	R 0	R 7,631,036	
Roof (EE-1)	R 807,326	R 358,400	R 7,956,271	4.26%
Roof (EE-2)	R 805,083	R 539,440	R 8,116,202	6.36%
Roof (EE-3)	R 803,742	R 721,360	R 8,285,501	8.58%
Base Case**	R 810,850	R 0	R 7,631,036	
Window (EE-1)	R 821,076	R 132,960	R 7,860,234	3.00%
Window (EE-2)	R 818,884	R 321,320	R 8,027,965	5.20%
Window (EE-3)	R 816,781	R 398,880	R 8,085,733	5.96%

* With respect to Base Case

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4, remain virtually unchanged.

Figure 4 EE Alternative LCC Comparison (Hospital – South Cape)



For the medium sized, single storey hospital building in the South Cape region, the base case results in the lowest life cycle costs.

Highveld/Interior Region

The modelling results are summarized in Table 13, Table 14 and Figure 5.

Table 13 Annual Electricity Consumption by End-Use and End Use Intensity (Hospital – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps/Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	459,738	146,727	950,775	692,005	108,168	33,796	421,773	805,920	3,618,902	447.9
Wall (EE-0)	459,738	146,727	947,730	685,988	106,785	33,232	420,556	805,920	3,606,676	446.4
Wall (EE-1)	459,738	146,727	944,440	684,127	106,440	33,087	420,352	805,920	3,600,831	445.6
Wall (EE-2)	459,738	146,727	942,692	683,173	106,276	33,014	420,258	805,920	3,597,798	445.3
Wall (EE-3)	459,738	146,727	939,770	682,599	106,179	32,978	420,237	805,920	3,594,148	444.8
Roof (EE-1)	459,738	146,727	945,099	680,340	105,611	32,972	420,422	805,920	3,596,829	445.2
Roof (EE-2)	459,738	146,727	942,191	675,476	105,350	32,869	419,692	805,920	3,587,963	444.1
Roof (EE-3)	459,738	146,727	940,993	670,934	104,460	32,579	419,270	805,920	3,580,621	443.1
Window (EE-1)	459,738	146,727	998,732	670,226	105,643	33,029	420,544	805,920	3,640,559	450.6
Window (EE-2)	459,738	146,727	991,385	670,955	105,520	32,929	420,317	805,920	3,633,491	449.7
Window (EE-3)	459,738	146,727	983,285	671,728	105,392	32,822	420,036	805,920	3,625,648	448.7

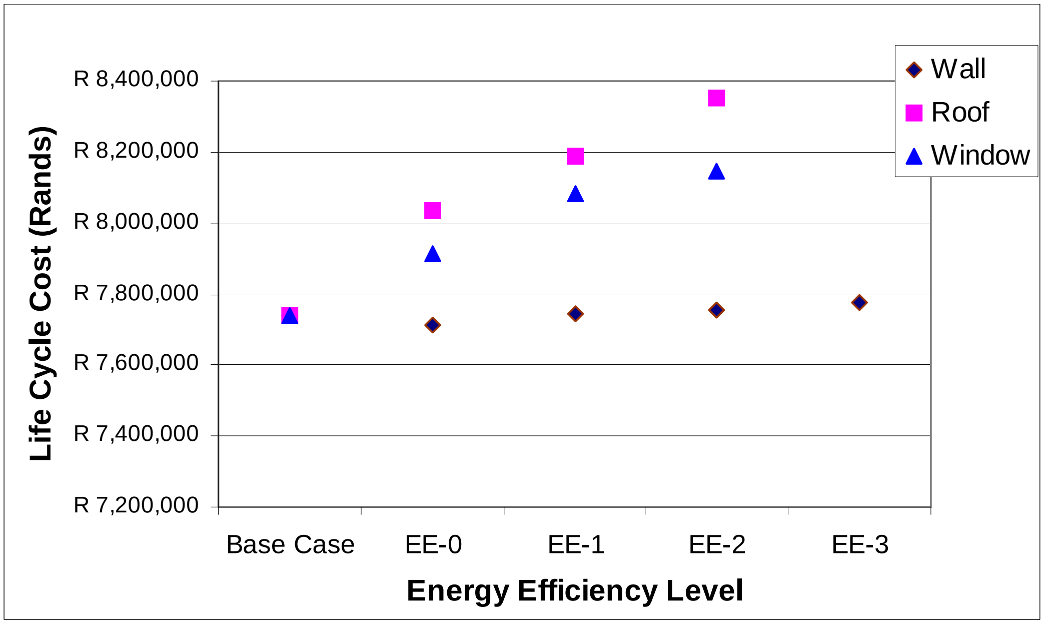
Table 14 EE Alternative LCC Comparison (Hospital – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 822,102	R 0	R 7,736,930	
Wall (EE-0)	R 816,098	R 33,000	R 7,713,426	-0.30%
Wall (EE-1)	R 813,906	R 82,552	R 7,742,348	0.07%
Wall (EE-2)	R 813,001	R 105,063	R 7,756,342	0.25%
Wall (EE-3)	R 812,169	R 130,146	R 7,773,595	0.47%
Base Case	R 822,102	R 0	R 7,736,930	
Roof (EE-1)	R 815,534	R 358,400	R 8,033,518	3.83%
Roof (EE-2)	R 812,894	R 539,440	R 8,189,712	5.85%
Roof (EE-3)	R 810,786	R 721,360	R 8,351,793	7.95%
Base Case**	R 822,102	R 0	R 7,736,930	
Window (EE-1)	R 826,609	R 132,960	R 7,912,306	2.27%
Window (EE-2)	R 824,974	R 321,320	R 8,085,279	4.50%
Window (EE-3)	R 822,938	R 398,880	R 8,143,678	5.26%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 5 EE Alternative LCC Comparison (Hospital – Highveld/Interior)



For the medium sized, single storey hospital building in the Highveld/Interior region, the base case window glazings and roofs result in the lowest life cycle costs. Walls insulated with 50 mm air gap (EE-0) provide the lowest life cycle cost.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 15, Table 16 and Figure 6.

Table 15 Annual Electricity Consumption by End-Use and End Use Intensity (Hospital – Lowveld/Mpumalanga)

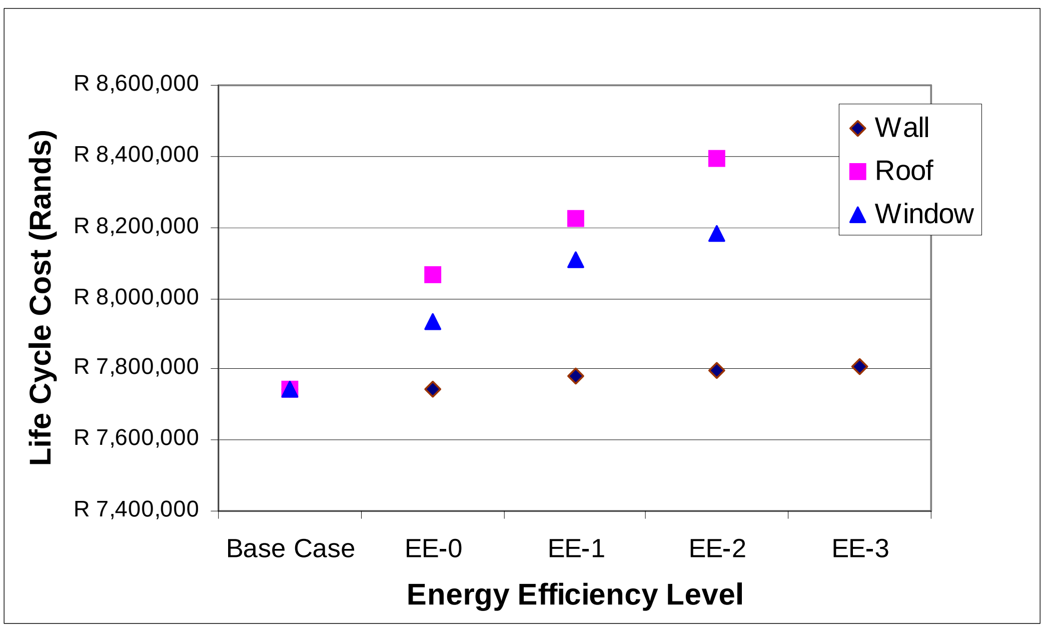
Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps/Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	459,738	146,727	926,777	771,893	111,236	33,478	420,260	805,920	3,676,029	455.0
Wall (EE-0)	459,738	146,727	923,232	767,044	109,774	32,968	419,671	805,920	3,665,085	453.6
Wall (EE-1)	459,738	146,727	918,083	765,725	109,484	32,860	419,607	805,920	3,658,144	452.7
Wall (EE-2)	459,738	146,727	915,537	765,000	109,332	32,802	419,573	805,920	3,654,629	452.3
Wall (EE-3)	459,738	146,727	908,510	764,462	109,240	32,775	419,497	805,920	3,646,869	451.3
Roof (EE-1)	459,738	146,727	920,282	764,092	109,142	32,819	419,445	805,920	3,658,165	452.7
Roof (EE-2)	459,738	146,727	916,560	758,810	107,714	32,366	418,884	805,920	3,646,719	451.3
Roof (EE-3)	459,738	146,727	914,727	755,610	106,854	32,099	418,563	805,920	3,640,238	450.5
Window (EE-1)	459,738	146,727	976,148	753,706	108,573	32,669	419,542	805,920	3,703,023	458.3
Window (EE-2)	459,738	146,727	971,328	754,336	108,469	32,618	419,494	805,920	3,698,630	457.8
Window (EE-3)	459,738	146,727	966,250	755,063	108,369	32,560	419,294	805,920	3,693,921	457.2

Table 16 EE Alternative LCC Comparison (Hospital – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 822,854	R 0	R 7,744,007	
Wall (EE-0)	R 819,400	R 33,000	R 7,744,501	0.01%
Wall (EE-1)	R 817,835	R 82,552	R 7,779,325	0.46%
Wall (EE-2)	R 817,194	R 105,063	R 7,795,803	0.67%
Wall (EE-3)	R 815,823	R 130,146	R 7,807,983	0.83%
Base Case	R 822,854	R 0	R 7,744,007	
Roof (EE-1)	R 819,037	R 358,400	R 8,066,485	4.16%
Roof (EE-2)	R 816,483	R 539,440	R 8,223,489	6.19%
Roof (EE-3)	R 815,236	R 721,360	R 8,393,673	8.39%
Base Case**	R 822,854	R 0	R 7,744,007	
Window (EE-1)	R 828,640	R 132,960	R 7,931,420	2.42%
Window (EE-2)	R 827,708	R 321,320	R 8,111,009	4.74%
Window (EE-3)	R 826,789	R 398,880	R 8,179,920	5.63%
W-3 R-1			R 8,157,424	5.34%

* With respect to Base Case.

Figure 6 EE Alternative LCC Comparison (Hospital – Lowveld/Mpumalanga)



For the medium sized, single storey hospital building in Lowveld/Mpumalanga region, the base case window glazings and roofs result in the lowest life cycle costs. However, the life cycle cost of the wall with the 50 mm air gap (EE-0) is only 0.006% higher than that of the base case and is therefore the recommended option.

3.2.5 Results and Comments

The energy efficiency improvements to the single storey hospital building that result in the lowest life-cycle costs are shown in Table 17.

Table 17 Energy Efficiency Alternative with Lowest Life-Cycle Cost

Region	Energy Efficiency Alternative
South Cape	Base case
Highveld/Interior	50 mm air gap added to walls (EE-0)
Lowveld/Mpumalanga	50 mm air gap added to walls (EE-0)

Additional information relevant to the results shown in the above table is provided in the Section 4.1.4 of this report.

3.3 High Rise Office Building

3.3.1 Introduction

This section describes the high rise office notional building.

3.3.2 Building Profile

The high rise office is defined as a 20 storey - 25,000 m² building with floor plate dimensions of ~35 x 35 m with a typical floor to floor height of 4 m.

The building is served by a central low pressure variable-air-volume (VAV) air handling system, requiring a duct static pressure of 70 Pa which includes the VAV terminal with a heater. The low pressure VAV systems do not have a VAV box as the volume is controlled at the diffuser. Perimeter heating is provided by electric terminal re-heaters in the low-pressure VAV terminals. The heaters switch on when the terminal reaches its minimum flow condition (30%). The supply air temperature is floated between 12 and 18 degrees C, controlled from the hottest room in the zone. If the system is properly zoned, the re-heating applies to 30% of the maximum air from 18 to 21 degrees C, plus the structural losses, minus credit for lights. The cooling load is met by central screw chillers rated at 5.5 $kW_{capacity}/kW_{input}$. Operation of the air handling unit is restricted to occupied hours only. Temperature set-back is assumed during unoccupied hours in the winter and summer time. Domestic hot water is met with electric water heaters located every three floors.

Building and Plenum Heights: Floor to floor height is 4 m. Plenum height is typically 650 mm and separated by a t-bar suspended ceiling

Fenestration: Glazing is assumed to be single pane thermally unbroken window employing 6 mm glass. The most popular glazing is a “cool grey” or grey tint with a shading coefficient of 0.7. This glazing construction has a heat transmission value of U=5.8W/m². Interior shading is assumed.

Opaque Wall: The opaque wall is assumed to be curtain wall with construction characteristics as shown in Table 18 and an overall insulation value of RSI 1.72.

Table 18 High Rise Office Opaque Wall Construction Detail (Curtain Cavity Wall)

- Metal or glass panel (aluminium)
- 50 mm rigid insulation
- Steel frame/aluminium
- Dry wall

(RSI=1.72)

Roof Construction: Roof construction is assumed to be a built-up roof with an overall insulation value of RSI 1.67. The roof construction characteristics and detail are shown in Table 19.

Table 19 High Rise Office Roof Construction Detail (Built-up Roof)

- 50 mm gravel ballast
- waterproofing membrane
- 50 mm rigid insulation
- 200 mm concrete roof
- beam/joist structure c/w suspended ceiling

(RSI = 1.67)

Building Facades: Bay width is assumed to be 7.0 m long. Overall length of glazing in the bay is 5.0 m. Window height is 1.5 m. Finally, sill height is assumed to be 0.9 m. The above applies to all four building facades.

General Lighting: Interior lighting is based on linear T8 fluorescent lamps with electronic control gear (ECG) or electronic ballasts. Recessed fluorescent luminaires are the norm for offices. Typical luminaires use either 3 x 18W, 590 mm lamps or 4 x 36W, 1200 mm lamps. The rated initial lumens and system wattage for the two luminaire types are shown in Table 20. General design assumes an illumination of 500 Lux. Table 20 also lists the calculated luminaire density and lighting power density (LPD) for the two luminaire types required for a 500 Lux lighting design.

Table 20 High Rise Office Fluorescent System Performance Parameters Using T8 Fluorescent Lighting with ECG

Luminaire Type	Lamp Initial Lumens	Total Luminaire Initial Lumens	Total Luminaire Wattage (Watts)	Calculated System Efficacy (Lumens/Watt)	Required Density at 500 Lux and 0.5 LL (m^2/luminaire)	Calculated LPD (W/m^2)
3 x 18 W	1150	3450	63	55	3.45	18.3
4 x 36W	2750	11 000	140	79	11.0	12.7

Exterior Lighting: Exterior lighting has been assumed with a provision of 2 150W HPS lamps per side for a total connected load of 1.2 kW.

Office Equipment & Plug Loads: A value of 10W/m² has been assumed for the electric power density value.

Occupancy: An average actual occupancy density of 18 m²/person is proposed. (AC design is generally based on 10 m²/person.)

Cooling Performance Characteristics & Sizing: A coefficient of performance (COP) of 5.5 at full load was assumed for the chillers. This is based on current manufacturer's specifications. Cooling plant has been assumed to be sized at a density of 100-120W/m^2. At a cooling plant design of 100 W/m², chiller size would be 2.5 MW.

Economizer Cycle: A dry-bulb based air side economizer has been assumed to be present to take advantage of outside air for free-cooling in the Highveld/Interior region only.

Cooling Tower: Standard cooling tower.

Heating Efficiency & Sizing: Electric re-heaters (terminal reheat)

Air Flow Rates: Air flow rate of 6.7 L/s.m² (corrected for 1700 m altitude for Johannesburg) at summer design conditions have been assumed based on the consultant suggested design practices. This is equivalent to an air handler unit sized to provide ~165 000 L/s. The VAV is assumed to throttle back to a minimum of 30% of peak design flow. Variable speed drives have been assumed in supply and return fans.

The air handling units assume full modulating dampers for exhaust, outside air and return in order to enable a dry-bulb based economizer cycle in the Highveld/Interior region only.

Supply and Return Fan Size: Supply fan size is based on a total static pressure of 500-750 Pa (Low pressure VAV). Return fan size is based on a total static pressure of 250 Pa.

Fresh Air Requirements: Fresh air ventilation rates have been assumed based on 7.5 L/s.person at 10m^2/person or 0.75 L/s.m².

Exhaust Fans: Washroom exhaust was assumed based on an exhaust rate of 15 l/s.m^2 washroom and two washrooms per floor. This results in a total exhaust volume of 3 800 l/s.

Domestic Hot Water: Hot water (at 60°C, electric heating assumed) is estimated as 15 L/capita/day for offices with canteen.

Miscellaneous Energy (Elevators): Energy use by elevators is based on the presence of 4 elevators. Each is equipped with a 44 kW electric motor.

Office Equipment and Plug Load Requirements: For the general office requirements, power points (16 amp 3 pin round switched socket outlets) are provided through power skirting run along the walls or by recessed floor outlets. A diversified plug load (including computers) of 10 W/m² has been assumed.

Operation Schedules: Operation of the air handling unit is restricted to occupied hours only, however the air handling unit is assumed to cycle during the unoccupied hours in the winter period on a call for heating. HVAC Equipment operation is in accordance with the schedule. This applies to fan operation and introduction of fresh air.

Weather Data: The weather data used in shown in Table 21.

Table 21 High Rise Office Weather Data and Elevations

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

Regional Variations: Air handling units are equipped with a dry-bulb based economizer in the Highveld/Interior region only.

Table 22 High Rise Office Air Handling Unit Operating Schedules

Fan Operation (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outside Air (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating Temperature °C (OFF=0)																								
W	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0	0	0
S	0	0	0	0	0	21	21	21	21	21	21	21	21	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooling Temperature °C (OFF=0)																								
W	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0	0	0
S	0	0	0	0	0	23	23	23	23	23	23	23	23	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting Operation (Fraction)																								
W	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2
S	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
H	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Equipment “Plug Loads” Operation (Fraction)																								
W	.15	.15	.15	.15	.15	1	1	1	1	1	1	1	1	1	1	1	1	1	.15	.15	.15	.15	.15	.15
S	.15	.15	.15	.15	.15	1	1	1	1	1	1	1	1	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
H	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Hours																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A.M.								Noon									P.M.						Midnight	

3.4 High Rise Office Building Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.4.1 Wall Construction

The wall constructions and their associated costs, together with the base case information, are summarized in Table 23.

Table 23 EE Alternatives for Wall Insulation (High Rise Office)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)
Base Case	Extruded Polystyrene	50	1.72	--	--	--
EE Level-1	Extruded Polystyrene	Base + 75	Base + 0.69	R 22.80	R 22.00	R 25.00
EE Level-2	Extruded Polystyrene	Base + 100	Base + 1.38	R 45.43	R 22.00	R 50.00

*Additional is in reference to the Base Case.

3.4.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 24.

Table 24 EE Alternatives for Roof Insulation (High Rise Office)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	—	50	1.67	--	--
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

*Additional is in reference to the Base Case.

3.4.3 Windows

Three energy efficiency alternative window glazings were analyzed. The descriptions and costs are summarized in Table 25.

Table 25 EE Alternatives for Window Glazing (High Rise Office)

EE Level	Glazing Description	Shading Coefficient	Overall RSI Value	Material Cost (R/m² window)	Additional Labour Cost (R/m² window)	Incremental Cost (R/m² window)
Base Case	Single 6.38 mm clear	0.7	0.17	R 200.00	--	--
EE Level-1	Single 6mm Grey Low E (e=0.1)	0.4	0.22	R 440.00	--	R 240.00
EE Level-2	Double 6/12/6 mm Grey	0.4	0.31	R 680.00	R 100.00	R 580.00
EE Level-3	Double 6/12/6 mm Low E	0.4	0.50	R 820.00	R 100.00	R 720.00

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

3.4.4 Modelling Results

Energy efficiency alternatives were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 26, Table 27 and Figure 7.

Table 26 Annual Electricity Consumption by End-Use (High Rise Office – South Cape)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower/ Heat Reject. (kWh/yr)	Pumps/ Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	1,441,540	922,811	1,031,098	1,392,122	87,463	51,541	754,383	295,286	244,760	6,221,004	248.8
Wall (EE-1)	1,441,540	922,811	938,199	1,389,341	87,379	51,666	753,148	295,286	244,760	6,124,130	245.0
Wall (EE-2)	1,441,540	922,811	884,467	1,388,101	87,557	51,838	752,486	295,286	244,760	6,068,846	242.8
Roof (EE-1)	1,441,540	922,811	1,011,169	1,391,968	87,392	51,510	754,294	295,286	244,760	6,200,730	248.0
Roof (EE-2)	1,441,540	922,811	1,000,486	1,391,945	87,368	51,525	754,244	295,286	244,760	6,189,965	247.6
Roof (EE-3)	1,441,540	922,811	993,584	1,391,903	87,298	51,510	754,217	295,286	244,760	6,182,909	247.3
Window (EE-1)	1,441,540	922,811	997,259	1,292,852	84,825	50,758	727,331	295,286	244,760	6,057,422	242.3
Window (EE-2)	1,441,540	922,811	833,470	1,303,139	85,243	51,055	729,040	295,286	244,760	5,906,344	236.3
Window (EE-3)	1,441,540	922,811	732,870	1,317,106	85,445	51,118	731,892	295,286	244,760	5,822,828	232.9

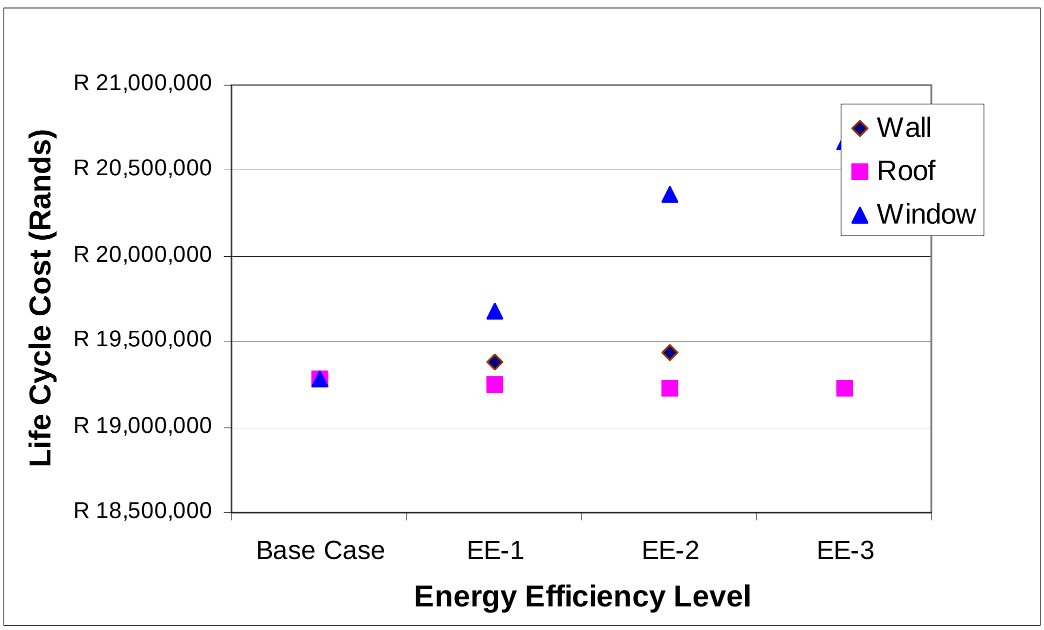
Table 27 EE Alternative LCC Comparison (High Rise Office – South Cape)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 2,049,170	R 0	R 19,285,060	
Wall (EE-1)	R 2,014,367	R 423,920	R 19,381,440	0.50%
Wall (EE-2)	R 1,994,247	R 672,697	R 19,440,860	0.81%
Base Case	R 2,049,170	R 0	R 19,285,060	
Roof (EE-1)	R 2,039,680	R 54,880	R 19,250,630	-0.18%
Roof (EE-2)	R 2,034,460	R 82,602	R 19,229,220	-0.29%
Roof (EE-3)	R 2,031,102	R 110,458	R 19,225,470	-0.31%
Base Case**	R 2,049,170	R 0	R 19,285,060	
Window (EE-1)	R 2,006,828	R 792,000	R 19,678,570	2.04%
Window (EE-2)	R 1,960,278	R 1,914,000	R 20,362,480	5.59%
Window (EE-3)	R 1,944,018	R 2,376,000	R 20,671,460	7.19%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 7 EE Alternative LCC Comparison (High Rise Office – South Cape)



For the high-rise office building in the South Cape region, the base case window glazings and walls result in the lowest life cycle costs. However, roofs EE-1, EE-2, and EE-3 do provide lower life cycle costs than that of the base case. The lowest life cycle cost is the base case roof with an additional 75 mm of extruded polystyrene insulation (EE-3). Combining additional roof insulation with wall insulation did not improve the life cycle cost.

Highveld/Interior Region

The modelling results are summarized in Table 28, Table 29 and Figure 8.

Table 28 Annual Electricity Consumption by End-Use and End Use Intensity (High Rise Office – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower/HeatReject. (kWh/yr)	Pumps/Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	1,441,540	922,811	713,244	1,567,263	83,582	48,156	811,778	280,795	244,760	6,113,929	244.6
Wall (EE-1)	1,441,540	922,811	647,269	1,560,662	83,211	48,169	809,233	280,795	244,760	6,038,450	241.5
Wall (EE-2)	1,441,540	922,811	610,147	1,557,432	83,198	48,263	807,834	280,795	244,760	5,996,780	239.9
Roof (EE-1)	1,441,540	922,811	702,506	1,564,963	83,388	48,123	811,143	280,795	244,760	6,100,029	244.0
Roof (EE-2)	1,441,540	922,811	696,705	1,563,664	83,338	48,107	810,790	280,795	244,760	6,092,510	243.7
Roof (EE-3)	1,441,540	922,811	692,999	1,562,865	83,312	48,107	810,561	280,795	244,760	6,087,750	243.5
Window (EE-1)	1,441,540	922,811	715,340	1,454,431	80,317	47,544	765,671	280,795	244,760	5,953,209	238.1
Window (EE-2)	1,441,540	922,811	608,366	1,458,538	80,418	47,637	766,675	280,795	244,760	5,851,540	234.1
Window (EE-3)	1,441,540	922,811	532,895	1,473,668	80,949	47,857	770,139	280,795	244,760	5,795,414	231.8

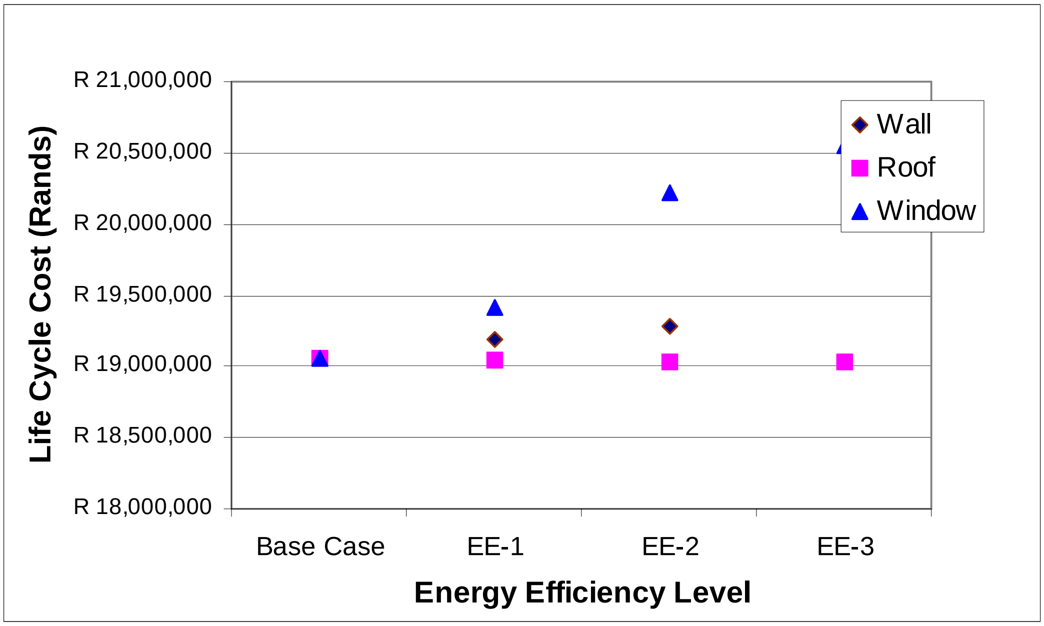
Table 29 EE Alternative LCC Comparison (High Rise Office – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 2,024,583	R 0	R 19,053,670	
Wall (EE-1)	R 1,993,690	R 423,920	R 19,186,850	0.70%
Wall (EE-2)	R 1,976,741	R 672,697	R 19,276,110	1.17%
Base Case	R 2,024,583	R 0	R 19,053,670	
Roof (EE-1)	R 2,017,472	R 54,880	R 19,041,620	-0.06%
Roof (EE-2)	R 2,013,578	R 82,602	R 19,032,700	-0.11%
Roof (EE-3)	R 2,011,104	R 110,458	R 19,037,270	-0.09%
Base Case**	R 2,024,583	R 0	R 19,053,670	
Window (EE-1)	R 1,979,380	R 792,000	R 19,420,250	1.92%
Window (EE-2)	R 1,945,298	R 1,914,000	R 20,221,500	6.13%
Window (EE-3)	R 1,931,550	R 2,376,000	R 20,554,120	7.87%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 8 EE Alternative LCC Comparison (High Rise Office – Highveld/Interior)



For the high-rise campus office building in Highveld/Interior region, the base case window glazings and walls result in the lowest life cycle costs. Additional roof insulation does lower life cycle costs for EE-1, EE-2, and EE-3. The base case roof insulated with an additional 50 mm of extruded polystyrene (EE-2) provides the lowest life cycle cost.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 30, Table 31 and Figure 9. Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Table 30 Annual Electricity Consumption by End-Use and End Use Intensity (High Rise Office – Lowveld/Mpumalanga)

Alternative	**Lights (kWh/yr)**	**Equipment (kWh/yr)**	**Heating (kWh/yr)**	**Cooling (kWh/yr)**	**Tower/HeatReject. (kWh/yr)**	**Pumps/Aux. (kWh/yr)**	**Fans (kWh/yr)**	**Hot Water (kWh/yr)**	**Ext. Lights (kWh/yr)**	**Total (kWh/yr)**	**EUI (kWh/m^2-yr)**
Base Case**	1,441,540	922,811	438,939	1,863,560	99,589	55,309	756,241	225,217	244,760	6,047,966	241.9
Wall (EE-1)	1,441,540	922,811	393,988	1,861,713	99,532	55,387	754,845	225,217	244,760	5,999,793	240.0
Wall (EE-2)	1,441,540	922,811	368,156	1,860,895	99,458	55,403	754,089	225,217	244,760	5,972,329	238.9
Roof (EE-1)	1,441,540	922,811	430,195	1,863,190	99,516	55,309	755,967	225,217	244,760	6,038,505	241.5
Roof (EE-2)	1,441,540	922,811	425,450	1,862,964	99,538	55,325	755,818	225,217	244,760	6,033,423	241.3
Roof (EE-3)	1,441,540	922,811	422,507	1,862,806	99,513	55,325	755,720	225,217	244,760	6,030,199	241.2
Window (EE-1)	1,441,540	922,811	417,618	1,771,496	96,915	55,090	729,280	225,217	244,760	5,904,727	236.2
Window (EE-2)	1,441,540	922,811	344,131	1,779,014	97,053	55,168	730,440	225,217	244,760	5,840,134	233.6
Window (EE-3)	1,441,540	922,811	295,822	1,791,122	97,217	55,152	733,046	225,217	244,760	5,806,687	232.3

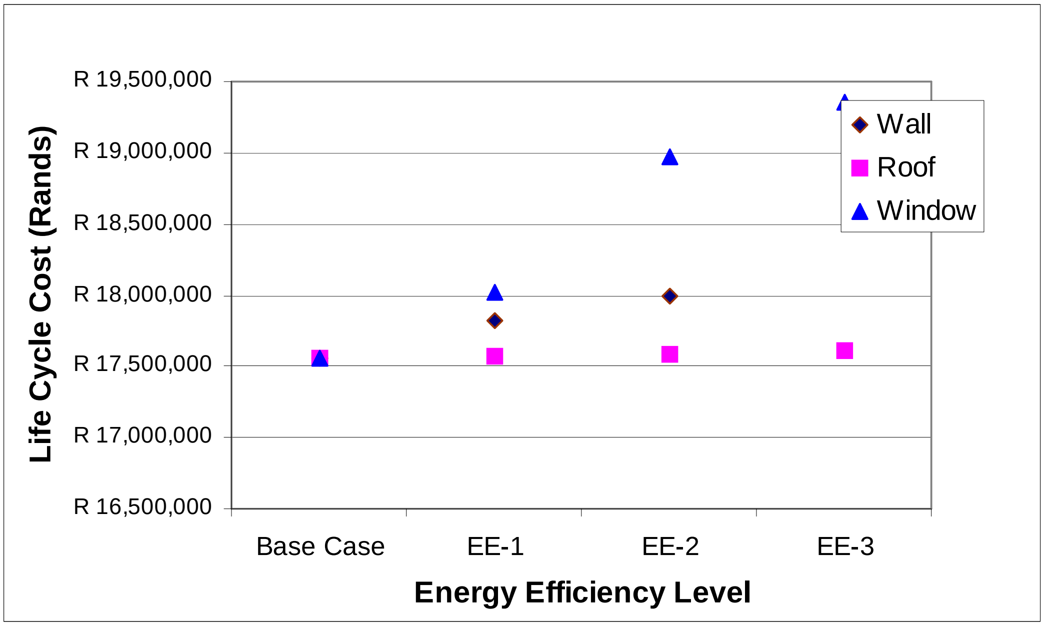
Table 31 EE Alternative LCC Comparison (High Rise Office – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 1,864,982	R 0	R 17,551,640	
Wall (EE-1)	R 1,849,053	R 423,920	R 17,825,650	1.56%
Wall (EE-2)	R 1,839,951	R 672,697	R 17,988,760	2.49%
Base Case	R 1,864,982	R 0	R 17,551,640	
Roof (EE-1)	R 1,861,454	R 54,880	R 17,573,310	0.12%
Roof (EE-2)	R 1,859,820	R 82,602	R 17,585,660	0.19%
Roof (EE-3)	R 1,858,792	R 110,458	R 17,603,840	0.30%
Base Case**	R 1,864,982	R 0	R 17,551,640	
Window (EE-1)	R 1,831,195	R 792,000	R 18,025,660	2.70%
Window (EE-2)	R 1,812,130	R 1,914,000	R 18,968,240	8.07%
Window (EE-3)	R 1,804,171	R 2,376,000	R 19,355,330	10.28%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 9 EE Alternative LCC Comparison (High Rise Office – Lowveld/Mpumalanga)



For the high-rise office building in Lowveld/Mpumalanga region, the base case results in the lowest life cycle cost.

3.4.5 Results and Comments

The energy efficiency alternatives with the lowest life-cycle costs for the notional large office building are shown in Table 32.

Table 32 Energy Efficiency Alternative with Lowest Life-Cycle Cost (High Rise Office)

Region	Energy Efficiency Alternative
South Cape	75 mm additional extruded polystyrene added to roof (EE-3)
Highveld/Interior	50 mm additional extruded polystyrene added to roof (EE-2)
Lowveld/Mpumalanga	Base case

Additional information relevant to the results shown in the above table is provided in Section 4.1.4 of this report.

3.5 Suburban Strip Shopping Mall

3.5.1 Introduction

This section describes the suburban strip shopping mall notional building.

3.5.2 Building Profile

The suburban strip shopping mall is assumed to be a 1 600 m², one-storey structure. The structure contains eight 10 x 20 m stores, each with a floor area of 200 m². Ceiling height is assumed to be 3.5 m. Each store is served by its own ceiling concealed DX split unit, which uses reverse cycles for heating. Fan-powered fresh air is introduced; however there is no economizer cycle. Domestic hot water is provided by electric water heaters.

Building and Plenum Heights: Floor to floor height is assumed to be 4.1 m with a plenum height of 600 mm.

Fenestration: Glazing is assumed to be clear, single pane windows in thermally-broken aluminium frames having a shading coefficient of 1.0. Some form of shading of glass surfaces, in conjunction with building orientation, is generally used. A 2m wide covered walkway has been assumed in front of all stores. There is no shading other than the overhang.

Opaque Wall: The opaque walls are assumed to be masonry unit walls with the construction characteristics shown in Table 33. As shown, construction in Cape Town assumes a masonry wall with a 50 mm air cavity. Other locations typically use a masonry wall with no air cavity.

Table 33 Strip Mall Opaque Wall Construction Detail

<u>Highveld/Interior and Lowveld/Mpumalanga Regions</u> o 10 mm cement/sand plaster o 180 mm cement brick o 10 mm cement/sand plaster (RSI =0.4) Or <u>South Cape Region</u> o 10 mm cement/sand plaster o 90 mm cement brick o 50 mm cavity o 90 mm cement brick o 10 mm cement/sand plaster (RSI = 0.56)

Roof Construction: Roof construction is assumed to be a mono pitch roof with profiled, coloured steel roof sheets on structural steel trusses as shown in Table 34.

Table 34 Strip Mall Roof Construction Detail

(Built-up Roof)
o 1 mm profiled steel roof sheet o Steel trusses o 50 mm foil backed fibre glass insulation installed over the purlins derated by 10% due to over purlins installation o Suspended ceiling (RSI = 1.27)

Building Facades: Bay width is assumed to be 10 m long, the width of one store. Overall length of glazing in the bay is 8.5 m. Window height is 2.4 m. Sill height is assumed to be 0.3 m. All facades other than the front are windowless.

Lighting: General lighting is based on T8 fluorescent lamps with electronic control gear (ECG) or electronic ballasts. Lighting is designed to 750 Lux. Fixtures are assumed to be 0.6 x 1.2 m two-lamps with a power draw of 70 W/fixture, translating into a lighting power density (LPD) of 24 to 26 W/m². This lighting design is assumed to cover 90% of the floor space. Architectural lighting based on incandescent/halogen/CFL lighting designed for 300 Lux is present in 10% of the floor with a LPD of 40 W/m². Weighted average LPD is therefore assumed to be 26.5 W/m².

Exterior Lighting: Exterior lighting has been assumed to have a total connected load of 1.5 kW. This is based on ten 150 HPS lamps for the building perimeter.

Office Equipment & Plug Loads: A value of 5 W/m² has been assumed for the plug load value.

Occupancy: An average occupancy density of 23 m²/person was assumed.

Cooling Performance Characteristics & Sizing: A COP of 3.0 (EER=10.3) is assumed for the 14-17 kW split units.

Economizers: The cooling equipment assumes a fixed fresh air volume with no damper modulation or economizer control.

Heating Efficiency & Sizing: Heating is provided by 14 –17 kW reverse cycle heat pumps. A COP of 2.8 was assumed.

Air Flow Rates: Air flow rates were assumed to be 6.7 L/s-m².

Supply Fan Size: Supply fans are included in the split unit COP/EER values.

Fresh Air Requirements: Fresh air requirements were set to 7.5 L/s-person at 5 m²/person or 1.5 L/s.m².

Exhaust Fans: Washroom exhaust was calculated based on an exhaust rate of 15 l/s-m^2 per washroom and two washrooms per store. Given a washroom floorspace of 1.57 m^2, this results in a total exhaust volume of 377 L/s.

Domestic Hot Water: Service hot water is heated electrically and is provided at 60^{o}C. Use is estimated at ½ l/capita/day.

Weather Data: The weather data used is shown in Table 35.

Table 35 Strip Mall Weather Data and Elevations

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

Regional Variations: As stated in the description of the opaque wall buildings in the South Cape region are built with a masonry wall containing a 50 mm air cavity. Buildings in all other regions use masonry wall with no cavity.

Operation Schedules: Operation schedules are shown in Table 36. There is no heating setback temperature, and no air-conditioning during unoccupied hours; however it is assumed that the units will cycle during unoccupied hours in the winter period on a call for heating.

Table 36 Strip Mall Air Handling Unit Operating Schedules

Fan Operation (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
H	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Outside Air (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
H	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Heating Temperature °C (OFF=0)																								
W	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0	0	0
S	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0	0	0
H	0	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0	0	0	0
Cooling Temperature °C (OFF=0)																								
W	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0	0	0
S	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0	0	0
H	0	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0	0	0	0
Lighting Operation (Fraction)																								
W	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2
S	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2
H	0.2	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Equipment “Plug Loads” Operation (Fraction)																								
W	.2	.2	.2	.2	.2	1	1	1	1	1	1	1	1	1	1	1	1	1	.2	.2	.2	.2	.2	.2
S	.2	.2	.2	.2	.2	1	1	1	1	1	1	1	1	1	1	1	1	1	.2	.2	.2	.2	.2	.2
H	.2	.2	.2	.2	.2	.2	1	1	1	1	1	1	1	1	1	1	1	.2	.2	.2	.2	.2	.2	.2
Hours																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				A.M.								Noon					P.M.						Midnight	

3.6 Suburban Strip Shopping Mall Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.6.1 Wall Construction

Because the base case wall construction varies by region, two different sets of energy efficiency wall constructions are presented. For the South Cape region, four alternatives were analyzed. These constructions and their associated costs, together with the base case information, are summarized in Table 37. For the other two regions, five alternatives are analyzed. Their constructions, the associated costs, and the base case information, are summarized in Table 38.

Table 37 EE Alternatives for Wall Insulation (Strip Mall – South Cape)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[4] (R/m façade)
Base Case	—	0	0.68	50	--	--	--
EE Level-1	Fiberglass batts	Base +25	Base + 0.63	25	R 12.78	R 17.00	--
EE Level-2	Fiberglass batts	Base +50	Base + 1.07	25	R 15.49	R 17.00	R 25.00
EE Level-3	Fiberglass batts	Base +75	Base + 1.67	25	R 19.36	R 17.00	R 50.00
EE Level-4	Fiberglass batts	Base +100	Base + 2.22	25	R 22.13	R 17.00	R 75.00

*Additional is in reference to the Base Case.

Table 38 EE Alternatives for Wall Insulation (Strip Mall – Highveld/Interior and Lowveld/Mpumalanga)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[5] (R/m façade)
Base Case	—	0	0.42	0	--	--	--
EE Level-0	—	Base + 0	Base + 0.26	50	--	--	R 50.00
EE Level-1	Fiberglass batts	Base + 25	Base+ 0.63	0	R 12.78	R 17.00	R 25.00
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	0	R 15.49	R 17.00	R 50.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	0	R 19.36	R 17.00	R 75.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	0	R 22.13	R 17.00	R 100.00

*Additional is in reference to the Base Case.

[4] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.
[5] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

3.6.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 39.

Table 39 EE Alternatives for Roof Insulation (Strip Mall)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	—	50	1.27	-	-
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

*Additional is in reference to the Base Case.

3.6.3 Windows

Three energy efficiency alternative window glazings were analyzed. The descriptions and costs are summarized in Table 40.

Table 40 EE Alternatives for Window Glazing (Strip Mall)

EE Level	Glazing Description	Shading Coefficient	Overall RSI Value	Material Cost (R/m² window)	Additional Labour Cost (R/m² window)	Incremental Cost (R/m² window)
Base Case	Single 6.38 mm clear	1	0.17	R 200.00	--	--
EE Level-1	Single 6mm Grey Low E (e=0.1)	0.4	0.22	R 440.00	--	R 240.00
EE Level-2	Double 6/12/6 mm Grey	0.4	0.31	R 680.00	R 100.00	R 580.00
EE Level-3	Double 6/12/6 mm Low E	0.4	0.50	R 820.00	R 100.00	R 720.00

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

3.6.4 Modelling Results

Energy efficiency alternatives were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 41, Table 42 and Figure 10.

Table 41 Annual Electricity Consumption by End-Use and End Use Intensity (Strip Mall – South Cape)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	230,830	43,560	8,251	26,082	38,056	2,033	6,214	355,026	118.3
Wall (EE-1)	230,830	43,560	6,872	26,583	38,056	2,033	6,214	354,148	118.0
Wall (EE-2)	230,830	43,560	6,359	26,793	38,056	2,033	6,214	353,845	117.9
Wall (EE-3)	230,830	43,560	6,043	26,933	38,056	2,033	6,214	353,669	117.9
Wall (EE-4)	230,830	43,560	5,820	27,035	38,056	2,033	6,214	353,548	117.8
Roof (EE-1)	230,830	43,560	6,180	25,682	38,056	2,033	6,214	352,555	117.5
Roof (EE-2)	230,830	43,560	5,283	25,500	38,056	2,033	6,214	351,476	117.2
Roof (EE-3)	230,830	43,560	4,790	25,400	38,056	2,033	6,214	350,883	117.0
Window (EE-1)	230,830	43,560	8,462	24,635	38,056	2,033	6,214	353,790	117.9
Window (EE-2)	230,830	43,560	7,525	24,964	38,056	2,033	6,214	353,182	117.7
Window (EE-3)	230,830	43,560	7,525	24,964	38,056	2,033	6,214	353,182	117.7

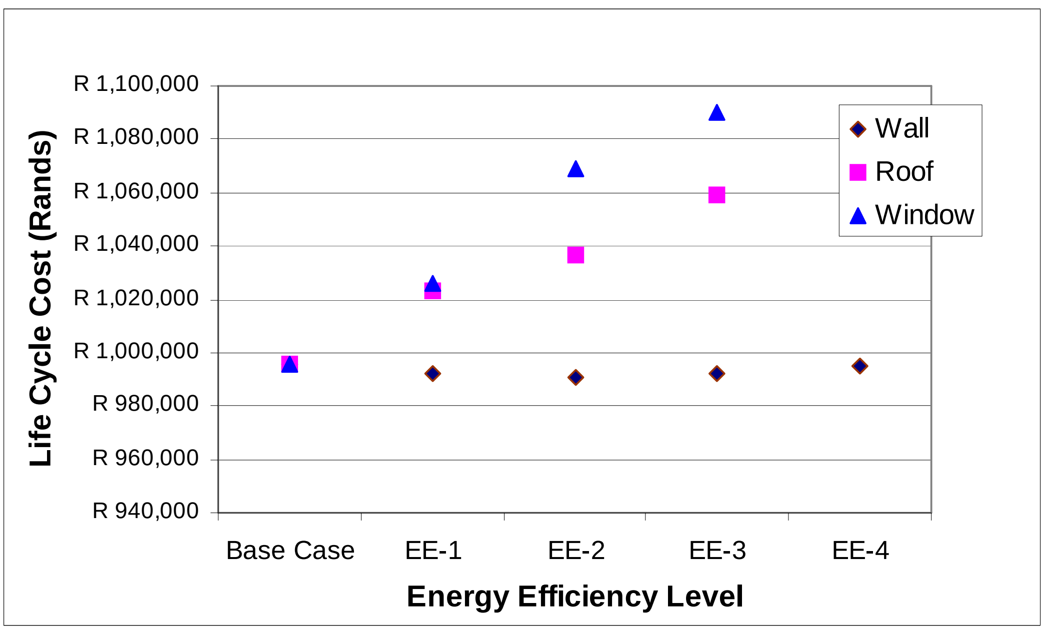
Table 42 EE Alternative LCC Comparison (Strip Mall – South Cape)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 105,792	R 0	R 995,625	
Wall (EE-1)	R 103,689	R 16,230	R 992,063	-0.36%
Wall (EE-2)	R 102,841	R 22,707	R 990,560	-0.51%
Wall (EE-3)	R 102,283	R 29,816	R 992,417	-0.32%
Wall (EE-4)	R 101,882	R 36,326	R 995,153	-0.05%
Base Case	R 105,792	R 0	R 995,625	
Roof (EE-1)	R 101,109	R 71,680	R 1,023,233	2.77%
Roof (EE-2)	R 98,686	R 107,888	R 1,036,637	4.12%
Roof (EE-3)	R 97,181	R 144,272	R 1,058,858	6.35%
Base Case **	R 105,792	R 0	R 995,625	
Window (EE-1)	R 105,078	R 37,200	R 1,026,105	3.06%
Window (EE-2)	R 104,009	R 89,900	R 1,068,745	7.34%
Window (EE-3)	R 104,009	R 111,600	R 1,090,445	9.52%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 10 EE Alternative LCC Comparison (Strip Mall – South Cape)



For the suburban strip mall in the South Cape region, the base case window glazings and roofs result in the lowest life cycle costs. However, walls EE-1, EE-2, EE-3, and EE-4 do provide lower life cycle costs than that of the base case. The lowest life cycle cost is that of the wall with an additional 50 mm fibreglass batt insulation (EE-2). Combining additional roof insulation with wall insulation did not provide additional life cycle cost reductions.

Highveld/Interior Region

The modelling results are summarized in Table 43, Table 44 and Figure 11.

Table 43 Annual Electricity Consumption by End-Use and End Use Intensity (Strip Mall – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	230,830	43,560	10,478	29,725	38,198	1,968	6,214	360,973	225.6
Wall (EE-0)	230,830	43,560	8,539	30,020	38,198	1,968	6,214	359,329	224.6
Wall (EE-1)	230,830	43,560	7,492	30,234	38,198	1,968	6,214	358,496	224.1
Wall (EE-2)	230,830	43,560	6,901	30,359	38,198	1,968	6,214	358,030	223.8
Wall (EE-3)	230,830	43,560	6,542	30,435	38,198	1,968	6,214	357,747	223.6
Wall (EE-4)	230,830	43,560	6,299	30,489	38,198	1,968	6,214	357,558	223.5
Roof (EE-1)	230,830	43,560	8,031	28,726	38,198	1,968	6,214	357,527	223.5
Roof (EE-2)	230,830	43,560	6,929	28,250	38,198	1,968	6,214	355,949	222.5
Roof (EE-3)	230,830	43,560	6,313	27,968	38,198	1,968	6,214	355,051	221.9
Window (EE-1)	230,830	43,560	11,195	29,593	38,198	1,968	6,214	361,558	226.0
Window (EE-2)	230,830	43,560	10,299	29,854	38,198	1,968	6,214	360,923	225.6
Window (EE-3)	230,830	43,560	9,135	28,586	38,198	1,968	6,214	358,491	224.1

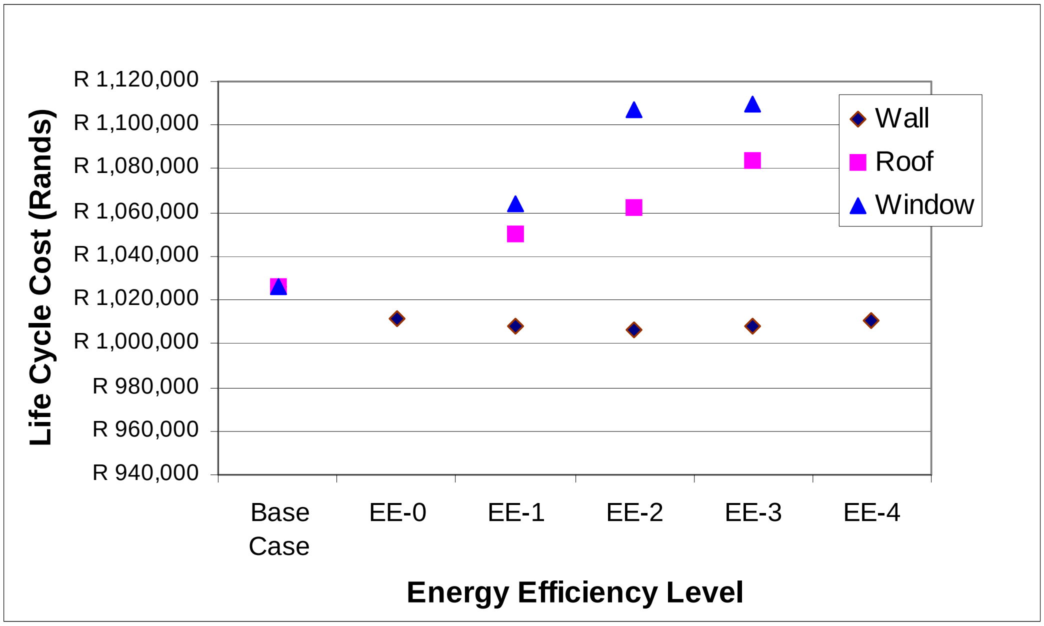
Table 44 EE Alternative LCC Comparison (Strip Mall – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 109,040	R 0	R 1,026,192	
Wall (EE-0)	R 106,384	R 10,000	R 1,011,196	-1.46%
Wall (EE-1)	R 104,852	R 21,230	R 1,008,009	-1.77%
Wall (EE-2)	R 103,948	R 27,707	R 1,005,978	-1.97%
Wall (EE-3)	R 103,376	R 34,816	R 1,007,704	-1.80%
Wall (EE-4)	R 102,973	R 41,326	R 1,010,421	-1.54%
Base Case	R 109,040	R 0	R 1,026,192	
Roof (EE-1)	R 103,994	R 71,680	R 1,050,384	2.36%
Roof (EE-2)	R 101,385	R 107,888	R 1,062,038	3.49%
Roof (EE-3)	R 99,789	R 144,272	R 1,083,402	5.57%
Base Case **	R 109,040	R 0	R 1,026,192	
Window (EE-1)	R 109,100	R 37,200	R 1,063,957	3.68%
Window (EE-2)	R 108,043	R 89,900	R 1,106,710	7.85%
Window (EE-3)	R 106,067	R 111,600	R 1,109,813	8.15%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 11 EE Alternative LCC Comparison (Strip Mall – Highveld/Interior)



For the suburban strip mall in the Highveld/Interior region, the base case window glazings and roofs result in the lowest life cycle costs. However, walls EE-1, EE-2, EE-3, and EE-4 do provide lower life cycle costs than that of the base case. The lowest life cycle cost is that of the wall with an additional 50 mm fibreglass batt insulation (EE-2). Combining additional roof insulation with wall insulation did not provide additional life cycle cost reductions.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 45, Table 46 and Figure 12.

Table 45 Annual Electricity Consumption by End-Use and End Use Intensity (Strip Mall – Lowveld/Mpumalanga)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	230,830	43,560	1,380	32,182	38,054	1,720	6,214	353,940	221.2
Wall (EE-0)	230,830	43,560	1,020	33,340	38,054	1,720	6,214	354,738	221.7
Wall (EE-1)	230,830	43,560	849	33,612	38,054	1,720	6,214	354,839	221.8
Wall (EE-2)	230,830	43,560	778	33,769	38,054	1,720	6,214	354,925	221.8
Wall (EE-3)	230,830	43,560	744	33,866	38,054	1,720	6,214	354,988	221.9
Wall (EE-4)	230,830	43,560	718	33,934	38,054	1,720	6,214	355,030	221.9
Roof (EE-1)	230,830	43,560	980	31,646	38,054	1,720	6,214	353,004	220.6
Roof (EE-2)	230,830	43,560	821	31,388	38,054	1,720	6,214	352,587	220.4
Roof (EE-3)	230,830	43,560	738	31,232	38,054	1,720	6,214	352,348	220.2
Window (EE-1)	230,830	43,560	1,497	32,810	38,054	1,720	6,214	354,685	221.7
Window (EE-2)	230,830	43,560	1,244	33,054	38,054	1,720	6,214	354,676	221.7
Window (EE-3)	230,830	43,560	1,244	33,054	38,054	1,720	6,214	354,676	221.7

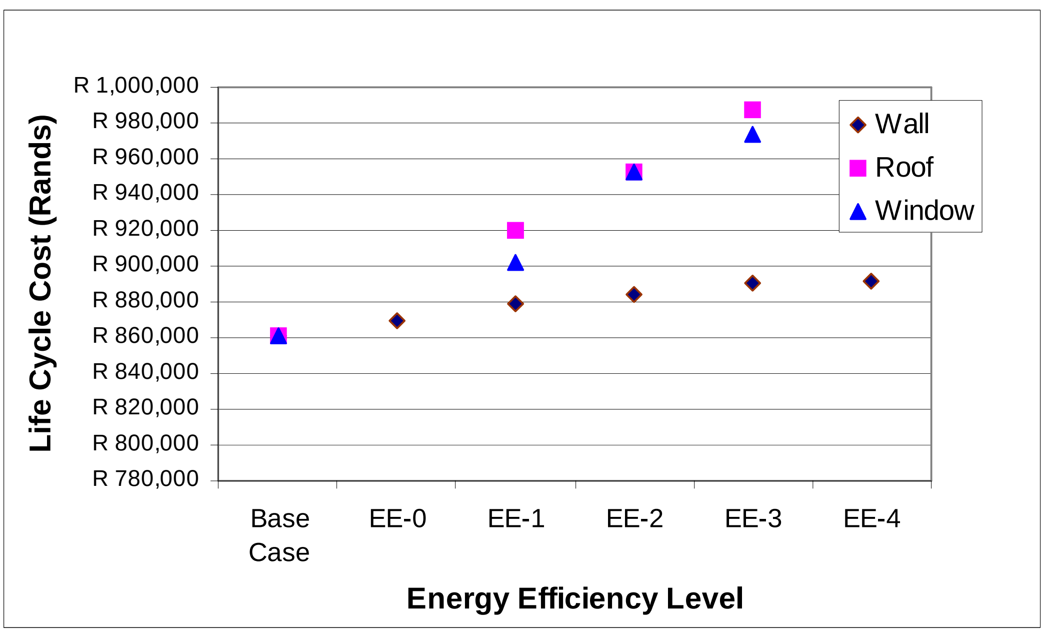
Table 46 EE Alternative LCC Comparison (Strip Mall – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 91,485	R 0	R 860,980	
Wall (EE-0)	R 91,332	R 10,000	R 869,540	0.99%
Wall (EE-1)	R 91,095	R 21,230	R 878,539	2.04%
Wall (EE-2)	R 90,994	R 27,707	R 884,066	2.68%
Wall (EE-3)	R 90,933	R 34,816	R 890,601	3.44%
Wall (EE-4)	R 90,901	R 41,326	R 896,809	4.16%
Base Case	R 91,485	R 0	R 860,980	
Roof (EE-1)	R 90,162	R 71,680	R 920,209	6.88%
Roof (EE-2)	R 89,773	R 107,888	R 952,756	10.66%
Roof (EE-3)	R 89,538	R 144,272	R 986,928	14.63%
Base Case**	R 91,485	R 0	R 860,980	
Window (EE-1)	R 91,904	R 37,200	R 902,123	4.78%
Window (EE-2)	R 91,656	R 89,900	R 952,489	10.63%
Window (EE-3)	R 91,656	R 111,600	R 974,189	13.15%

* With respect to Base Case.

Sensitivity runs were completed with revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 12 EE Alternative LCC Comparison (Strip Mall – Lowveld/Mpumalanga)



For the suburban strip mall in Lowveld/Mpumalanga region, the lowest life cycle cost is achieved with the base case.

3.6.5 Results and Comments

The energy efficiency alternatives with the lowest life-cycle costs for the notional suburban strip mall are shown in Table 47.

Table 47 Energy Efficiency Alternative with Lowest Life-Cycle Cost (Strip Mall)

Region	Energy Efficiency Alternative
South Cape	50 mm fibreglass insulation added to base case walls (EE-2)
Highveld/Interior	50 mm fibreglass insulation added to base case walls (EE-2)
Lowveld/Mpumalanga	Base case

Additional information relevant to the results shown in the above table is provided in Section 4.1.4 of this report.

3.7 Low Rise Office Park Building

3.7.1 Introduction

This section describes the low-rise office park notional building.

3.7.2 Building Profile

The low-rise office park building is defined as a 3-storey building with a naturally-ventilated basement parking garage and conditioned ground and first floor office space. The total floorspace is 3 000 m² (floor plate dimensions of 12.5 x 80 m). The floor-to-floor heights are assumed to be 3 m for the basement and 3.5 m for the office floors.

The two office floors are conditioned by DX split ceiling concealed fan coil units with ducting, constant volume diffusers and remote air-cooled condensing units. Fan operation is restricted to occupied hours only. No heating temperature setback is assumed during unoccupied hours and it is assumed that the units will cycle during unoccupied hours in the winter period on a call for heating. Summer air-conditioning operation is restricted to occupied hours only.

Building and Plenum Heights: Floor to floor height is assumed to be 3.5 m. Plenum height is typically 650 mm and separated by a T-bar suspended ceiling.

Fenestration: Glazing is assumed to be single-pane, thermally unbroken aluminium-framed windows with single-pane 6 mm clear glass with an overall U-value of 5.8 W/m².°C. Windows are assumed to be un-shaded by overhangs, however interior shades are assumed.

Opaque Wall: The opaque walls are assumed to be masonry unit cavity walls with construction characteristics shown in Table 48. As shown, construction for the South Cape region assumes a masonry wall with a 50 mm air cavity with an overall thermal performance of RSI 0.68. Other locations typically use a masonry wall with no air cavity (RSI 0.42).

Table 48 Low Rise Office Opaque Wall Construction Detail (Brick Cavity Wall)

Highveld/Interior and Lowveld/Mpumalanga Regions

- 10 mm cement/sand plaster
- 180 mm cement brick
- 10 mm cement/sand plaster

(RSI =0.42)

Or

South Cape Region

- 10 mm cement/sand plaster
- 90 mm masonry block
- 50 mm cavity
- 90 mm masonry block
- 10 mm cement/sand plaster

(RSI = 0.68)

Roof Construction: Roof construction is assumed to be a pitched roof with profiled, coloured steel roof sheets on timber trusses as shown in Table 49. This configuration results in an overall thermal performance of RSI 1.27.

Table 49 Low Rise Office Roof Construction Detail

- 1 mm profiled steel roof sheet
- Prefabricated timber trusses
- 50 mm foil backed fibre glass installed over the purlins and derated by 10% due to the over purlins installation
- suspended ceiling

(RSI = 1.27

Building Facades: Bay width is assumed to be 5 m long. Overall length of glazing in the bay is 3.6 m. Window height is 1.3 m. and sill height is assumed to be 1.07 m. All four building facades are assumed to be identical.

Parking Garage Ceiling: The parking garage ceiling is assumed to be 30 mm concrete without insulation.

Lighting: Interior lighting is based on linear T8 fluorescent lamps with electronic control gear (ECG) or electronic ballasts. Recessed fluorescent luminaires are the norm for offices. Typical luminaires use either 3 x 18W, 590 mm lamps or 4 x 36W, 1200 mm lamps. The rated initial lumens and system wattage for the two luminaire types are shown in Table 50. General design assumes an illumination of 500 Lux. Table 50 also lists the calculated luminaire density and lighting power densities (LPDs) for the two luminaire types required for a 500 Lux lighting design. An intermediate value of 15.5 W/m^2 was used in the model.

An LPD of 5 W/m^2 was assumed for the parking garage.

Interior lighting is assumed to operate as indicated in the lighting schedule in Table 50.

Table 50 Low Rise Office Fluorescent System Performance Parameters Using T8 Fluorescent Lighting with ECG

Luminaire Type	Lamp Initial Lumens	Total Luminaire Initial Lumens	Total Luminaire Wattage (Watts)	Calculated System Efficacy (Lumens/Watt)	Required Density at 500 Lux and 0.5 LL (m²/luminaire)	Calculated LPD (W/m²)
3 x 18 W	1150	3450	63	55	3.45	18.3
4 x 36W	2750	11 000	140	79	11.0	12.7

Exterior Lighting: Exterior lighting has been assumed with a total connected load of 1.5 kW. This is based on ten 150 HPS lamps for the building perimeter.

Office Equipment & Plug Loads: The average office equipment and plug load has assumed to be 10 W/m^2 in the office areas and 1 W/m^2 in the parking garage. The equipment load schedule can be found in Table 53.

Occupancy: An average actual occupancy density of 18 m²/person has been assumed for the office areas. An occupancy density of 100 m²/person was assumed for the parking garage.

Cooling Performance Characteristics & Sizing: A COP of 3.0 (EER=10.3) is assumed for cooling operation. Equipment sizing can be found in Table 51. The cooling temperature schedule can be found in Table 53.

Table 51 Low Rise Office Cooling Plant Equipment Sizing

Component	Designer's Sizing
Air Flow -perimeter -interior	 8.13 L/s.m² 5 L/s.m²
Cooling Plant Capacity	120 W/m^2

Economizers: The DX cooling equipment assumes a fixed fresh air volume with no damper modulation or economizer control.

Heating Efficiency & Sizing: Heating is assumed to be provided by a reverse cycle (COP=3). The heating temperature schedule can be found in Table 53.

Air Flow Rates: Air flow rates can be found in Table 51.

Supply Fan Size: The supply fan size power is assumed to be included in the COP values.

Fresh Air Requirements: Fresh air ventilation rates have been assumed to be 7.5 L/s-person at 10 m²/person or 0.75L/s.m².

Exhaust Fans: Washroom exhaust was assumed based on an exhaust rate of 15 l/s-m^2 per washroom, and two washrooms per floor. (Each washroom was assumed to be 20 m^2.)

Domestic Hot Water: Hot water consumption is estimated at 10 l/capita/day. Hot water heating is provided at 60^{o}C by an electric tank heater.

Operating Schedules: HVAC Equipment operation (fan operation and introduction of fresh air) is in accordance with the schedule in Table 53.

Weather Data: The weather data used is shown in Table 52.

Table 52 Low Rise Office Weather Data and Elevations

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

Regional Variations: As stated in the description of the opaque wall buildings, in the South Cape region are built with a masonry wall containing a 50 mm air cavity. Building in all other regions use masonry wall with no wall cavity.

Table 53 Low Rise Office Air Handling Unit Operating Schedules

Fan Operation (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outside Air (ON=1, OFF=0)																								
W	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
S	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heating Temperature °C (OFF=0)																								
W	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0	0	0
S	0	0	0	0	0	21	21	21	21	21	21	21	21	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooling Temperature °C (OFF=0)																								
W	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0	0	0
S	0	0	0	0	0	23	23	23	23	23	23	23	23	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting Operation (Fraction)																								
W	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2
S	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
H	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Equipment "Plug Loads" Operation (Fraction)																								
W	.2	.2	.2	.2	.2	1	1	1	1	1	1	1	1	1	1	1	1	1	.2	.2	.2	.2	.2	.2
S	.2	.2	.2	.2	.2	1	1	1	1	1	1	1	1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
H	**.2**	**.2**	**.2**	**.2**	**.2**	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Hours																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
			A.M.									Noon						P.M.						Midnight

3.8 Low Rise Office Park Building Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.8.1 Wall Construction

Because the base case wall construction varies by region, two different sets of energy efficiency wall constructions are presented. For the South Cape region, four alternatives were analyzed. These constructions and their associated costs, together with the base case information, are summarized in Table 54. For the other two regions, five alternatives are analyzed. Their constructions, the associated costs, and the base case information, are summarized in Table 55.

Table 54 EE Alternatives for Wall Insulation (Low Rise Office – South Cape Region)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[6] (R/m façade)
Base Case	—	0	0.68	50			
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	25	R 12.78	R 17.00	
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	25	R 15.49	R 17.00	R 25.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	25	R 19.36	R 17.00	R 50.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	25	R 22.13	R 17.00	R 75.00

*Additional is in reference to the Base Case

Table 55 EE Alternatives for Wall Insulation (Low Rise Office – Highveld/Interior and Lowveld/Mpumalanga Regions)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[7] (R/m façade)
Base Case	—	0	0.42	0	-	-	-
EE Level-0	—	Base + 0	Base + 0.26	50	-	-	R 50.00
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	0	R 12.78	R 17.00	R 25.00
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	0	R 15.49	R 17.00	R 50.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	0	R 19.36	R 17.00	R 75.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	0	R 22.13	R 17.00	R 100.00

*Additional is in reference to the Base Case

[6] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.
[7] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

3.8.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 56.

Table 56 EE Alternatives for Roof Insulation (Low Rise Office)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	—	50	1.27	-	-
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

*Additional is in reference to the Base Case

3.8.3 Windows

Three energy efficiency alternative window glazings were analyzed. The descriptions and costs are summarized in Table 57.

Table 57 EE Alternatives for Window Glazing (Low Rise Office)

EE Level	Glazing Description	Shading Coefficient	RSI Value	Material Cost (R/m² window)	Additional Labour Cost (R/m² window)	Incremental Cost (R/m² window)
Base Case	Single 6.38 mm clear	1	0.17	R 200.00	--	--
EE Level-1	Single 6mm Grey Low E (e=0.1)	0.4	0.22	R 440.00	--	R 240.00
EE Level-2	Double 6/12/6 mm Grey	0.4	0.31	R 680.00	R 100.00	R 580.00
EE Level-3	Double 6/12/6 mm Low E	0.4	0.5	R 820.00	R 100.00	R 720.00

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

3.8.4 Modelling Results

Energy efficiency alternatives were first modelled individually. Based on these results, combinations of alternatives that might lead to even lower life-cycle costs were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 58, Table 59 and Figure 13.

Table 58 Annual Electricity Consumption by End-Use and End Use Intensity (Low Rise Office – South Cape)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	168,538	98,301	12,107	28,193	41,929	168,561	8,022	525,651	175.2
Wall (EE1)	168,538	98,301	10,409	29,147	41,929	168,561	8,022	524,907	175.0
Wall (EE2)	168,538	98,301	10,040	29,367	41,929	168,561	8,022	524,758	174.9
Wall (EE3)	168,538	98,301	9,676	29,594	41,929	168,561	8,022	524,621	174.9
Wall (EE4)	168,538	98,301	9,411	29,759	41,929	168,561	8,022	524,521	174.8
Roof (EE-1)	168,538	98,301	10,875	28,252	41,929	168,561	8,022	524,478	174.8
Roof (EE-2)	168,538	98,301	10,205	28,295	41,929	168,561	8,022	523,851	174.6
Roof (EE-3)	168,538	98,301	9,748	28,327	41,929	168,561	8,022	523,426	174.5
Window (EE-1)	168,538	98,301	12,309	23,738	41,929	168,561	8,022	521,398	173.8
Window (EE-2)	168,538	98,301	10,958	24,395	41,929	168,561	8,022	520,704	173.6
Window (EE-3)	168,538	98,301	9,590	25,140	41,929	168,561	8,022	520,081	173.4
Wall (EE2) and Roof (EE-1)	168,538	98,301	8,689	29,495	41,929	168,561	8,022	523,535	174.5

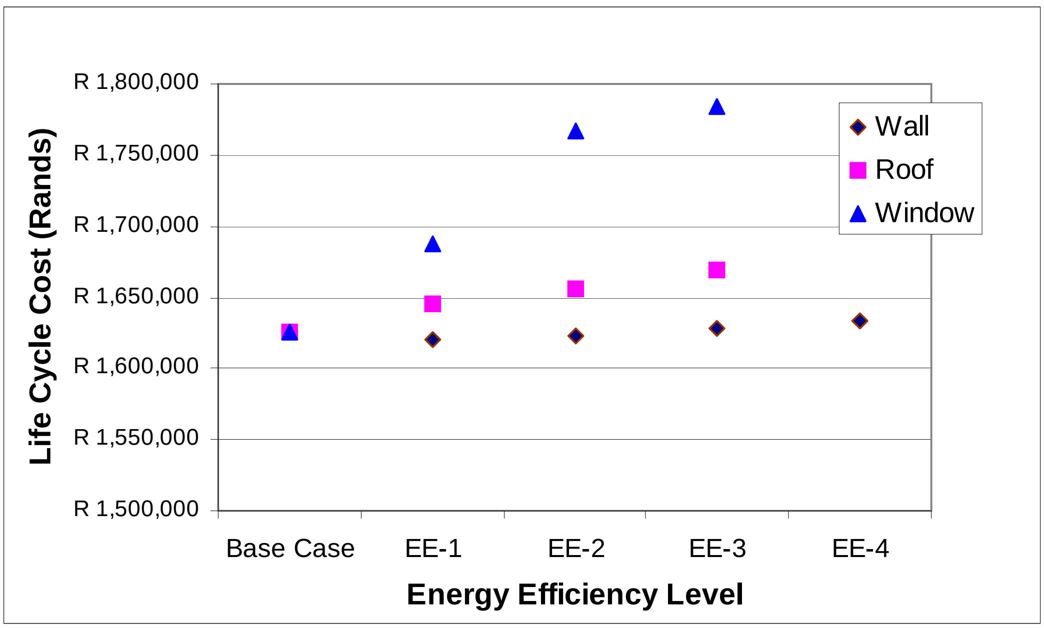
Table 59 EE Alternative LCC Comparison (Low Rise Office – South Cape)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 172,674	R 0	R 1,625,062	
Wall (EE-1)	R 168,964	R 29,572	R 1,619,719	-0.33%
Wall (EE-2)	R 168,097	R 41,512	R 1,623,499	-0.10%
Wall (EE-3)	R 167,199	R 54,605	R 1,628,141	0.19%
Wall (EE-4)	R 166,535	R 66,606	R 1,633,893	0.54%
Base Case	R 172,674	R 0	R 1,625,062	
Roof (EE-1)	R 170,139	R 44,800	R 1,646,005	1.29%
Roof (EE-2)	R 168,747	R 67,430	R 1,655,534	1.88%
Roof (EE-3)	R 167,843	R 90,170	R 1,669,767	2.75%
Base Case**	R 172,674	R 0	R 1,625,062	
Window (EE-1)	R 171,599	R 72,480	R 1,687,425	3.84%
Window (EE-2)	R 169,187	R 175,160	R 1,767,405	8.76%
Window (EE-3)	R 166,521	R 217,440	R 1,784,595	9.82%
Wall (EE2) Roof (EE-1)	R 165,152	R 96,312	R 1,650,583	1.57%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 13 EE Alternative LCC Comparison (Low Rise Office – South Cape)



For the low-rise office building in the South Cape region, the base case window glazings and roofs result in the lowest life cycle costs. However, walls EE-1 and EE-2 do provide lower life cycle costs than that of the base case. The lowest life cycle cost is the wall with an additional 25 mm of fibreglass batt insulation (EE-1). Combining additional roof insulation with wall insulation did not provide additional life cycle cost reductions.

Highveld/Interior Region

The modelling results are summarized in Table 60, Table 61 and Figure 14.

Table 60 Annual Electricity Consumption by End-Use and End Use Intensity (Low Rise Office – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	168,538	98,301	12,893	33,975	42,629	163,216	8,022	527,574	175.9
Wall (EE-0)	168,538	98,301	10,902	34,794	42,629	163,216	8,022	526,402	175.5
Wall (EE-1)	168,538	98,301	9,855	35,333	42,629	163,216	8,022	525,894	175.3
Wall (EE-2)	168,538	98,301	9,290	35,641	42,629	163,216	8,022	525,637	175.2
Wall (EE-3)	168,538	98,301	8,911	35,832	42,629	163,216	8,022	525,449	175.1
Wall (EE-4)	168,538	98,301	8,671	35,964	42,629	163,216	8,022	525,341	175.1
Roof (EE-1)	168,538	98,301	9,549	34,641	42,629	163,216	8,022	524,896	175.0
Roof (EE-2)	168,538	98,301	8,876	34,566	42,629	163,216	8,022	524,148	174.7
Roof (EE-3)	168,538	98,301	8,463	34,521	42,629	163,216	8,022	523,690	174.6
Window (EE-1)	168,538	98,301	11,247	29,921	42,629	163,216	8,022	521,874	174.0
Window (EE-2)	168,538	98,301	10,024	30,386	42,629	163,216	8,022	521,116	173.7
Window (EE-3)	168,538	98,301	8,786	31,115	42,629	163,216	8,022	520,607	173.5
Wall (EE2) and Roof (EE-1)	168,538	98,301	7,938	35,507	42,629	163,216	8,022	524,151	174.7
Wall (EE-0) and Roof (EE-1)	168,538	98,301	9,549	34,641	42,629	163,216	8,022	524,896	175.0
Wall (EE-1) and Roof (EE-1)	168,538	98,301	8,504	35,190	42,629	163,216	8,022	524,400	174.8

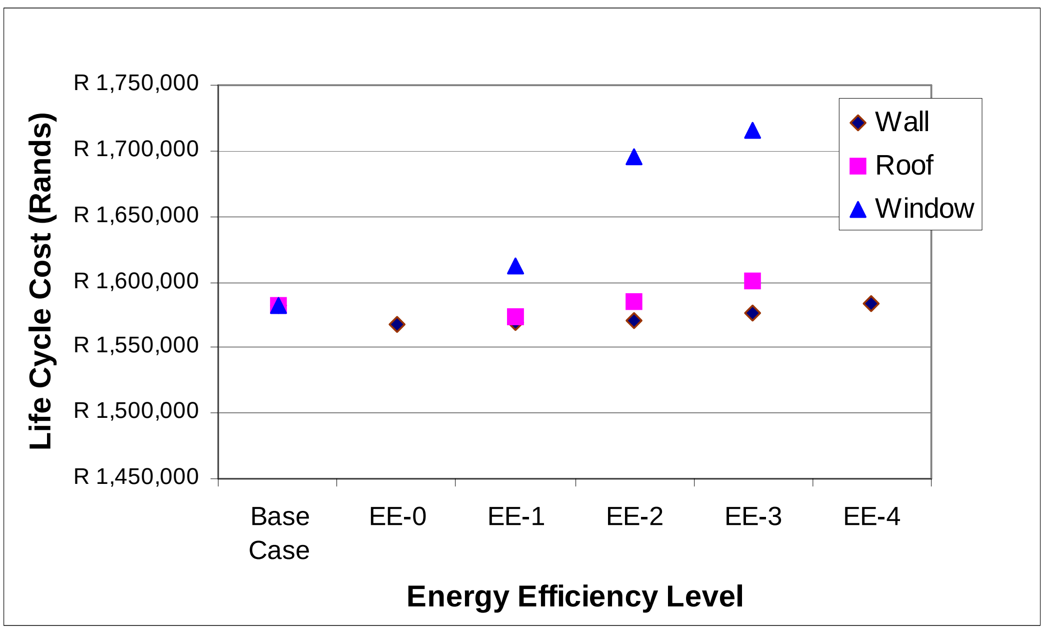
Table 61 EE Alternative LCC Comparison (Low Rise Office – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 168,070	R 0	R 1,581,733	
Wall (EE-0)	R 164,646	R 18,500	R 1,568,009	-0.87%
Wall (EE-1)	R 162,668	R 38,822	R 1,569,716	-0.76%
Wall (EE-2)	R 161,479	R 50,762	R 1,570,466	-0.71%
Wall (EE-3)	R 160,750	R 63,855	R 1,576,698	-0.32%
Wall (EE-4)	R 160,236	R 75,856	R 1,583,862	0.13%
Base Case	R 168,070	R 0	R 1,581,733	
Roof (EE-1)	R 162,450	R 44,800	R 1,573,642	-0.51%
Roof (EE-2)	R 161,244	R 67,430	R 1,584,922	0.20%
Roof (EE-3)	R 160,463	R 90,170	R 1,600,312	1.17%
Base Case**	R 168,070	R 0	R 1,581,733	
Window (EE-1)	R 163,654	R 72,480	R 1,612,653	1.95%
Window (EE-2)	R 161,482	R 175,160	R 1,694,892	7.15%
Window (EE-3)	R 159,192	R 217,440	R 1,715,621	8.46%
Wall (EE-0) Roof (EE-1)	R 162,450	R 63,300	R 1,592,142	0.66%
Wall (EE-1) Roof (EE-1)	R 160,337	R 83,622	R 1,592,579	0.69%
Wall (EE-2) Roof (EE-1)	R 159,111	R 95,562	R 1,592,980	0.71%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 14 EE Alternative LCC Comparison (Low Rise Office – Highveld/Interior)



For the low-rise campus office building in Highveld/Interior region, the base case window glazings and roofs result in the lowest life cycle costs. Wall insulation does lower life cycle costs for alternatives EE-0, EE-1, EE-2, and EE-3. Walls insulated with 50 mm air gap provide the lowest life cycle cost. The addition of further roof insulation did not reduce the life cycle costs.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 62, Table 63 and Figure 15.

Table 62 Annual Electricity Consumption by End-Use and End Use Intensity (Low Rise Office – Lowveld/Mpumalanga)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	168,538	98,301	1,509	33,923	41,899	142,552	8,022	494,744	164.9
Wall (EE-0)	168,538	98,301	1,167	34,782	41,899	142,552	8,022	495,261	165.1
Wall (EE-1)	168,538	98,301	998	35,358	41,899	142,552	8,022	495,668	165.2
Wall (EE-2)	168,538	98,301	927	35,700	41,899	142,552	8,022	495,939	165.3
Wall (EE-3)	168,538	98,301	881	35,914	41,899	142,552	8,022	496,107	165.4
Wall (EE-4)	168,538	98,301	854	36,064	41,899	142,552	8,022	496,230	165.4
Roof (EE-1)	168,538	98,301	927	34,828	41,899	142,552	8,022	495,067	165.0
Roof (EE-2)	168,538	98,301	812	34,864	41,899	142,552	8,022	494,988	165.0
Roof (EE-3)	168,538	98,301	741	34,891	41,899	142,552	8,022	494,944	165.0
Window (EE-1)	168,538	98,301	1,262	31,334	41,899	142,552	8,022	491,908	164.0
Window (EE-2)	168,538	98,301	1,095	31,873	41,899	142,552	8,022	492,280	164.1
Window (EE-3)	168,538	98,301	940	32,650	41,899	142,552	8,022	492,902	164.3
Wall (EE-0) & Roof (EE-1)	168,538	98,301	927	34,828	41,899	142,552	8,022	495,067	165.0
Wall (EE-1) & Roof (EE-1)	168,538	98,301	793	35,429	41,899	142,552	8,022	495,534	165.2
Wall (EE2) & Roof (EE-1)	168,538	98,301	726	35,784	41,899	142,552	8,022	495,822	165.3

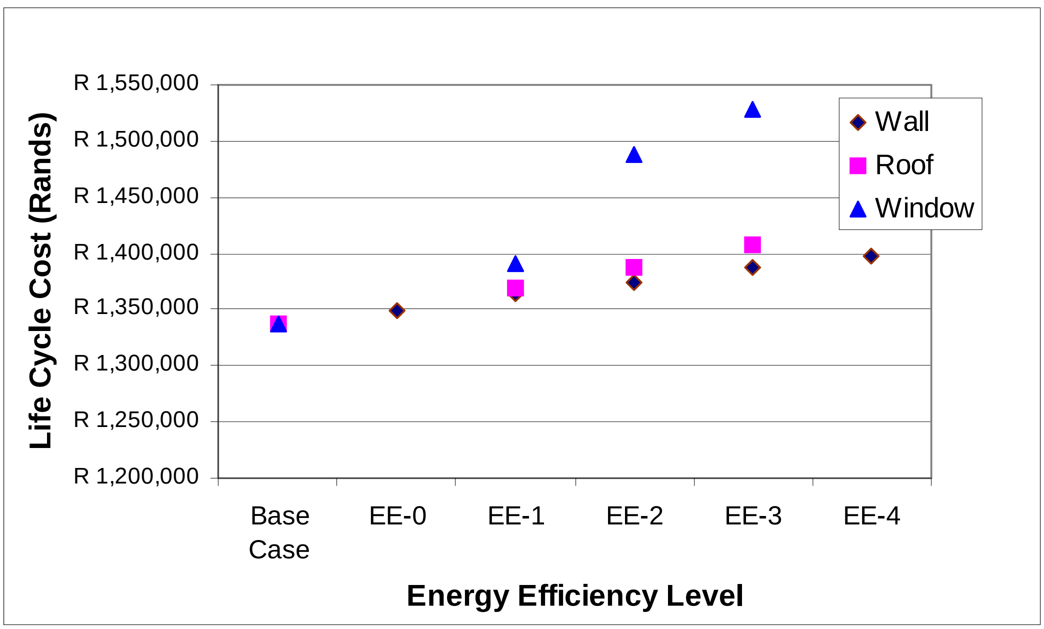
Table 63 EE Alternative LCC Comparison (Low Rise Office – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 142,069	R 0	R 1,337,034	
Wall (EE-0)	R 141,293	R 18,500	R 1,348,231	0.84%
Wall (EE-1)	R 140,906	R 38,822	R 1,364,910	2.08%
Wall (EE-2)	R 140,697	R 50,762	R 1,374,883	2.83%
Wall (EE-3)	R 140,567	R 63,855	R 1,386,753	3.72%
Wall (EE-4)	R 140,479	R 75,856	R 1,397,926	4.55%
Base Case	R 142,069	R 0	R 1,337,034	
Roof (EE-1)	R 140,642	R 44,800	R 1,368,404	2.35%
Roof (EE-2)	R 140,291	R 67,430	R 1,387,731	3.79%
Roof (EE-3)	R 140,067	R 90,170	R 1,408,362	5.33%
Base Case**	R 142,069	R 0	R 1,337,034	
Window (EE-1)	R 140,059	R 72,480	R 1,390,597	4.01%
Window (EE-2)	R 139,585	R 175,160	R 1,488,816	11.35%
Window (EE-3)	R 139,232	R 217,440	R 1,527,774	14.27%
Wall (EE0) Roof (EE-1)	R 140,642	R 63,300	R 1,386,904	3.73%
Wall (EE-1) Roof (EE-1)	R 140,234	R 83,622	R 1,403,386	4.96%
Wall (EE-2) Roof (EE-1)	R 140,087	R 95,562	R 1,413,943	5.75%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 15 EE Alternative LCC Comparison (Low Rise Office – Lowveld/Mpumalanga)



For the low-rise campus office building in Lowveld/Mpumalanga region, the base case window glazings, roofs and walls result in the lowest life cycle costs.

3.8.5 Results and Comments

The energy efficiency alternatives with the lowest life-cycle costs for the notional low-rise campus office building are shown in Table 64.

Table 64 Energy Efficiency Alternatives with Lowest Life-Cycle Cost (Low Rise Office)

Region	**Energy Efficiency Alternative**
South Cape	25 mm fibreglass insulation added to walls (EE-1)
Highveld/Interior	50 mm air gap added to walls (EE-0)
Lowveld/Mpumalanga	Base Case

Additional information relevant to the results shown in the above table is provided in Section 4.1.4 of this report.

3.9 Hotels/Leisure Complexes

3.9.1 Introduction

This section describes the hotels/leisure complexes notional building.

3.9.2 Building Profile

The hotel/resort notional building is defined as a 12 story building with a floor plate dimension of 52.5 m x 20m comprising a ground floor area with reception and administration offices, lounges, a commercial component and public amenities. The notional building is depicted in Figure 16. Notional schematic layouts are presented in Figure 17 at the end of this section.

Figure 16 Hotel/Leisure Complex Notional Building

The notional building has a total floor area of 8 000 m². The podium includes the first and second floors. These two floors have a total area of 2 000 m². The first floor contains restaurants and kitchen facilities. The second floor includes the staff facilities and restrooms together with hotel training facilities, lecture areas, conference centre, banquet halls and stores.

The tower contains the guest rooms with dimensions of 40 x 12.5 m. The dimensions were derived using the individual room dimensions and number of rooms per floor. Typical hotel bedroom floors comprise a central 1.54 m wide passage, with hotel suites/rooms on either side. Hotel rooms are generally 5.5 m deep x 3.68 m wide with a bathroom and lobby. There are 20 rooms on each of the twelve floors. Luxury suites are located on the top floor with 2 x presidential suites, 2 x luxury suites and 1 x deluxe suite.

There are 2 lifts serving all the floors and a goods lift at lower level up to the service floor. Basement parking is provided on several levels – these areas require mechanical ventilation.

The bedrooms are served by room fan coil units located in a bulkhead in the passage leading into the room (opposite the bath room). Air handling units (constant volume) serve the public areas. Heating is provided by electric heaters. The cooling load is met by central screw chillers rated at $5.5kW_{capacity}/kW_{input}$.

Building and Plenum Heights: Floor to floor height is assumed to be 4 m with a plenum height of 790 mm. Drywall ceilings are assumed in all areas except conference/lecture rooms.

Fenestration: Glazing is assumed to be single pane windows with opening sections. The most popular glazing is clear glass SC= 1.0 – U=5.8W/m²K, RSI 0.17. Interior shading is assumed for the windows in the guest rooms.

Opaque Wall: External walls are assumed to be framed concrete structure with plastered and painted masonry brick infill walls. Table 65 provides wall construction details. As shown, construction for the South Cape region assumes a masonry wall with a 50 mm air cavity with an overall thermal performance of RSI 0.68. Other locations typically use a masonry wall with no air cavity.

Table 65 Hotel/Leisure Complex Opaque Wall Construction Detail

Highveld/Interior and Lowveld/Mpumalanga Regions o 10 mm cement/sand plaster o 180 mm cement brick o 10 mm cement/sand plaster (RSI =0.42) Or South Cape Region o 10 mm cement/sand plaster o 90 mm cement brick o 50 mm cavity o 90 mm cement brick o 10 mm cement/sand plaster (RSI = 0.68)

Roof Construction: The roof construction is assumed to be a built-up concrete roof with an overall insulation value of RSI – 1.67 and construction characteristics are shown in Table 66.

Table 66 Hotel/Leisure Complex Roof Construction Detail (Built-up Roof)

o 50 mm gravel ballast
o waterproofing membrane
o 50 mm rigid insulation
o 200 mm concrete roof
o beam/joist structure c/w suspended ceiling
(RSI = 0.68)

Building Facades: Bay width is assumed to be 7,8 m long. The overall length of glazing in each bay is 3.0 m. Window height is 1.5 m and sill height is 625 mm. This would apply to two of the building facades.

General Lighting: Lighting levels for hotels can be broken up into:

- Rooms
- Circulation Areas ((lobbies, Passages, Stair Wells etc)
- Restaurants
- Kitchens / Laundries
- Parking (basement)
- Plant rooms

General lighting is based on incandescent and linear T8 fluorescent lamps with electronic control gear (ECG) or electronic ballasts. Table 67 lists the assumed lighting power densities (LPDs) per area.

Table 67 Hotel/Leisure Complex LPD, EPD and Occupant Densities Assumed

Area	LPD (W/m²)	Plug Loads (W/m²)	Occ. Density (m²/occupant)
Guest Rooms	15 (~285 W/room)	4 (75 W/room)	10
Restaurant	15	1	3
Banquet / Meeting Rooms	40	1.1	3
Lobby	10	1	20
Corridor	20	0	50
Kitchen / Back of House	12	75	8

Exterior Lighting: Exterior lighting has been assumed with a total connected load of 1.5 kW. This is based on provision of 10 -150 HPS lamps for the building perimeter.

Plug Loads: Table 67 lists the typical plug load power densities assumed.

Occupancy: Occupancy densities are shown in Table 67.

Cooling Performance Characteristics: The cooling load is met with a central screw chiller rated with a coefficient of performance (COP) of 5.5 at full load.

Economizer Cycle: Air handling units serving the main areas in the first and second floors have been assumed to have a fixed outside air volume with no damper modulation and no economizer cycle.

Air Flow Rates: Air flow rates of 8 l/s.m² at summer design conditions have been assumed based on the current design practices.

Supply Fan Size: Supply fan size is based on a total static pressure of 750 Pa. No return fan is present.

Fresh Air Requirements: Fresh air ventilation rates have been assumed based on 7.5 l/s. person.

Exhaust Fans: Bathroom exhaust was assumed based on an exhaust rate of 50 l/s per bath room.

Domestic Hot Water: Hot water (electric heating and 60°C), is estimated as 150 l/capita/day, or 100 l/s which derives a consumption intensity of 83 kWh/m²yr or 300 MJ/m²yr.

Weather Data: The weather data used is shown in Table 68.

Table 68 Hotel/Leisure Complex Weather Data and Elevations

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

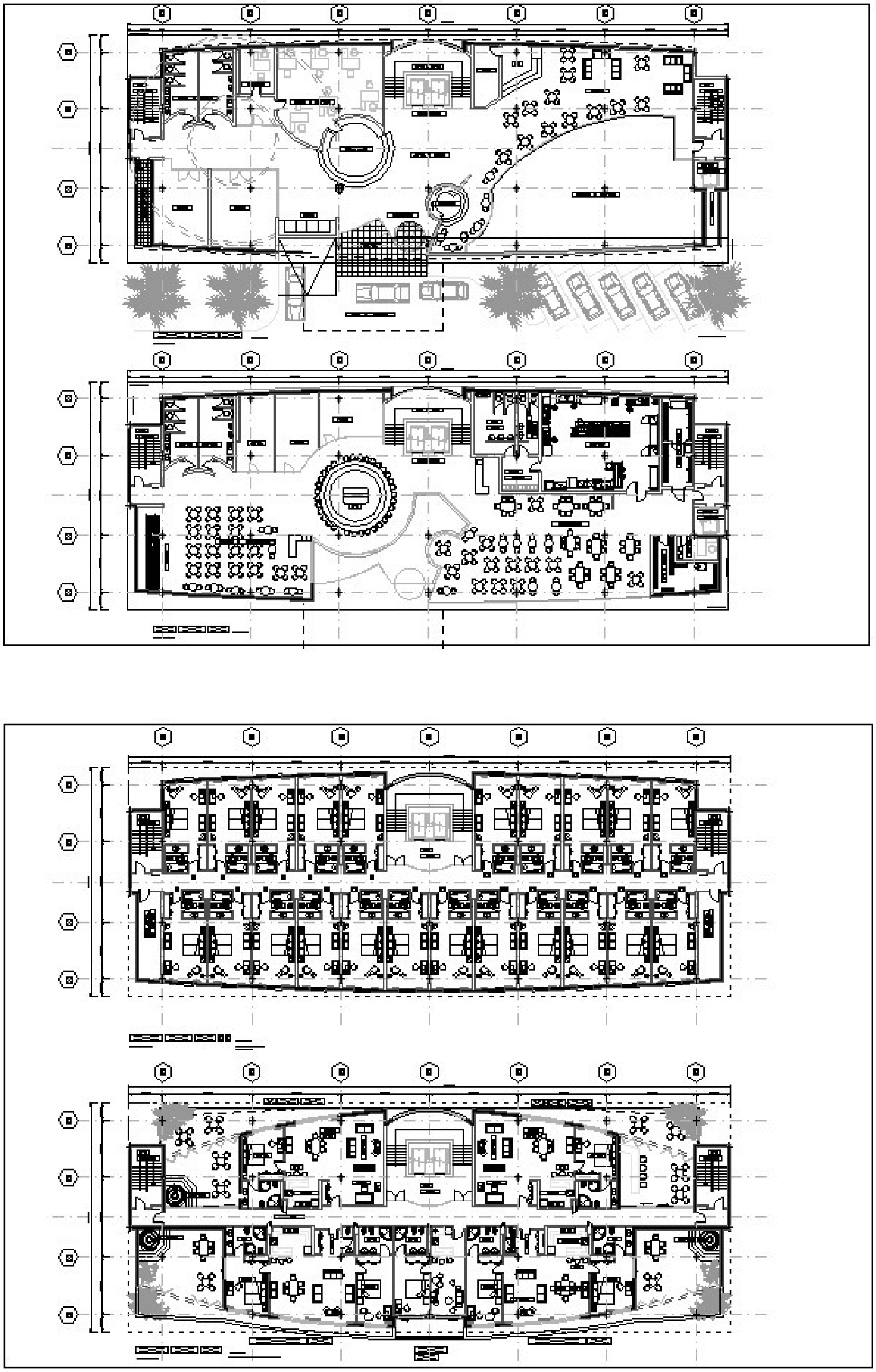
Regional Variations: As stated in the description of the opaque wall buildings in the South Cape region are built with a masonry wall containing a 50 mm air cavity. Building in all other regions use masonry wall with no cavity.

Operating Schedules: HVAC Equipment operation is assumed to be continuous. This applies to fan operation and introduction of fresh air. Temperature is also maintained constant. Lighting would be operated at nearly 100%. It would only be administration areas (offices etc) that would not operate at night or over weekends. Bedroom plugs would be included as part of the normal operation as it would include television and radio. The usage would depend on hotel occupancy.

Table 69 Hotel/Leisure Complex Air Handling Unit Operating Schedules

Fan Operation (ON=1, OFF=0)																								
W	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
H	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Outside Air (ON=1, OFF=0)																								
W	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
H	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Heating Temperature °C (OFF=0)																								
W	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
S	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
H	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Cooling Temperature °C (OFF=0)																								
W	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
S	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
H	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Lighting Operation (Fraction)																								
W	0.85	0.85	0.85	0.85	0.85	1	1	1	1	1	1	1	1	1	1	1	1	0.85	0.85	0.85	0.85	0.85	0.85	0.85
S	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	
H	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	
Equipment “Plug Loads” Operation (Fraction)																								
W	.15	.15	.15	.15	.15	1	1	1	1	1	1	1	1	1	1	1	1	1	.15	.15	.15	.15	.15	.15
S	.15	.15	.15	.15	.15	1	1	1	1	1	1	1	1	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
H	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
Hours																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A.M.								Noon									P.M.						Midnight	

Figure 17 Hotel/Leisure Complex Notional Schematic Layout



3.10 Hotels Leisure Complexes Building Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.10.1 Wall Construction

Because the base case wall construction varies by region, two different sets of energy efficiency wall constructions are presented. For South Cape region, four alternatives were analyzed. These constructions and their associated costs, together with the base case information, are summarized in Table 70. For the other two regions, five alternatives are analyzed. Their constructions, the associated costs, and the base case information, are summarized in Table 71.

Table 70 EE Alternatives for Wall Insulation (Hotel/Leisure Complex – South Cape)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[8] (R/m façade)
Base Case	—	0	0.68	50	--	--	--
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	25	R 12.78	R 17.00	--
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	25	R 15.49	R 17.00	R 25.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	25	R 19.36	R 17.00	R 50.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	25	R 22.13	R 17.00	R 75.00

*Additional is in reference to the Base Case.

Table 71 EE Alternatives for Wall Insulation (Hotel/Leisure Complex – Highveld/Interior and Lowveld/Mpumalanga)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[9] (R/m façade)
Base Case	—	0	0.42	0	--	--	--
EE Level-0	—	Base + 0	Base + 0.26	50	--	--	R 50.00
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	0	R 12.78	R 17.00	R 25.00
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	0	R 15.49	R 17.00	R 50.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	0	R 19.36	R 17.00	R 75.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	0	R 22.13	R 17.00	R 100.00

*Additional is in reference to the Base Case.

[8] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.
[9] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

3.10.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 72.

Table 72 EE Alternatives for Roof Insulation (Hotel/Leisure Complex)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	—	50	1.67	--	--
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

*Additional is in reference to the Base Case.

3.10.3 Windows

Three energy efficiency alternative window glazings were analyzed. The descriptions and costs are summarized in Table 73.

Table 73 EE Alternatives for Window Glazing (Hotel/Leisure Complex)

EE Level	Glazing Description	Shading Coefficient	Overall RSI Value	Material Cost (R/m² window)	Additional Labour Cost (R/m² window)	Incremental Cost (R/m² window)
Base Case	Single 6.38 mm clear	1	0.17	R 200.00		
EE Level-1	Single 6mm Grey Low E (e=0.1)	0.4	0.22	R 440.00		R 240.00
EE Level-2	Double 6/12/6 mm Grey	0.4	0.31	R 680.00	R 100.00	R 580.00
EE Level-3	Double 6/12/6 mm Low E	0.4	0.5	R 820.00	R 100.00	R 720.00

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

3.10.4 Modelling Results

Energy efficiency alternatives were first modelled individually. Based on these results, combinations of alternatives that might lead to even lower life-cycle costs were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 74, Table 75 and Figure 18.

Table 74 Annual Electricity Consumption by End-Use and End Use Intensity (Hotel/Leisure Complex – South Cape)

Alternative	**Lights (kWh/yr)**	**Equipment (kWh/yr)**	**Heating (kWh/yr)**	**Cooling (kWh/yr)**	**Tower (kWh/yr)**	**Pumps/Aux. (kWh/yr)**	**Fans (kWh/yr)**	**Hot Water (kWh/yr)**	**Ext. Lights (kWh/yr)**	**Ext. Equip. (kWh/yr)**	**Total (kWh/yr)**	**EUI (kWh/m^2-yr)**
Base Case	406,797	93,755	1,462,646	770,424	26,970	16,761	327,321	657,000	4,895	100,318	3,866,887	483.4
Wall (EE-1)	406,797	93,755	1,374,555	771,063	26,975	16,761	327,316	657,000	4,895	100,318	3,779,435	472.4
Wall (EE-2)	406,797	93,755	1,337,502	771,387	26,978	16,761	327,316	657,000	4,895	100,318	3,742,709	467.8
Wall (EE-3)	406,797	93,755	1,312,319	771,629	26,979	16,761	327,316	657,000	4,895	100,318	3,717,769	464.7
Wall (EE-4)	406,797	93,755	1,293,468	771,796	26,980	16,761	327,316	657,000	4,895	100,318	3,699,086	462.4
Roof (EE-1)	406,797	93,755	1,457,560	769,849	26,968	16,761	327,321	657,000	4,895	100,318	3,861,224	482.7
Roof (EE-2)	406,797	93,755	1,454,344	769,494	26,966	16,761	327,321	657,000	4,895	100,318	3,857,651	482.2
Roof (EE-3)	406,797	93,755	1,452,091	769,255	26,965	16,761	327,321	657,000	4,895	100,318	3,855,158	481.9
Window (EE-1)	406,797	93,755	1,551,480	732,750	26,773	16,761	326,947	657,000	4,895	100,318	3,917,476	489.7
Window (EE-2)	406,797	93,755	1,508,059	735,793	26,791	16,761	326,960	657,000	4,895	100,318	3,877,129	484.6
Window (EE-3)	406,797	93,755	1,463,853	739,287	26,811	16,761	326,960	657,000	4,895	100,318	3,836,437	479.6
Wall (EE1) & Roof (EE1)	406,797	93,755	1,367,884	770,391	26,972	16,761	327,316	657,000	4,895	100,318	3,772,089	471.5
Wall (EE1) & Roof (EE2)	406,797	93,755	1,363,584	769,954	26,971	16,761	327,316	657,000	4,895	100,318	3,767,351	470.9
Wall (EE1) & Roof (EE3)	406,797	93,755	1,360,569	769,678	26,969	16,761	327,316	657,000	4,895	100,318	3,764,058	470.5
Wall (EE2) & Roof (EE1)	406,797	93,755	1,329,973	770,682	26,974	16,761	327,316	657,000	4,895	100,318	3,734,471	466.8
Wall (EE2) & Roof (EE2)	406,797	93,755	1,325,145	770,262	26,972	16,761	327,316	657,000	4,895	100,318	3,729,221	466.2
Wall (EE3) & Roof (EE1)	406,797	93,755	1,303,941	770,900	26,976	16,761	327,316	657,000	4,895	100,318	3,708,659	463.6
Wall (EE3) & Roof (EE2)	406,797	93,755	1,298,620	770,449	26,974	16,761	327,316	657,000	4,895	100,318	3,702,885	462.9
Wall (EE4) & Roof (EE1)	406,797	93,755	1,284,568	771,065	26,977	16,761	327,316	657,000	4,895	100,318	3,689,452	461.2
Wall (EE4) & Window (EE1)	406,797	93,755	1,370,307	728,836	26,755	16,761	326,940	657,000	4,895	100,318	3,732,364	466.5

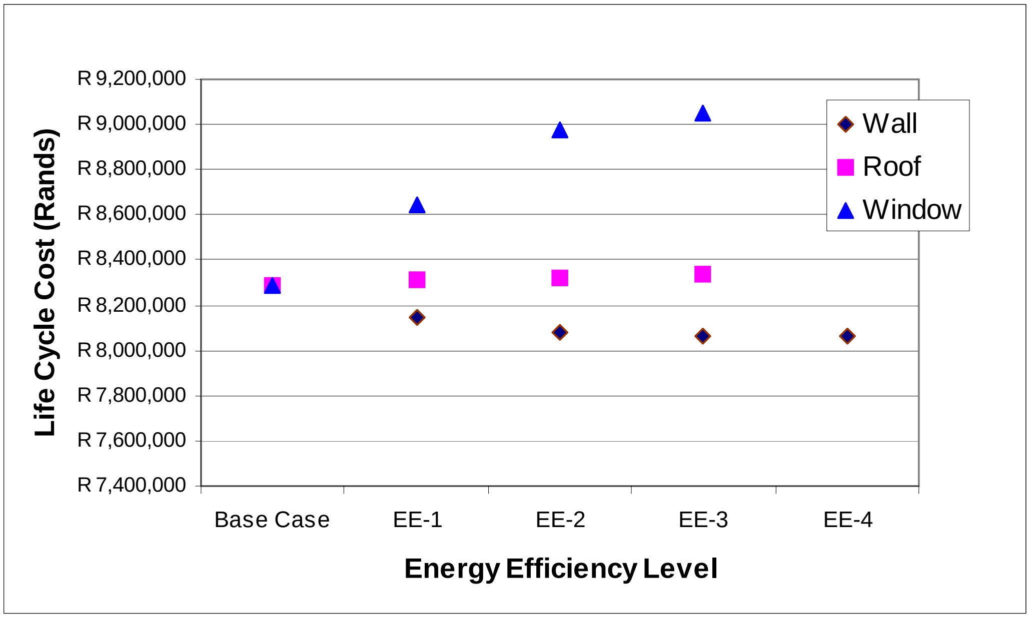
Table 75 EE Alternative LCC Comparison (Hotel/Leisure Complex – South Cape)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 880,198	R 0	R 8,283,680	
Wall (EE-1)	R 849,978	R 144,850	R 8,144,126	-1.68%
Wall (EE-2)	R 838,010	R 196,531	R 8,083,174	-2.42%
Wall (EE-3)	R 829,937	R 253,855	R 8,064,522	-2.65%
Wall (EE-4)	R 823,924	R 305,828	R 8,059,905	-2.70%
Base Case	R 880,198	R 0	R 8,283,680	
Roof (EE-1)	R 878,334	R 44,800	R 8,310,938	0.33%
Roof (EE-2)	R 877,161	R 67,430	R 8,322,529	0.47%
Roof (EE-3)	R 876,352	R 90,170	R 8,337,655	0.65%
Base Case**	R 880,198	R 0	R 8,283,680	
Window (EE-1)	R 885,373	R 311,040	R 8,643,423	4.34%
Window (EE-2)	R 873,922	R 751,680	R 8,976,296	8.36%
Window (EE-3)	R 862,831	R 933,120	R 9,053,356	9.29%
Wall (EE1) -- Roof (EE1)	R 847,750	R 189,650	R 8,167,957	-1.40%
Wall (EE1) -- Roof (EE2)	R 846,308	R 212,280	R 8,177,017	-1.29%
Wall (EE1) -- Roof (EE3)	R 845,302	R 235,020	R 8,190,289	-1.13%
Wall (EE2) -- Roof (EE1)	R 835,461	R 241,331	R 8,103,985	-2.17%
Wall (EE2) -- Roof (EE2)	R 833,850	R 263,961	R 8,111,453	-2.08%
Wall (EE3) -- Roof (EE1)	R 827,151	R 298,655	R 8,083,102	-2.42%
Wall (EE3) -- Roof (EE2)	R 825,358	R 321,285	R 8,088,858	-2.35%
Wall (EE4) -- Roof (EE1)	R 820,939	R 350,628	R 8,076,613	-2.50%
Wall (EE4) -- Window (EE1)	R 826,472	R 616,868	R 8,394,924	1.34%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 18 EE Alternative LCC Comparison (Hotel/Leisure Complex – South Cape)



For hotels/leisure complexes in the South Cape region, improved window glazings and better insulated roofs do not result in lower life cycle costs. Better-insulated walls do provide lower life cycle costs than that of the base case. The lowest life cycle cost is that of the wall with 100 mm fibreglass batt insulation (EE-4). Combining additional roof insulation with wall insulation did not improve the life cycle cost.

Highveld/Interior Region

The modelling results are summarized in Table 76, Table 77 and Figure 19.

Table 76 Annual Electricity Consumption by End-Use and End Use Intensity (Hotel/Leisure Complex – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps & Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Ext. Equip. (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	406,797	93,755	1,312,862	855,497	27,173	16,761	327,426	657,000	4,895	100,318	3,802,484	475.3
Wall (EE-0)	406,797	93,755	1,248,790	840,552	27,110	16,761	327,399	657,000	4,895	100,318	3,723,377	465.4
Wall (EE-1)	406,797	93,755	1,219,140	833,595	27,076	16,761	327,384	657,000	4,895	100,318	3,686,721	460.8
Wall (EE-2)	406,797	93,755	1,201,433	828,660	27,052	16,761	327,383	657,000	4,895	100,318	3,664,054	458.0
Wall (EE-3)	406,797	93,755	1,189,840	825,059	27,034	16,761	327,379	657,000	4,895	100,318	3,648,838	456.1
Wall (EE-4)	406,797	93,755	1,181,458	822,275	27,020	16,761	327,379	657,000	4,895	100,318	3,637,658	454.7
Roof (EE-1)	406,797	93,755	1,245,817	839,491	27,105	16,761	327,399	657,000	4,895	100,318	3,719,338	464.9
Roof (EE-2)	406,797	93,755	1,243,900	838,818	27,102	16,761	327,399	657,000	4,895	100,318	3,716,745	464.6
Roof (EE-3)	406,797	93,755	1,242,549	838,359	27,100	16,761	327,399	657,000	4,895	100,318	3,714,933	464.4
Window (EE-1)	406,797	93,755	1,551,480	732,750	26,773	16,761	326,947	657,000	4,895	100,318	3,917,476	489.7
Window (EE-2)	406,797	93,755	1,508,059	735,793	26,791	16,761	326,960	657,000	4,895	100,318	3,877,129	484.6
Window (EE-3)	406,797	93,755	1,463,853	739,287	26,811	16,761	326,960	657,000	4,895	100,318	3,836,437	479.6
Wall (EE1) -- Roof (EE1)	406,797	93,755	1,215,503	832,242	27,070	16,761	327,384	657,000	4,895	100,318	3,681,725	460.2
Wall (EE1) -- Roof (EE2)	406,797	93,755	1,213,186	831,374	27,066	16,761	327,384	657,000	4,895	100,318	3,678,536	459.8
Wall (EE1) -- Roof (EE3)	406,797	93,755	1,211,542	830,776	27,064	16,761	327,384	657,000	4,895	100,318	3,676,292	459.5
Wall (EE2) -- Roof (EE1)	406,797	93,755	1,197,180	827,032	27,044	16,761	327,383	657,000	4,895	100,318	3,658,165	457.3
Wall (EE2) -- Roof (EE2)	406,797	93,755	1,194,445	826,009	27,040	16,761	327,383	657,000	4,895	100,318	3,654,403	456.8
Wall (EE3) -- Roof (EE1)	406,797	93,755	1,185,148	823,253	27,026	16,761	327,379	657,000	4,895	100,318	3,642,332	455.3
Wall (EE3) -- Roof (EE2)	406,797	93,755	1,182,150	822,093	27,021	16,761	327,379	657,000	4,895	100,318	3,638,169	454.8
Wall (EE2) -- Window (EE1)	406,797	93,755	1,324,710	791,570	26,877	16,761	326,947	657,000	4,895	100,318	3,749,630	468.7
Wall (EE2) -- Window (EE2)	406,797	93,755	1,294,116	795,117	26,896	16,761	326,960	657,000	4,895	100,318	3,722,615	465.3
Wall (EE3) -- Window (EE1)	406,797	93,755	1,312,776	787,361	26,856	16,761	326,945	657,000	4,895	100,318	3,733,464	466.7
Wall (EE3) -- Window (EE2)	406,797	93,755	1,281,967	790,901	26,876	16,761	326,946	657,000	4,895	100,318	3,706,216	463.3

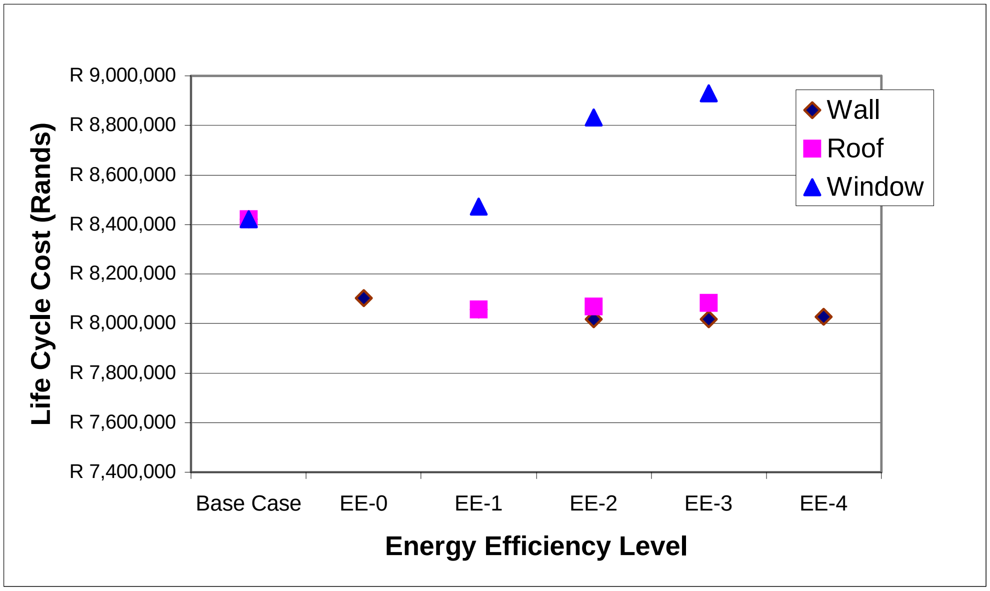
Table 77 EE Alternative LCC Comparison (Hotel/Leisure Complex – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 894,837	R 0	R 8,421,450	
Wall (EE-0)	R 852,915	R 77,000	R 8,103,916	-3.77%
Wall (EE-1)	R 836,468	R 183,350	R 8,055,481	-4.35%
Wall (EE-2)	R 827,047	R 235,031	R 8,018,500	-4.78%
Wall (EE-3)	R 820,904	R 292,355	R 8,018,011	-4.79%
Wall (EE-4)	R 816,453	R 344,328	R 8,028,094	-4.67%
Base Case	R 894,837	R 0	R 8,421,450	
Roof (EE-1)	R 851,220	R 44,800	R 8,055,764	-4.34%
Roof (EE-2)	R 850,125	R 67,430	R 8,068,089	-4.20%
Roof (EE-3)	R 849,360	R 90,170	R 8,083,629	-4.01%
Base Case**	R 894,837	R 0	R 8,421,450	
Window (EE-1)	R 867,066	R 311,040	R 8,471,133	0.59%
Window (EE-2)	R 858,738	R 751,680	R 8,833,397	4.89%
Window (EE-3)	R 849,773	R 933,120	R 8,930,466	6.04%
Wall (EE1) -- Roof (EE1)	R 834,373	R 228,150	R 8,080,564	-4.05%
Wall (EE1) -- Roof (EE2)	R 833,020	R 250,780	R 8,090,461	-3.93%
Wall (EE1) -- Roof (EE3)	R 832,071	R 273,520	R 8,104,270	-3.77%
Wall (EE2) -- Roof (EE1)	R 824,624	R 279,831	R 8,040,496	-4.52%
Wall (EE2) -- Roof (EE2)	R 823,059	R 302,461	R 8,048,397	-4.43%
Wall (EE3) -- Roof (EE1)	R 818,245	R 337,155	R 8,037,786	-4.56%
Wall (EE3) -- Roof (EE2)	R 816,523	R 359,785	R 8,044,210	-4.48%
Wall (EE2) -- Window (EE1)	R 840,625	R 546,071	R 8,457,324	0.43%
Wall (EE2) -- Window (EE2)	R 831,688	R 986,711	R 8,813,856	4.66%
Wall (EE3) -- Window (EE1)	R 834,411	R 603,395	R 8,456,166	0.41%
Wall (EE3) -- Window (EE2)	R 825,357	R 1,044,035	R 8,811,598	4.63%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in Section 4.1.4 of this report, remain virtually unchanged.

Figure 19 EE Alternative LCC Comparison (Hotel/Leisure Complex – Highveld/Interior)



For the hotels leisure complexes in Highveld/Interior region, the base case window glazings result in the lowest life cycle cost. Additional wall insulation and roof insulation reduce life cycle costs. The lowest life cycle cost is the base case wall with an additional 75 mm of fibreglass batt insulation (EE-3). Combining additional roof insulation with wall insulation did not further reduce the life cycle costs.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 78, Table 79 and Figure 20.

Table 78 Annual Electricity Consumption by End-Use and End Use Intensity (Hotel/Leisure Complex – Lowveld/Mpumalanga)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps/Aux. (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Ext. Equip. (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	406,797	93,755	1,242,425	928,789	29,050	16,761	327,219	657,000	4,895	100,318	3,807,009	475.9
Wall (EE-0)	406,797	93,755	1,192,759	918,213	29,005	16,761	327,153	657,000	4,895	100,318	3,746,656	468.3
Wall (EE1)	406,797	93,755	1,143,351	905,407	28,941	16,761	327,138	657,000	4,895	100,318	3,684,363	460.5
Wall (EE2)	406,797	93,755	1,132,029	902,194	28,926	16,761	327,137	657,000	4,895	100,318	3,669,812	458.7
Wall (EE3)	406,797	93,755	1,125,163	899,908	28,914	16,761	327,136	657,000	4,895	100,318	3,660,647	457.6
Wall (EE4)	406,797	93,755	1,120,544	898,177	28,906	16,761	327,136	657,000	4,895	100,318	3,654,289	456.8
Roof (EE1)	406,797	93,755	1,190,555	917,599	29,002	16,761	327,153	657,000	4,895	100,318	3,743,835	468.0
Roof (EE2)	406,797	93,755	1,189,191	917,197	29,001	16,761	327,153	657,000	4,895	100,318	3,742,068	467.8
Roof (EE3)	406,797	93,755	1,188,270	916,924	29,000	16,761	327,153	657,000	4,895	100,318	3,740,873	467.6
Window (EE-1)	406,797	93,755	1,242,932	872,512	28,770	16,761	326,884	657,000	4,895	100,318	3,750,624	468.8
Window (EE-2)	406,797	93,755	1,222,134	875,343	28,787	16,761	326,884	657,000	4,895	100,318	3,732,674	466.6
Window (EE-3)	406,797	93,755	1,202,729	879,251	28,810	16,761	326,884	657,000	4,895	100,318	3,717,200	464.7
Wall (EE1) -- Roof (EE1)	406,797	93,755	1,140,892	904,599	28,938	16,761	327,138	657,000	4,895	100,318	3,681,093	460.1
Wall (EE1) -- Roof (EE2)	406,797	93,755	1,139,257	904,088	28,936	16,761	327,138	657,000	4,895	100,318	3,678,945	459.9
Wall (EE1) -- Roof (EE3)	406,797	93,755	1,138,165	903,734	28,934	16,761	327,138	657,000	4,895	100,318	3,677,497	459.7
Wall (EE2) -- Roof (EE1)	406,797	93,755	1,129,227	901,217	28,921	16,761	327,137	657,000	4,895	100,318	3,666,028	458.3
Wall (EE2) -- Roof (EE2)	406,797	93,755	1,127,466	900,609	28,918	16,761	327,137	657,000	4,895	100,318	3,663,656	458.0
Wall (EE3) -- Roof (EE1)	406,797	93,755	1,122,254	898,835	28,909	16,761	327,136	657,000	4,895	100,318	3,656,660	457.1
Wall (EE3) -- Roof (EE2)	406,797	93,755	1,120,484	898,168	28,906	16,761	327,136	657,000	4,895	100,318	3,654,220	456.8
Wall (EE2) -- Window (EE1)	406,797	93,755	1,208,041	861,117	28,713	16,761	326,864	657,000	4,895	100,318	3,704,261	463.0
Wall (EE2) -- Window (EE2)	406,797	93,755	1,190,140	864,965	28,736	16,761	326,864	657,000	4,895	100,318	3,690,231	461.3
Wall (EE3) -- Window (EE1)	406,797	93,755	1,200,640	858,106	28,698	16,761	326,864	657,000	4,895	100,318	3,693,834	461.7
Wall (EE3) -- Window (EE2)	406,797	93,755	1,182,930	862,060	28,722	16,761	326,863	657,000	4,895	100,318	3,680,101	460.0
Wall (EE4) -- Roof (EE1)	406,797	93,755	1,117,538	897,024	28,900	16,761	327,136	657,000	4,895	100,318	3,650,124	456.3
Wall (EE4) -- Window (EE1)	406,797	93,755	1,195,567	855,848	28,686	16,761	326,863	657,000	4,895	100,318	3,686,490	460.8

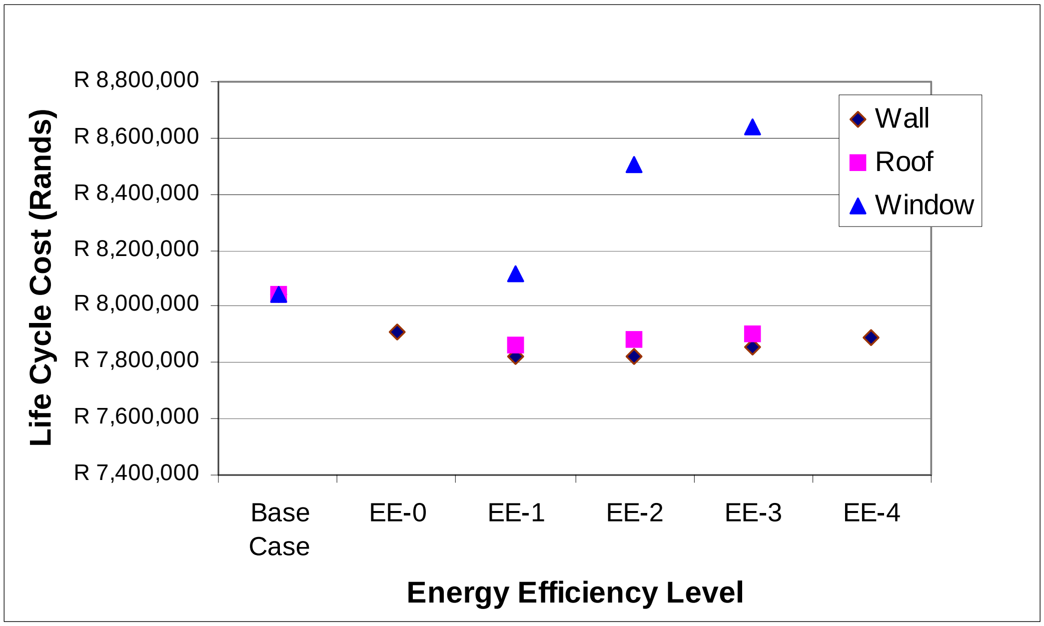
Table 79 EE Alternative LCC Comparison (Hotel/Leisure Complex – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 854,648	R 0	R 8,043,225	
Wall (EE-0)	R 831,870	R 77,000	R 7,905,858	-1.71%
Wall (EE-1)	R 811,496	R 183,350	R 7,820,466	-2.77%
Wall (EE-2)	R 806,121	R 235,031	R 7,821,561	-2.76%
Wall (EE-3)	R 803,397	R 292,355	R 7,853,249	-2.36%
Wall (EE-4)	R 801,444	R 344,328	R 7,886,842	-1.94%
Base Case	R 854,648	R 0	R 8,043,225	
Roof (EE-1)	R 830,934	R 44,800	R 7,864,849	-2.22%
Roof (EE-2)	R 830,335	R 67,430	R 7,881,842	-2.01%
Roof (EE-3)	R 829,923	R 90,170	R 7,900,705	-1.77%
Base Case**	R 854,648	R 0	R 8,043,225	
Window (EE-1)	R 829,117	R 311,040	R 8,113,989	0.88%
Window (EE-2)	R 823,975	R 751,680	R 8,506,237	5.76%
Window (EE-3)	R 819,091	R 933,120	R 8,641,713	7.44%
Wall (EE1) -- Roof (EE1)	R 810,288	R 228,150	R 7,853,897	-2.35%
Wall (EE1) -- Roof (EE2)	R 809,553	R 250,780	R 7,869,610	-2.16%
Wall (EE1) -- Roof (EE3)	R 809,064	R 273,520	R 7,887,748	-1.93%
Wall (EE2) -- Roof (EE1)	R 804,954	R 279,831	R 7,855,378	-2.34%
Wall (EE2) -- Roof (EE2)	R 804,219	R 302,461	R 7,871,091	-2.14%
Wall (EE3) -- Roof (EE1)	R 802,124	R 337,155	R 7,886,069	-1.95%
Wall (EE3) -- Roof (EE2)	R 801,328	R 359,785	R 7,901,208	-1.77%
Wall (EE2) -- Window (EE1)	R 812,562	R 546,071	R 8,193,219	1.86%
Wall (EE2) -- Window (EE2)	R 808,911	R 986,711	R 8,599,498	6.92%
Wall (EE3) -- Window (EE1)	R 809,635	R 603,395	R 8,222,996	2.24%
Wall (EE3) -- Window (EE2)	R 805,745	R 1,044,035	R 8,627,026	7.26%
Wall (EE4) -- Roof (EE1)	R 800,112	R 389,128	R 7,919,107	-1.54%
Wall (EE4) -- Window (EE1)	R 807,583	R 655,368	R 8,255,658	2.64%

* With respect to Base Case.

Sensitivity runs were completed using revised labour costs and shading coefficients. The LCC results using the revised inputs, which are presented in the Section 4.1.4 of this report, remain virtually unchanged.

Figure 20 EE Alternative LCC Comparison (Hotel/Leisure Complex – Lowveld/Mpumalanga)



For hotels/leisure complexes in Lowveld/Mpumalanga region, the base case window glazings result in the lowest life cycle cost. Additional roof and wall insulation result in lower life cycle costs than the base case. The lowest life cycle cost is the base case wall with an additional 25 mm of insulation (EE-1).

3.10.5 Results and Comments

The energy efficiency improvements to the notional hotel leisure complexes that provide the lowest life-cycle costs are shown in Table 80.

Table 80 Energy Efficient Alternative with Lowest Life-Cycle Cost (Hotel/Leisure Complex)

Region	Energy Efficiency Alternative
South Cape	100 mm fibreglass insulation added to walls (EE-4)
Highveld/Interior	75 mm fibreglass insulation added to walls (EE-3)
Lowveld/Mpumalanga	25 mm fibreglass insulation added to walls (EE-1)

Additional information relevant to the results shown in the above table is provided in Section 4.1.4 this report.

3.11 Regional Shopping Centres

3.11.1 Introduction

This section describes the regional shopping mall notional building.

3.11.2 Building Profile

The regional shopping mall is defined as a 3 storey, 64,000 m² complex with a varying footprint. The shopping centre comprises 275 shops, including a banking mall, medical & dental facilities, and 10 cinemas. Schematic layouts of such a facility in Cape Town are shown in Figures 21 through 23. Conditioned areas are further allocated as presented in Table 81. In addition, there is a 30 000 m² naturally ventilated basement parking garage.

Table 81 Regional Shopping Centre Area by Space Type

Space Type	Area (m²)
Anchor Stores (assumed to be 85% non-food retail, 15% supermarket)	23 040
Line Shops, Banks and Restaurants (assumed to be 65% shops, 10% banks and 25% restaurants, by area)	26 240
Mall and Circulation Areas (includes public restrooms)	9 600
Cinemas (10% of this area is assumed to be foyer space)	3 840
Service/General (mechanical/store room space not open to the public)	1 280

All shops face onto a mall of varying width, a promotions court and an atrium. The ground and first floor levels of the centre contain anchor tenants and large department stores and several line shops along the malls. The malls have double volume areas in places, and at the atrium and promotions court. The second floor level comprises the banking hall with a double volume over the atrium area. There are eight roof lights, which allow natural light into the mall areas.

The building is served by multiple air-handling units. For the anchor stores, cinemas, mall/circulation and service areas, these are constant volume systems; while for the line shops, banks and restaurants, the systems are low-pressure variable air volume (VAV) systems. Heating is provided by electric heaters (terminal reheat). The cooling load is met by central screw chillers rated at $5.5kW_{capacity}/kW_{input}$. Operation of the air handling unit is restricted to occupied hours only; however it is assumed that the units will cycle during unoccupied hours in the winter period on a call for heating. There is no setback. There are economizer cycles in the Highveld/Interior region only.

Building and Plenum Heights: Floor to ceiling heights are assumed to be 3.5 m for the anchor and line stores, banks and restaurants; 3 m for the parking garage, and 4 m for the cinema. Plenum heights are assumed to be 790 mm.

Fenestration: There are no external windows to the complex. Internally, shop fronts face onto the mall and circulation space. The eight roof sky lights are assumed to be pyramid shaped, with a 10 m by 10 m base. The single glazing is assumed to be heat-reflecting glass with a shading coefficient of 0.3. This glazing construction has a heat transmission value of $U=5.8W/m^2K$ (RSI 0.17).

Wall: External walls are assumed to be of framed concrete structure with plastered and painted masonry brick infill walls. Table 82 provides wall construction details. As shown, construction for the South Cape region assumes a masonry wall with a 50 mm air cavity with an overall thermal performance of RSI 0.68. Other locations typically use a masonry wall with no air cavity (RSI 0.42).

Table 82 Regional Shopping Centre Opaque Wall Construction Detail

Highveld/Interior and Lowveld/Mpumalanga Regions o 10 mm cement/sand plaster o 180 mm cement brick o 10 mm cement/sand plaster (RSI =0.42) Or South Cape Region o 10 mm cement/sand plaster o 90 mm cement brick o 50 mm cavity o 90 mm cement brick o 10 mm cement/sand plaster (RSI = 0.68)

Roof Construction: The roof is assumed to be of steel truss and purlin construction with coloured sheet metal profiled roof sheeting covering and 50 mm foil backed fibre glass over purlin insulation material. Table 83 provides roof construction details.

Table 83 Regional Shopping Centre Roof Construction Detail (Built-up Roof)

o 0.5 mm profiled steel roof sheet o 50 mm foil backed fibre glass insulation installed over the purlins and derated by 10% due to the over purlin installation o steel trusses o suspended ceiling (RSI = 1.27)

Building Facades: Bay widths vary. There are no windows on the external façade.

Lighting: Lighting levels for regional shopping malls are specified by space type, as shown in Table 84 overleaf.

Table 84 Regional Shopping Centre Lighting Levels by Space Type

SPACE TYPE	LIGHTING LUX LEVELS	LIGHTING W/m²	TYPE OF LIGHTING
Line and Anchor Shops	350	30	Decorative / Low voltage down lights
Restaurants	200	15	Decorative / Low voltage down lights
Banks	500	20	Decorative / Low voltage down lights & T8 Fluorescents with ECG
Supermarket	750	50	High Level Roof Mercury Vapour
Mall and Circulation Areas	150	40	Decorative / Low voltage down lights
Cinemas (Auditorium)	50	2	Generally wall mounted decorative on dimmer plus stair lights on dimmer
Cinemas (Foyer)	150	20	Decorative down lights (Low voltage) plus sign lights with fluorescents
Parking	80	5	T8 Fluorescents with ECG
General/Service Areas	150	10	T8 Fluorescents with ECG

Exterior lighting:

- Parking: 70W mercury.
- Signage/building exterior: Perspex with fluorescent background on 5% of external façade area, with 40W/m² total power.
  - Features – not applicable.

Occupancy: An average actual density of 30 m²/person is estimated.

Cooling Performance Characteristics: A coefficient of performance (COP) of 5.5 at full load was assumed for the chillers. This is based on current manufacturer's specifications.

Economizer Cycle (Free-Cooling): A dry-bulb based airside economizer has been assumed for the Highveld/Interior region only to take advantage of outside air for free-cooling.

Fresh Air Requirements: Fresh air requirements are set at 7.5 l/s-person at 5 m²/person or 1.5 l/s.m².

Ventilation Air: There are no minimum air change requirements under SA law/regulations.

Exhaust Fans: Washroom exhaust was assumed based on an exhaust rate of 15 l/s-m^2 per washroom and two washrooms per store. This includes main washrooms off malls.

Plug Loads: Plug loads are defined in Table 85Table 85 Regional Shopping Centre Plug Loads by Space Type (W/m^2)

Space Type	Plug Loads

Anchor and Line Shops	2.5
Restaurants (excludes large ovens & gas cooking equipment)	4
Banks	10
Supermarket	20
Circulation Areas	0
Cinemas (Auditorium)	2.5
Cinemas (Foyer)	1
Parking	1
General/Service	1

Domestic Hot Water: Hot water is supplied at 60°C by electric water heaters. The consumption is estimated at ½ l/capita/day.

Weather Data: The weather data used is shown in Table 86.

Table 86 Hotel/Leisure Complex Weather Data and Elevations

Region	Weather Data	Elevation
South Cape	Cape Town	42 m
Highveld/Interior	Johannesburg	1700 m
Lowveld/Mpumalanga	Durban	8 m

Regional Variations: As stated in the description of the opaque wall buildings, in the South Cape region are built with a masonry wall containing a 50 mm air cavity. Buildings in all other regions use masonry wall with no cavity.

In addition, air handling units are equipped with dry-bulb based economizers in the Highveld/Interior region only.

Operation Schedules: Operational schedules for all but the mall/circulation areas and the cinemas can be found in Table 87. Operating schedules for the mall/circulation areas and cinemas continue until 24:00hr everyday except for Sundays and holidays. There is no heating setback temperature, and no air-conditioning during unoccupied hours; however it is assumed that the air handling units will cycle during unoccupied hours in the winter period on a call for heating.

Figure 21 Regional Shopping Centre Notional Building – Level 1

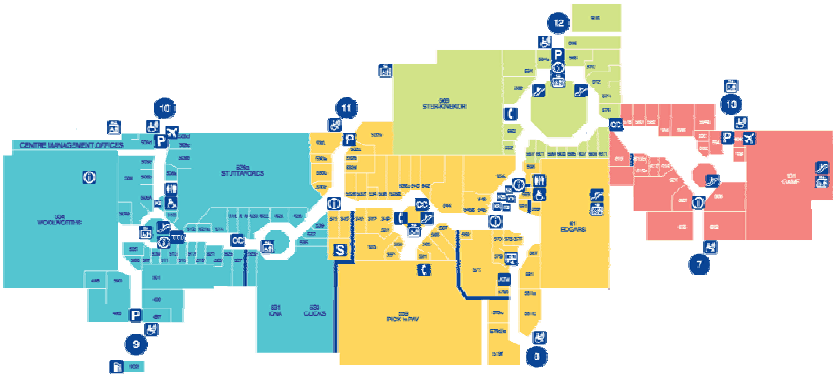


Figure 22 Regional Shopping Centre Notional Building – Level 2

Figure 23 Regional Shopping Centre Notional Building – Level 3

Table 87 Regional Shopping Centre Air Handling Unit Operating Schedules

Fan Operation (ON=1, OFF=0)																								
W	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
S	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
H	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Outside Air (ON=1, OFF=0)																								
W	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
S	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
H	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Heating Temperature °C (OFF=0)																								
W	0	0	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0
S	0	0	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0
H	0	0	0	0	0	0	0	21	21	21	21	21	21	21	21	21	21	21	21	21	0	0	0	0
Cooling Temperature °C (OFF=0)																								
W	0	0	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0
S	0	0	0	0	0	0	0	23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0
H	0	0	0	0	0			23	23	23	23	23	23	23	23	23	23	23	23	23	0	0	0	0
Lighting Operation (Fraction)																								
W	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2
S	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2
H	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	1	1	1	1	1	1	1	1	1	1	1	1	0.2	0.2	0.2	0.2
Equipment "Plug Loads" Operation (Fraction)																								
W	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.8	0.8
S	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1	1	1	1	1	1	1	1	1	1	0.8	0.8	0.8	0.8
H	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1	1	1	1	1	1	1	1	1	1	0.8	0.8	0.8	0.8
Hours																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A.M.								Noon									P.M.						Midnight	

3.12 Regional Shopping Centres - Shell Thermal Performance Levels

This section defines the energy efficient building shell alternatives modelled for this notional building.

3.12.1 Wall Construction

Because the base case wall construction varies by region, two different sets of energy efficiency wall constructions are presented. For South Cape region, four alternatives were analyzed. These constructions and their associated costs, together with the base case information, are summarized in Table 88. For the other two regions, five alternatives are analyzed. Their constructions, the associated costs, and the base case information, are summarized in Table 89.

Table 88 EE Alternatives for Wall Insulation (Regional Shopping Centre – South Cape)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[10] (R/m façade)
Base Case	—	0	Base + 0.68	50	--	--	--
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	25	R 12.78	R 17.00	--
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	25	R 15.49	R 17.00	R 25.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	25	R 19.36	R 17.00	R 50.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	25	R 22.13	R 17.00	R 75.00

*Additional is in reference to the Base Case.

Table 89 EE Alternatives for Wall Insulation (Regional Shopping Centre – Highveld/Interior and Lowveld/Mpumalanga)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Air Gap Thickness (mm)	Additional* Material Cost (R/m² wall)	Additional Labour Cost (R/m² wall)	Structural Modification Costs[11] (R/m façade)
Base Case	—	0	0.42	0	--	--	--
EE Level-0	—	Base + 0	Base + 0.26	50	--	--	R 50.00
EE Level-1	Fiberglass batts	Base + 25	Base + 0.63	0	R 12.78	R 17.00	R 25.00
EE Level-2	Fiberglass batts	Base + 50	Base + 1.07	0	R 15.49	R 17.00	R 50.00
EE Level-3	Fiberglass batts	Base + 75	Base + 1.67	0	R 19.36	R 17.00	R 75.00
EE Level-4	Fiberglass batts	Base + 100	Base + 2.22	0	R 22.13	R 17.00	R 100.00

*Additional is in reference to the Base Case.

3.12.2 Roof

Three energy efficiency roof alternatives were analyzed. The roof constructions and costs are summarized in Table 90.

[10] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

[11] Because the wall is thicker than the base case wall, either the useable floor space is decreased or the walls must be slightly longer. Either situation will lead to additional costs, which are captured in this column.

Table 90 EE Alternatives for Roof Insulation (Regional Shopping Centre)

EE Level	Insulation Material Type	Overall Insulation Thickness (mm)	Overall Insulation RSI Value	Additional* Material Cost (R/m² roof)	Additional Labour Cost (R/m² roof)
Base Case	—	50	1.27	--	--
EE Level-1	Extruded Polystyrene	Base + 25	Base + 0.69	R 22.80	R 22.00
EE Level-2	Extruded Polystyrene	Base + 50	Base + 1.38	R 45.43	R 22.00
EE Level-3	Extruded Polystyrene	Base + 75	Base + 2.08	R 68.17	R 22.00

*Additional is in reference to the Base Case.

3.12.3 Modelling Results

Energy efficiency alternatives were first modelled individually. Based on these results, combinations of alternatives that might lead to even lower life-cycle costs were modelled. The results are shown below, in both tabular and graphical form, by geographical region.

South Cape Region

The modelling results are summarized in Table 91, Table 92 and Figure 24.

Table 91 Annual Electricity Consumption by End-Use and End Use Intensity (Regional Shopping Centre – South Cape)

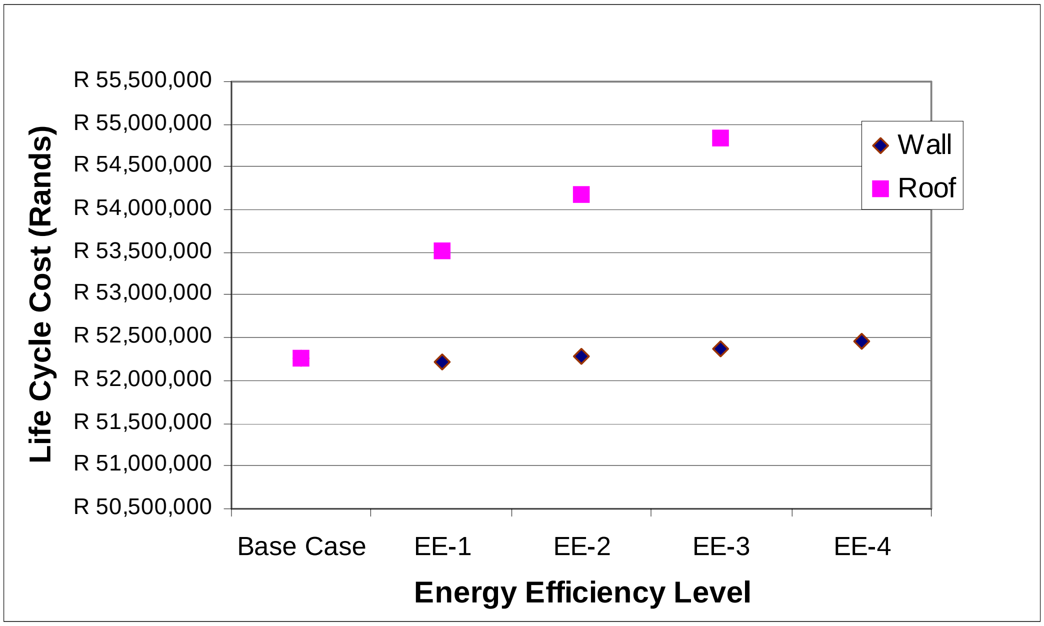
Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	11,896,780	2,002,595	2,475,223	5,213,062	85,788	104,248	1,891,825	61,081	5,775	23,736,380	370.9
Wall (EE-1)	11,896,780	2,002,595	2,472,582	5,101,532	82,700	85,915	1,885,081	61,081	5,775	23,594,040	368.7
Wall (EE-2)	11,896,780	2,002,595	2,470,545	5,099,212	82,025	84,776	1,883,346	61,081	5,775	23,586,140	368.5
Wall (EE-3)	11,896,780	2,002,595	2,470,175	5,099,913	81,769	84,264	1,882,621	61,081	5,775	23,584,980	368.5
Wall (EE-4)	11,896,780	2,002,595	2,469,467	5,099,343	81,479	83,830	1,882,029	61,081	5,775	23,582,380	368.5
Roof (EE-1)	11,896,780	2,002,595	2,470,834	5,196,664	84,590	86,959	1,890,952	61,081	5,775	23,696,230	370.3
Roof (EE-2)	11,896,780	2,002,595	2,468,778	5,190,828	84,115	85,279	1,890,622	61,081	5,775	23,685,860	370.1
Roof (EE-3)	11,896,780	2,002,595	2,468,131	5,185,659	83,574	84,043	1,890,836	61,081	5,775	23,678,480	370.0

Table 92 EE Alternative LCC Comparison (Regional Shopping Centre)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 5,553,488	R 0	R 52,264,740	
Wall (EE-1)	R 5,520,352	R 254,291	R 52,207,180	-0.11%
Wall (EE-2)	R 5,519,640	R 338,007	R 52,284,200	0.04%
Wall (EE-3)	R 5,519,945	R 431,628	R 52,380,690	0.22%
Wall (EE-4)	R 5,520,245	R 515,856	R 52,467,740	0.39%
Base Case	R 5,553,488	R 0	R 52,264,740	
Roof (EE-1)	R 5,546,436	R 1,317,165	R 53,515,540	2.39%
Roof (EE-2)	R 5,545,575	R 1,982,509	R 54,172,780	3.65%
Roof (EE-3)	R 5,545,438	R 2,651,088	R 54,840,070	4.93%

* With respect to Base Case.

Figure 24 EE Alternative LCC Comparison (Regional Shopping Centre)



For regional shopping centres in the South Cape region, the base case roof results in the lowest life cycle cost. The base case wall with an additional 25 mm of fibreglass batt insulation (EE-1) provides the lowest life cycle cost.

Highveld/Interior Region

The modelling results are summarized in Table 93, Table 94 and Figure 25.

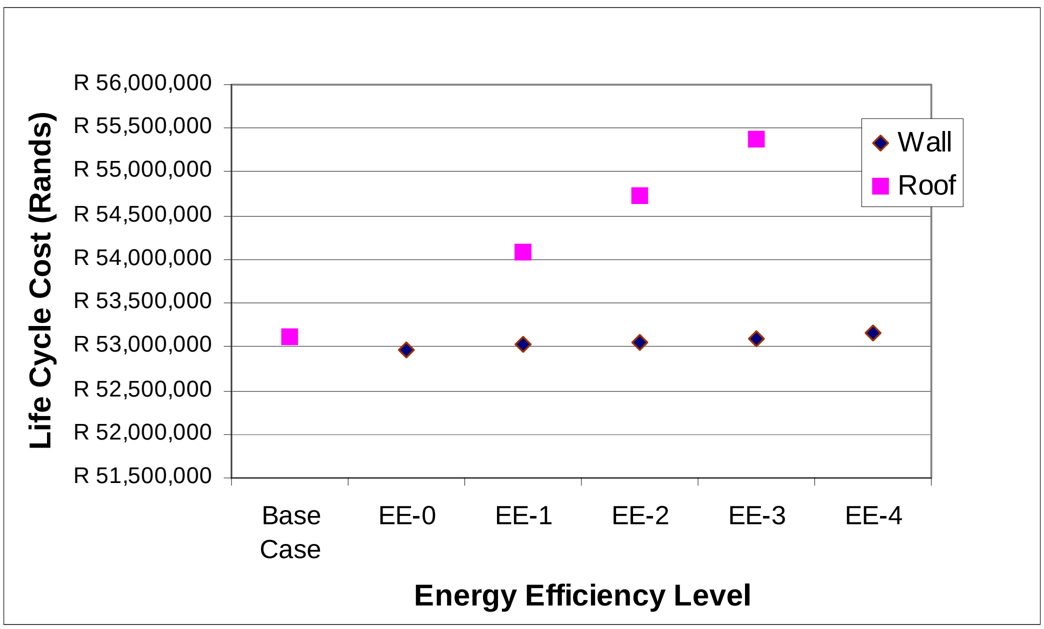
Table 93 Annual Electricity Consumption by End-Use and End Use Intensity (Regional Shopping Centre – Highveld/Interior)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	11,896,780	2,002,595	1,901,336	5,499,732	114,964	119,052	1,926,082	59,129	5,775	23,525,450	367.6
Wall (EE-0)	11,896,780	2,002,595	1,898,144	5,428,184	102,113	110,457	1,902,670	59,129	5,775	23,405,850	365.7
Wall (EE-1)	11,896,780	2,002,595	1,896,798	5,391,722	100,639	108,018	1,891,638	59,129	5,775	23,353,100	364.9
Wall (EE-2)	11,896,780	2,002,595	1,896,408	5,373,086	99,804	106,760	1,886,234	59,129	5,775	23,326,570	364.5
Wall (EE-3)	11,896,780	2,002,595	1,896,184	5,362,222	99,296	106,109	1,883,216	59,129	5,775	23,311,310	364.2
Wall (EE-4)	11,896,780	2,002,595	1,896,035	5,354,854	98,931	105,611	1,881,069	59,129	5,775	23,300,780	364.1
Roof (EE-1)	11,896,780	2,002,595	1,895,753	5,411,439	101,127	103,857	1,900,125	59,129	5,775	23,376,580	365.3
Roof (EE-2)	11,896,780	2,002,595	1,894,797	5,403,360	100,640	102,104	1,899,153	59,129	5,775	23,364,340	365.1
Roof (EE-3)	11,896,780	2,002,595	1,894,448	5,398,476	100,414	100,992	1,898,618	59,129	5,775	23,357,230	365.0

Table 94 EE Alternative LCC Comparison (Regional Shopping Centre – Highveld/Interior)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 5,644,850	R 0	R 53,124,560	
Wall (EE-0)	R 5,614,350	R 121,150	R 52,958,670	-0.31%
Wall (EE-1)	R 5,600,865	R 314,866	R 53,025,480	-0.19%
Wall (EE-2)	R 5,593,546	R 398,582	R 53,040,310	-0.16%
Wall (EE-3)	R 5,589,446	R 492,203	R 53,095,350	-0.05%
Wall (EE-4)	R 5,586,843	R 576,431	R 53,155,080	0.06%
Base Case	R 5,644,850	R 0	R 53,124,560	
Roof (EE-1)	R 5,607,580	R 1,317,165	R 54,090,970	1.82%
Roof (EE-2)	R 5,604,924	R 1,982,509	R 54,731,320	3.02%
Roof (EE-3)	R 5,603,260	R 2,651,088	R 55,384,240	4.25%

Figure 25 EE Alternative LCC Comparison (Regional Shopping Centre – Highveld/Interior)



For regional shopping centres in Highveld/Interior region, the base case roof results in the lowest life cycle cost. Walls EE-0, EE-1, EE-2, and EE-3 provide lower life cycle costs than that of the base case. The base case walls insulated with an additional 50 mm air gap (EE-0) provide the lowest life cycle cost.

Lowveld/Mpumalanga Region

The modelling results are summarized in Table 95, Table 96 and Figure 26.

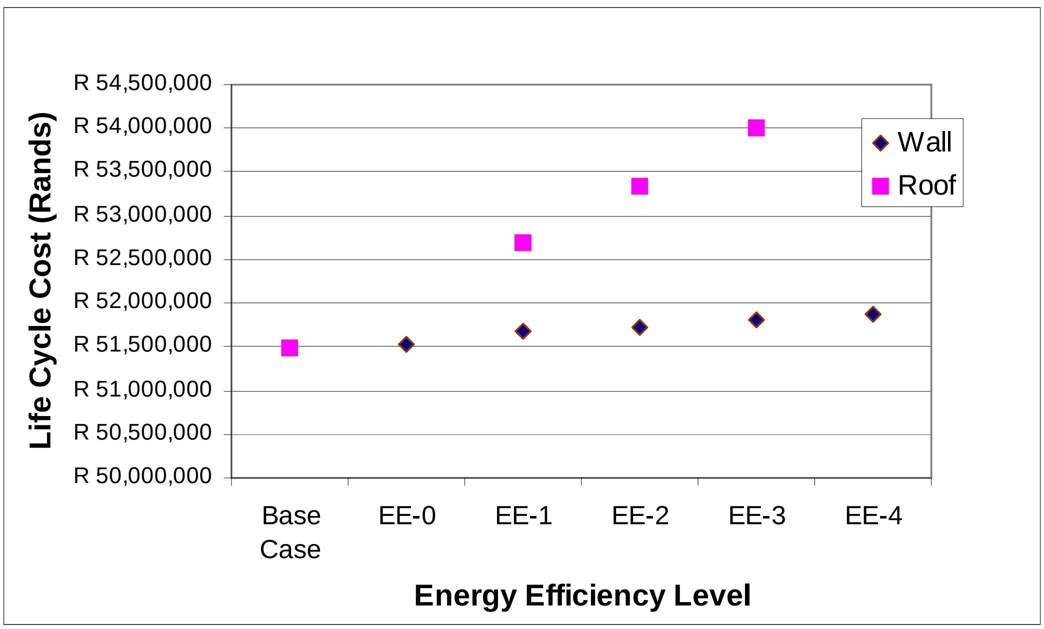
Table 95 Annual Electricity Consumption by End-Use and End Use Intensity (Regional Shopping Centre – Lowveld/Mpumalanga)

Alternative	Lights (kWh/yr)	Equipment (kWh/yr)	Heating (kWh/yr)	Cooling (kWh/yr)	Tower (kWh/yr)	Pumps (kWh/yr)	Fans (kWh/yr)	Hot Water (kWh/yr)	Ext. Lights (kWh/yr)	Total (kWh/yr)	EUI (kWh/m^2-yr)
Base Case	11,896,780	2,002,595	1,533,475	5,981,424	94,320	83,039	1,882,003	51,690	5,775	23,531,100	367.7
Wall (EE-0)	11,896,780	2,002,595	1,532,521	5,961,969	93,428	80,215	1,869,127	51,690	5,775	23,494,100	367.1
Wall (EE-1)	11,896,780	2,002,595	1,532,186	5,947,793	92,899	78,705	1,863,989	51,690	5,775	23,472,410	366.8
Wall (EE-2)	11,896,780	2,002,595	1,531,995	5,939,198	92,603	77,936	1,861,594	51,690	5,775	23,460,170	366.6
Wall (EE-3)	11,896,780	2,002,595	1,531,870	5,934,250	92,448	77,552	1,860,288	51,690	5,775	23,453,250	366.5
Wall (EE-4)	11,896,780	2,002,595	1,531,784	5,931,010	92,338	77,325	1,859,474	51,690	5,775	23,448,770	366.4
Roof (EE-1)	11,896,780	2,002,595	1,532,053	5,951,138	92,915	78,391	1,869,768	51,690	5,775	23,481,110	366.9
Roof (EE-2)	11,896,780	2,002,595	1,531,777	5,944,924	92,638	77,359	1,870,271	51,690	5,775	23,473,810	366.8
Roof (EE-3)	11,896,780	2,002,595	1,531,599	5,940,708	92,499	76,684	1,870,631	51,690	5,775	23,468,960	366.7

Table 96 EE Alternative LCC Comparison (Regional Shopping Centre – Lowveld/Mpumalanga)

Alternative	Annual Electricity Cost	Incremental First Cost	Life Cycle Cost	% Change*
Base Case	R 5,469,920	R 0	R 51,478,270	
Wall (EE-0)	R 5,462,689	R 121,150	R 51,531,370	0.10%
Wall (EE-1)	R 5,456,802	R 314,866	R 51,669,680	0.37%
Wall (EE-2)	R 5,453,622	R 398,582	R 51,723,460	0.48%
Wall (EE-3)	R 5,451,578	R 492,203	R 51,797,850	0.62%
Wall (EE-4)	R 5,450,094	R 576,431	R 51,868,120	0.76%
Base Case	R 5,469,920	R 0	R 51,478,270	
Roof (EE-1)	R 5,459,151	R 1,317,165	R 52,694,080	2.36%
Roof (EE-2)	R 5,456,533	R 1,982,509	R 53,334,790	3.61%
Roof (EE-3)	R 5,455,734	R 2,651,088	R 53,995,850	4.89%

Figure 26 EE Alternative LCC Comparison (Regional Shopping Centre – Lowveld/Mpumalanga)



For the regional shopping centres building in Lowveld/Mpumalanga region, the base case walls and roof result in the lowest cycle costs.

3.12.4 Results and Comments

The energy efficiency alternatives with the lowest life-cycle costs for the notional regional shopping centres are shown in Table 97.

Table 97 Energy Efficiency Alternatives with Lowest Life-Cycle Cost

Region	**Energy Efficiency Alternative**
South Cape	25 mm fibreglass insulation added to walls (EE-1)
Highveld/Interior	50 mm air gap added to walls (EE-0)
Lowveld/Mpumalanga	Base Case

Additional information relevant to the results shown in the above Table is provided in Section 4.1.4 of this report.

4 Discussion

This section presents a summary and interpretation of results, sensitivity analyses and comments. It further provides a discussion on renewable energy EE alternatives for commercial building design, as well as on current initiatives within AAAMSA concerning energy efficient building design.

4.1 Summary and Interpretation of Results

Table 98 below provides a summary of the results of the life cycle analysis of the thermal performance levels for each of the notional building types. The results are presented for each building component and for each weather zone included in the study scope. For reader reference, Table 98 shows three sets of thermal performance levels:

- Current practice (Base Case);
- The level of thermal performance (RSI) that would be achieved by using the EE alternatives that had the lowest life cycle cost in the analysis presented previously in Section 3.2 through Section 3.12 (Lowest LCC); and,
- The level of thermal performance (RSI) that would be achieved by using the most efficient EE alternative that was within 5% of the lowest life cycle cost alternative presented previously in Section 3.2 through Section 3.12 (Best Performance + 5% LCC).

Table 98 Summary of Cost Effective Thermal Performance Levels (RSI)

Building	Envelope	South Cape (RSI)			Highveld/Interior (RSI)			Lowveld/Mpumalanga (RSI)		
		Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC
Hospital	Wall	0.68	0.68	2.35	0.42	0.68	2.09	0.42	0.42	2.09
	Roof	1.27	1.27	1.27	1.27	1.27	1.96	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Low Rise Campus Office	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	3.35	1.27	1.27	3.35	1.27	1.27	1.96
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Large Office	Wall	1.72	1.72	2.79	1.72	1.72	2.79	1.72	1.72	2.79
	Roof	1.67	3.75	3.75	1.67	3.05	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.39	0.17	0.17	0.39	0.17	0.17	0.17
Hotel	Wall	0.68	2.9	2.9	0.42	2.09	2.64	0.42	1.05	2.64
	Roof	1.67	1.67	3.75	1.67	1.67	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Regional Shopping Centre	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	2.65
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Strip Mall	Wall	0.68	1.75	2.9	0.42	1.49	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

In theory, the energy efficiency alternative with the lowest life cycle cost represents the financially optimal combination of capital investment in energy efficiency at the time of the building’s construction and future

payments for energy operating costs over the life of the building, under the set of assumptions employed by the analysis.

In practice, any analysis such as this one requires a large number of assumptions and is subject to uncertainties. Under ideal conditions, the results of a modeling exercise such as this should be considered to have an accuracy of +/- 10%. Among other things, this means that the results should not be narrowly interpreted or applied. Rather, the results should be used by stakeholders to inform their decisions on specific performance levels to be applied in SANS 204. Consequently, the range of RSI values shown in Table 98 provides a better basis for the required decision making than a single set of values.

One of the observations from the results shown in Table 98 and in the graphics that follow is that if the lowest life cycle cost criteria is strictly adhered to, then the range for thermal performance improvements is limited primarily to walls when compared to the current practices that have been assumed in this analysis. However, by selecting those EE alternatives that are within 5% of the lowest cost EE alternatives the range for improved thermal performance levels increases significantly in both walls and roofs.

The following sections provide additional insights into the results for each of three building components addressed in this study.

4.1.1 Thermal Performance Levels for Roofs

A graphical presentation of the thermal performance levels for roofs shown in Table 98 is presented below in Figure 27 to Figure 29 for, respectively, the South Cape, Highveld/Interior and Lowveld/Mpumalanga regions. Key observations are provided below.

- The analysis shows that in the current practice for roof insulation in South Africa achieves a thermal performance of approximately RSI 1.3.
- The lowest LCC analysis was not successful in demonstrating a cost effective, higher thermal performance level, except for the large office building.
- However, under the 5% sensitivity analysis, the cost effective thermal performance level rises to a level that ranges from RSI 3.2 to 3.5.

Given that a significant improvement in thermal performance level is achieved by the 5% sensitivity analysis and that this 5% is well within the range of uncertainty that is inherent in any analysis such as this, it is recommended that the thermal performance values contained in the 5% sensitivity scenario provide the starting point for discussions on the values to be incorporated into SANS 204.

Figure 27 Cost Effective Thermal Performance Values – Roofs – South Cape

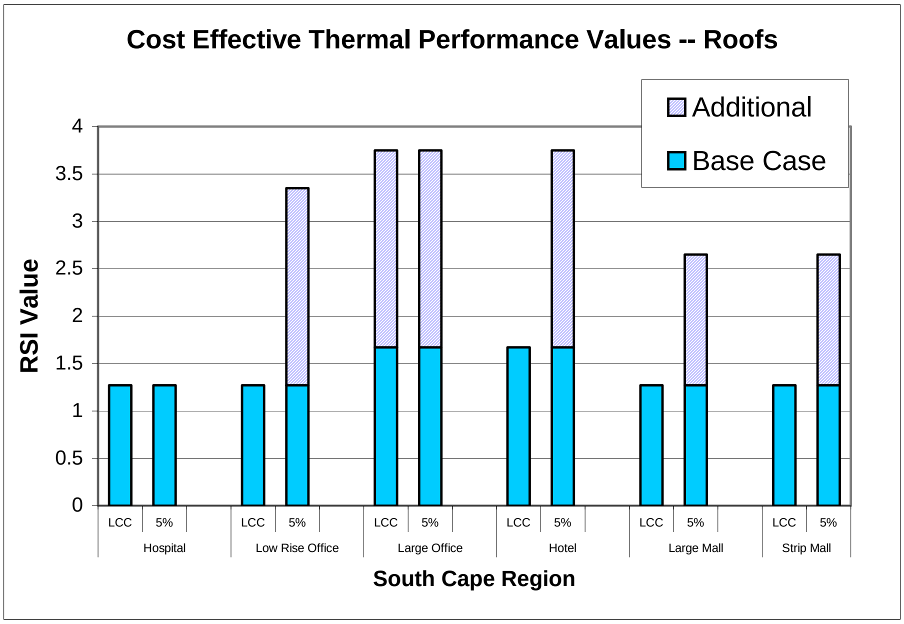


Figure 28 Cost Effective Thermal Performance Values – Roofs – Highveld/Interior

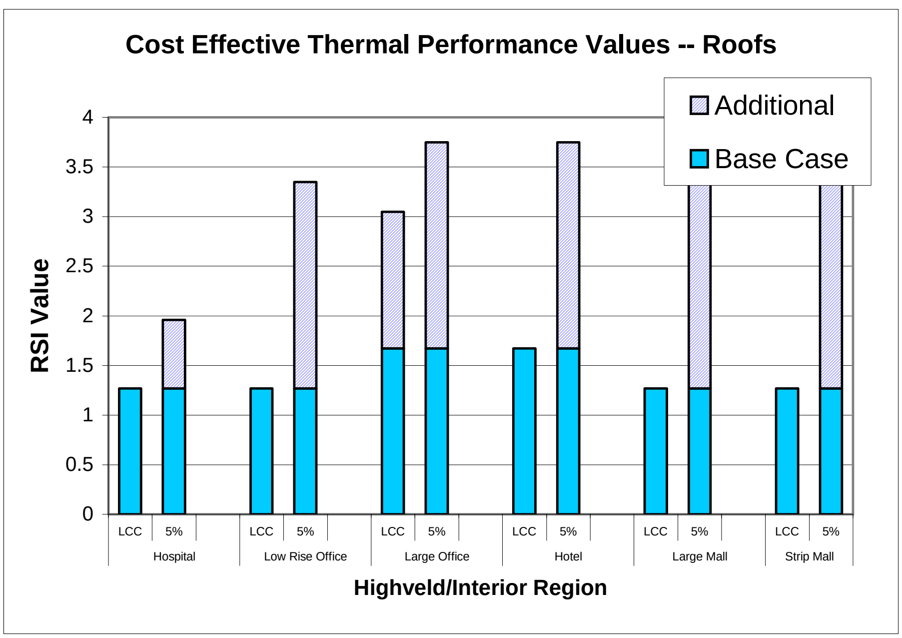
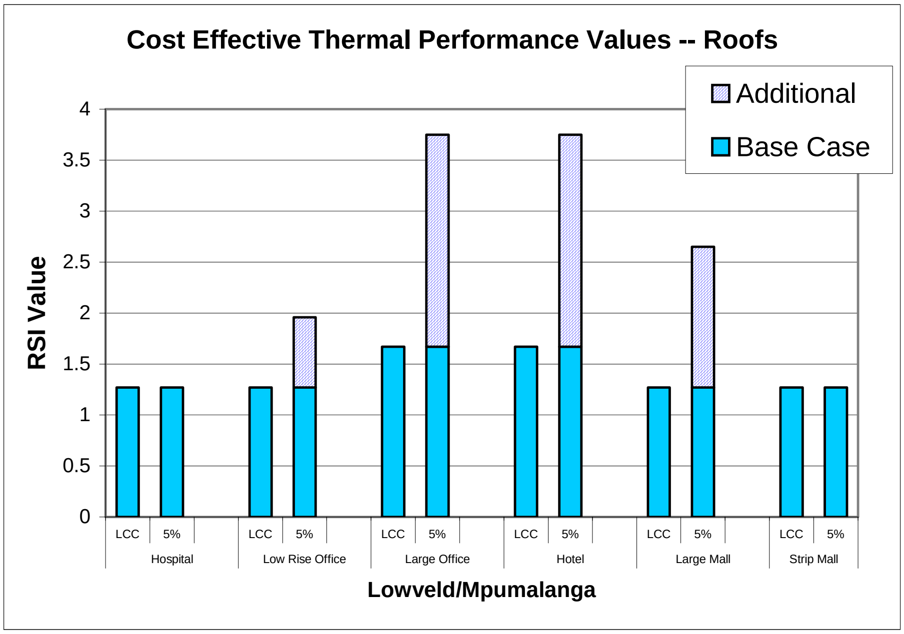


Figure 29 Cost Effective Thermal Performance Values – Roofs – Lowveld/Mpumalanga



4.1.2 Thermal Performance Levels for Walls

A graphical presentation of the thermal performance levels for walls shown in Table 98 is presented below in Figure 30 to Figure 32 for, respectively, the South Cape, Highveld/Interior and Lowveld/Mpumalanga regions. Key observations are provided below:

- The analysis shows that current practice for wall insulation achieves a thermal performance of approximately RSI 0.5 with a slightly higher thermal performance level in the South Cape Region.
- The lowest cost LCC analysis show, in contrast, that a higher performance level that ranges from 0.7 to 1.3 RSI that is cost effective in most building types. In effect, this indicates that an additional 25 to 50 mm of insulation is cost effective in most applications on a 20 year life cycle basis.
- Under a 5% sensitivity analysis, the cost effective performance level rises significantly to a RSI level between 2 and 2.5.

Although there is variability, and some segments did not show a cost improvement level beyond current practice, it is recommended that an RSI value in the range of 2 to 2.5 provides the starting point for the discussions on the values to be incorporated into SANS 204.

Figure 30 Cost Effective Thermal Performance Values – Walls – South Cape

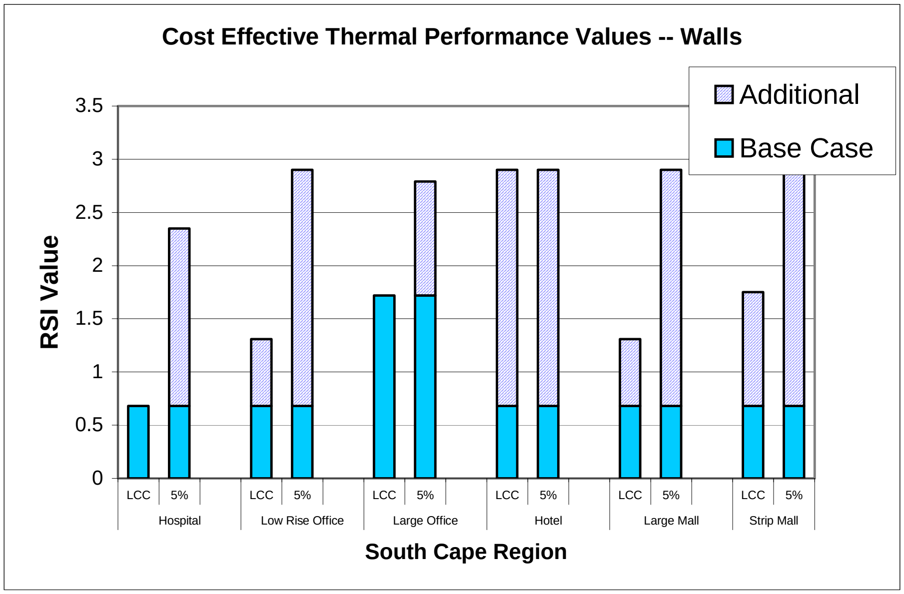


Figure 31 Cost Effective Thermal Performance Values – Walls – Highveld/Interior

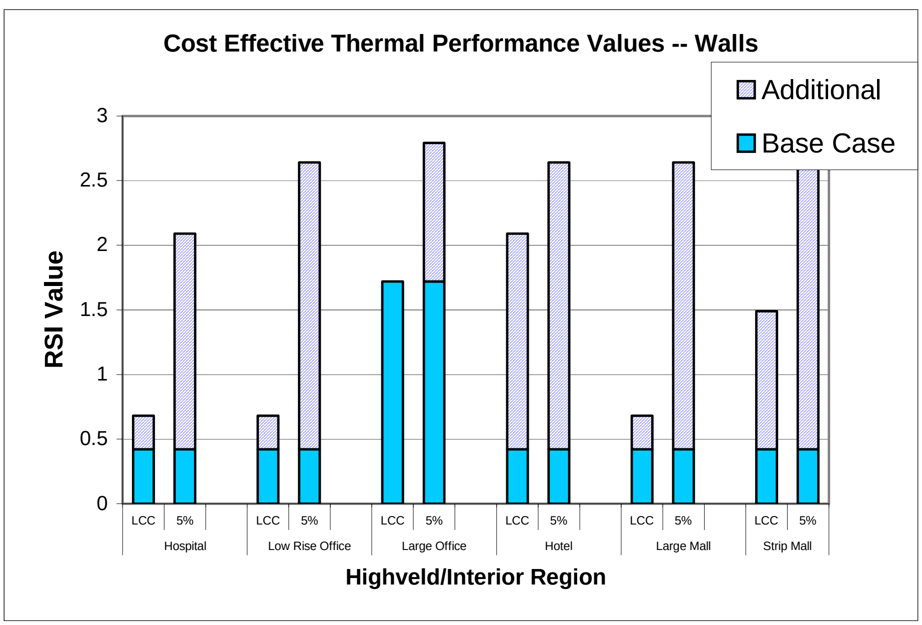
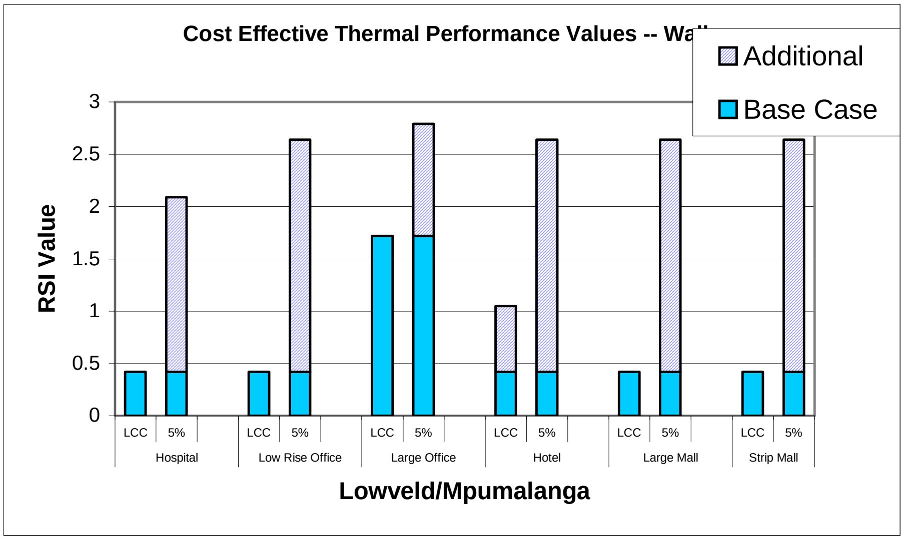


Figure 32 Cost Effective Thermal Performance Values – Walls – Lowveld/Mpumalanga



4.1.3 Thermal Performance Levels for Windows

A graphical presentation of the thermal performance levels for walls shown in Table 98 is presented below in Figure 33 to Figure 35 for, respectively, the South Cape, Highveld/Interior and Lowveld/Mpumalanga regions.

The LCC analysis of glazing systems failed to show cost effective higher thermal performance options, with the possible exception of large office buildings (LCC +5%). This is not surprising given South Africa's relatively mild winter climate. The improved windows reduce solar gain, which often increases heating requirements. However, windows with better thermal performance often also reduce the amount of "free cooling" obtained at night and during mild weather, which increases the energy required for mechanical cooling. As a result, the overall savings are relatively small.

Figure 33 Cost Effective Thermal Performance Values – Windows – South Cape

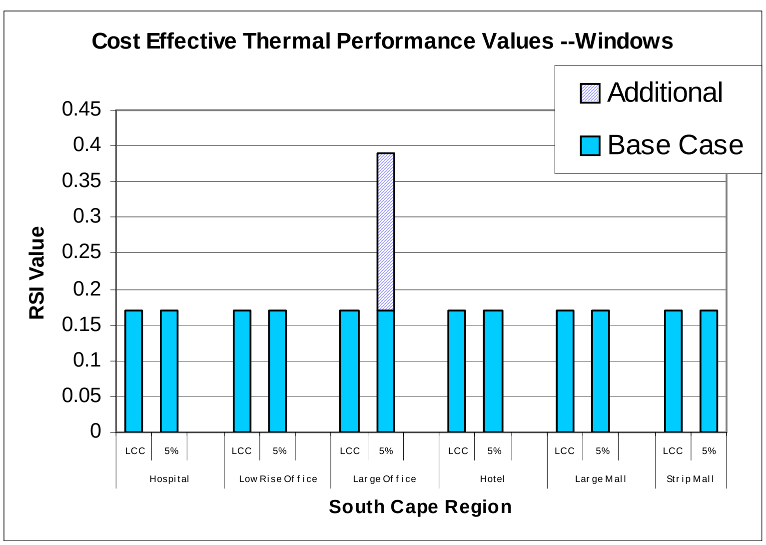


Figure 34 Cost Effective Thermal Performance Values – Windows – Highveld/Interior

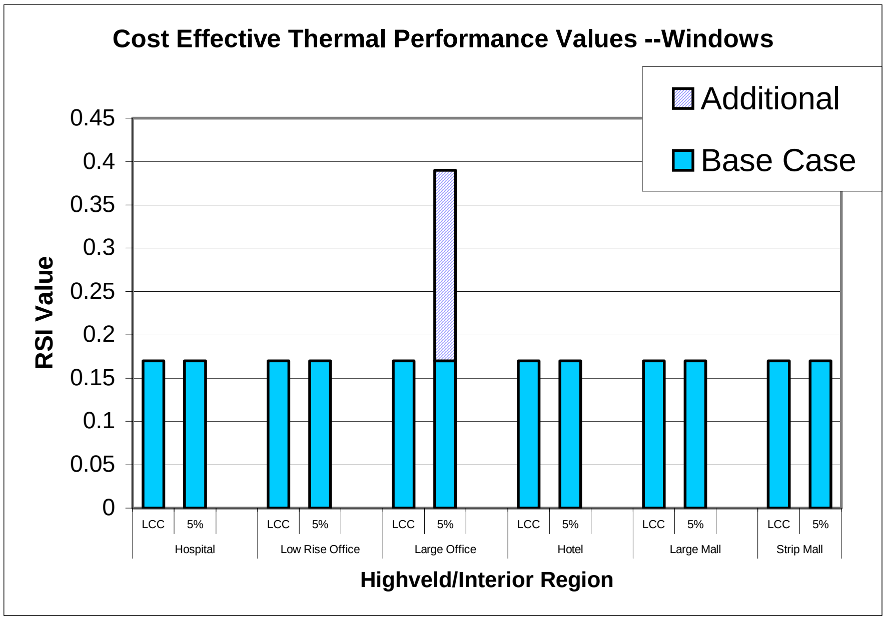
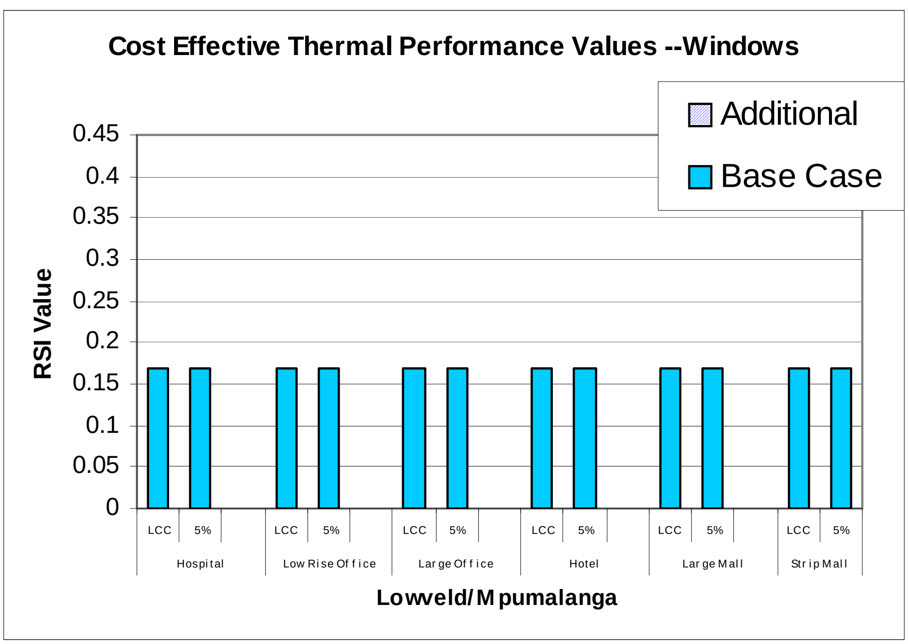


Figure 35 Cost Effective Thermal Performance Values – Windows – Lowveld/Mpumalanga



4.1.4 Sensitivity Analysis

During the final workshop and stakeholder review process, the following items were identified for further review.

- Electricity price escalation
- Labour costs and shading coefficients for EE window upgrades

As there was insufficient time or budget available to redo all of the building energy use simulation runs using the revised data, the approach taken was to conduct a sensitivity analysis on each. The results of the sensitivity analyses are presented below, together with comment on the implications for the study results.

Future Electricity Prices

Consistent with the direction provided by the client, the main analysis of energy efficiency upgrade alternatives assumes an average increase in electricity prices of 1.6% per annum (net of inflation). This low price increase combined with South Africa's current low electricity rates results in electricity prices that remain well below the rates found in most other jurisdictions.

Consequently, to test the sensitivity of the Life Cycle Cost results to higher electricity prices, one notional building type (Low Rise Office) was tested in the South Cape climate zone using future electricity escalation (net of inflation) rates of 3%, 5%, 10% and 15%. It should be emphasized this sensitivity analysis was applied only to the rate of future price increase, not to current costs. The results are shown below in Table 99.

Table 99 Sensitivity of Results to Future Electricity Prices

	LCC at Escalation Rate				
EE Scenario	1.62%	3%	5%	10%	15%
Base Case	R 1,625,062	R 1,757,091	R 1,948,438	R 2,426,805	R 2,905,171
Wall (EE1)	R 1,619,719	R 1,748,911	R 1,936,146	R 2,404,235	R 2,872,324
Wall (EE2)	R 1,623,499	R 1,752,029	R 1,938,303	R 2,403,990	R 2,869,677
Wall (EE3)	R 1,628,141	R 1,755,984	R 1,941,263	R 2,404,463	R 2,867,662
Wall (EE4)	R 1,633,893	R 1,761,228	R 1,945,772	R 2,407,131	R 2,868,491
Roof (EE-1)	R 1,646,005	R 1,776,096	R 1,964,633	R 2,435,977	R 2,907,321
Roof (EE-2)	R 1,655,534	R 1,784,561	R 1,971,556	R 2,439,044	R 2,906,531
Roof (EE-3)	R 1,669,767	R 1,798,102	R 1,984,095	R 2,449,078	R 2,914,061
Window (EE-1)	R 1,687,425	R 1,818,632	R 2,008,788	R 2,484,176	R 2,959,565
Window (EE-2)	R 1,767,405	R 1,896,768	R 2,084,251	R 2,552,957	R 3,021,664
Window (EE-3)	R 1,784,595	R 1,911,920	R 2,096,448	R 2,557,769	R 3,019,089

As illustrated in Table 99, the escalated electricity prices substantially increase the life-cycle cost of the building's operation over the life of the measures; however, they have only marginal impacts on the relative ranking of the EE alternatives. One of the key reasons that the impacts are not more significant is that the impact of future price increases is significantly reduced by the effect of the 10% discount factor. A lower discount rate or a higher energy cost in the current year would be expected to favour higher levels of energy efficiency investment.

In summary, the results of Table 99 indicate that the results shown in Table 98 and Table 99 are not significantly affected by the change in energy price escalation. They would, however, be more strongly affected if higher energy prices existed today.

4.1.5 Window Labour Costs and Shading Coefficient

Following the final project workshop, it was agreed that the labour costs for the EE window upgrades should be lower than the values used in the draft report and that the window shading co-efficients should be altered. To test the sensitivity of the window results (as contained in the draft report) to these changes the high rise office notional building was selected. The large office was selected as it has the largest total window area (3,300 sq.m.) and the largest window to surface area ratio (29.5%).

The large office building was rerun for two weather regions: South Cape region, which has the largest heating load and the Lowveld/Mpumalanga region, which has the largest cooling load. The results, which are shown in Table 100, indicate the combined input changes have very minimal impact on the life cycle cost values contained in the draft report and in this final version.

Table 100 Sensitivity to Revised Window Assumptions

	Large Office (South Cape)				
	Draft Report		Revised		Difference
	Shading Coefficient	Draft Results	Shading Coefficient	Revised Results	
Base Case	0.95	R 19,285,060	0.95	R 19,285,060	
Window (EE-1)	0.4	R 19,678,570	0.52	R 19,701,730	0.12%
Window (EE-2)	0.4	R 20,362,480	0.81	R 20,299,780	-0.31%
Window (EE-3)	0.4	R 20,671,460	0.65	R 20,546,800	-0.61%
	Large Office (Durban)				
	Draft Report		Revised		Difference
	Shading Coefficient	Draft Results	Shading Coefficient	Revised Results	
Base Case	0.95	R 17,551,640	0.95	R 17,551,640	
Window (EE-1)	0.4	R 18,025,660	0.52	R 18,097,520	0.40%
Window (EE-2)	0.4	R 18,968,240	0.81	R 19,053,200	0.45%
Window (EE-3)	0.4	R 19,355,330	0.65	R 19,311,330	-0.23%

4.1.6 Conclusion

The results of the sensitivity analysis noted above demonstrate that the results and relative performance trends contained in Table 98, above, remain robust under the conditions addressed within the sensitivity analysis.

The thermal performance and life cycle cost results presented in the Tables and Figures above, therefore, provide a clear and robust reference point for the subsequent discussion on changes to the performance levels contained in SANS 204.

4.2 Existing Buildings

4.2.1 Energy Consumption in Existing Buildings

The Service Provider solicited owners and managers of existing buildings to provide energy consumption information as indicated in Table 101 overleaf.

Table 101 Existing Buildings Targeted for Energy Consumption Assessment

	NOTIONAL BUILDING	BUILDING(S)	OWNER	CONTACT MADE
1	Regional shopping centres/malls	• Brooklyn Mall, Pretoria • Menlyn Mall, Pretoria • Tyger Valley Shopping Centre, Cape Town • Gateway Shopping Centre, Durban	Growth Point Properties, managed by Investec Property Group Growth Point Properties managed by Investec Property Group Old Mutual Properties (owners and managers)	Yes Yes Yes Yes
2	Suburban strip shopping/value centres	Glen Village, Pretoria	Christodoulou Group	Yes
3	Low rise /campus style office park developments	• Africon, Pretoria • Melrose Arch	Intersite Managed by Investec Asset Management	Yes
4	High rise office blocks	Forum Building, Sandton The Spearhead, Cape Town	Sanlam TBA	Yes Yes
5	Hotels & resorts	Montecasino	Tsogo Sun Hotels and Resorts	Yes
6	Hospitals	Netcare Hospitals	Netcare Hospital Group	Yes
	South African Property Owners Association	Rod Oosthuizen, Chairman SAPOA Property Developers Committee		Yes

The format shown in Annex 2 was used to solicit electrical energy data from owners and managers of existing buildings. Initially, the project team experienced some difficulty in obtaining data, and had to approach senior members of owners' teams on the basis that they would be in a position to "unlock" data considered strategic. The approach produced some positive results.

Figure 36 Energy Consumption in Existing Buildings

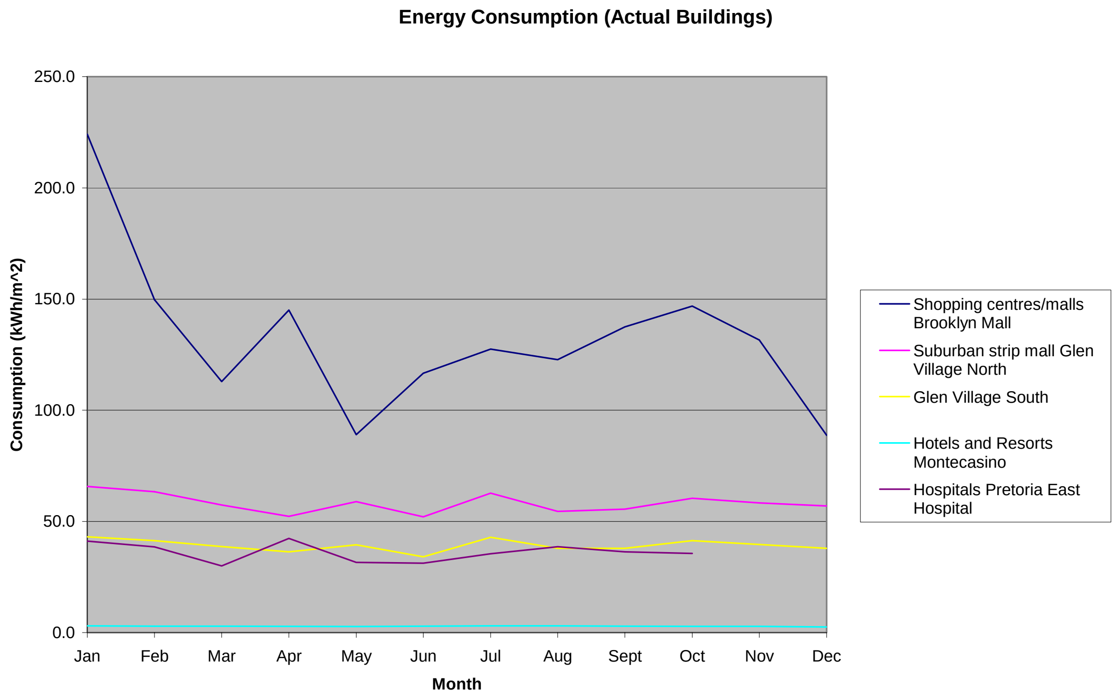


Figure 37 Energy Consumption in Notional Buildings

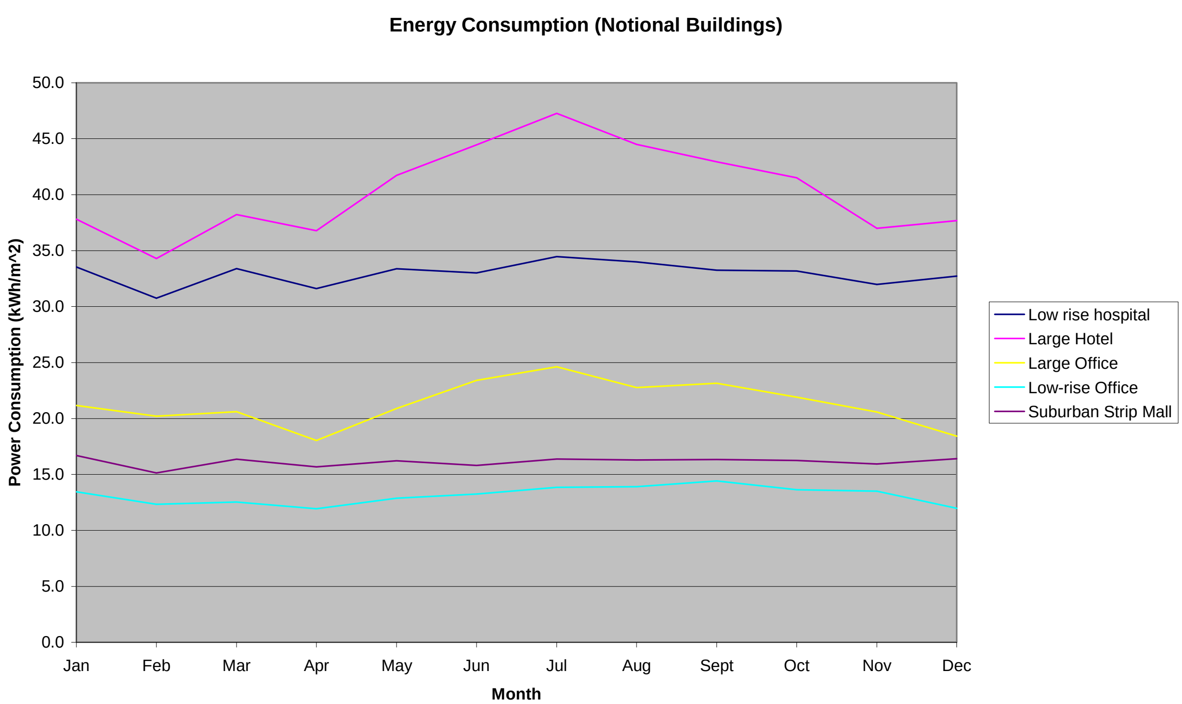


Table 102 Comparison of Energy Consumption in Existing Buildings and Notional Buildings

	Existing Building	**Notional Building**	
	Range of Energy Consumption (Jan-Dec), kWh/m^2		
Low Rise Hospital	30-40	16-17	Notional Building
Large Hotel	5	38-47	Existing Building
Large Office		18-25	
Low-rise Office	30-40	12-13	Notional Building
Suburban Strip Mall	50-66	15-17	Notional Building
Large Mall	80-220		

The comparison of energy consumption in existing and notional buildings for four types of buildings revealed relatively low energy consumption in notional buildings in three out of the four cases. Lower energy consumption was found in Low Rise Hospital, Low Rise Office and Suburban Strip Mall. The lower energy consumption in existing building occurred in Large Hotel.

Comparison of Results from existing Large Office building energy audit (Johannesburg) with the LCC analysis for the same building is undertaken in Table 103 in order to validate results of the analysis.

Table 103 Comparison of Energy Audit in Large Office Buildings with the LCC Analysis for the Same Building Type

<table>
<tr><th>Building</th><th colspan="2">Energy Consumption (kWh)</th><th>Assumption</th></tr>
<tr><td rowspan="2">Large Office (Notional)</td><td>Electrical use summary (Base Case) for the year</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>6,221,004 (Table 26)</td></tr>
<tr><td rowspan="4">Existing Large Office (JHB)</td><td rowspan="4"></td><td>Estimate per day</td><td></td></tr>
<tr><td>47,982 (Annex 4)</td><td></td></tr>
<tr><td>Estimate for the year</td><td>240 working days/year</td></tr>
<tr><td>11,515,680</td><td></td></tr>
</table>

Thus, the selected existing Large Office building (Johannesburg) consumed 85% more energy in the survey period than the Large Office notional building. Although this does not provide a basis for broad conclusions, it does indicate that the results of the analysis are of the same order of magnitude as actual building energy consumption.

The Renewable Energy specialist on the project team carried out building energy audits for several existing buildings in Johannesburg in 2004. He has provided several building energy audit results courtesy of the buildings' owner.

A sample of the energy audit and preliminary consumption analysis is presented in Annex 2. Preliminary results show that a saving of 25% is easily achievable. In addition, Case Studies of energy consumption in several commercial buildings are presented in Annex 5.

4.3 Renewable Energy Solutions for Energy Savings in Buildings

This section presents principles of renewable energy design for commercial buildings as an introduction to the analysis and development of design guidelines, which will be carried out during the remainder of the project.

4.3.1 Introduction

Renewable energy solutions for energy savings in buildings are normally categorized as active and passive and normally with specific reference to solar energy.

Passive solar design uses incident solar energy, the natural movement of heat and air to maintain comfortable living conditions, while operating with limited mechanical input. Passive solar design maximizes the benefits it receives from the sun with standard construction features. It also takes advantage of natural air movement and features such as trees for shade and windbreaks. The objective is to use simple systems to collect and store solar energy with no switches or controls.

However, active solar design incorporates the use mechanical devices such as pumps and fans to in conjunction with solar thermal collectors. Photovoltaic arrays are also considered an active solar system.

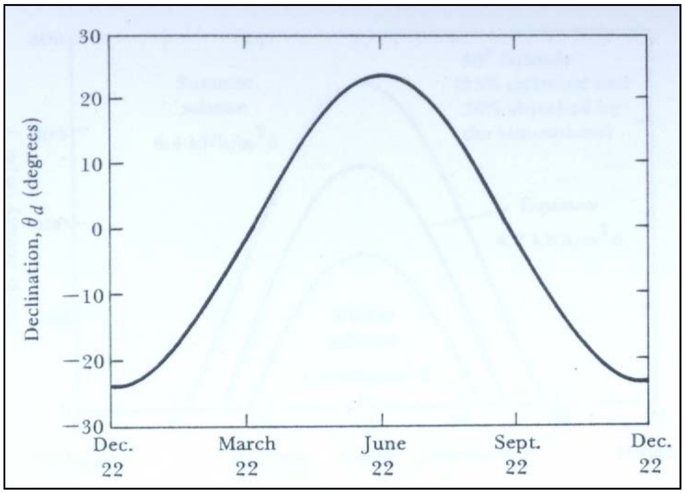
4.3.2 The Usefulness of Sunlight

Due to its nature, solar energy is a notoriously complicated energy source to make use of in a controlled manner for building energy design and management.

The average solar energy intensity outside the earth's atmosphere is approximately 1395 W/m² for a plane normal to the rays of the sun. A small variation in the intensity occurs as a result of the elliptical orbit of the earth. This variation is approximately ± 3.5% or ± 50 W/m². However, the radiation which reaches the earth's surface differs significantly from that at the outer atmosphere. Taking an average reflectivity of 35% and an atmospheric absorption of approximately 20% the average radiation reaching the earth from a directly overhead sun is (1- 0.35)(1 – 0.2) or 52% of the solar energy incident at outer space.

Absorption is dependent on the distance which the sun's rays travel through the atmosphere and the local climatic conditions and the reflection is dependant on the angle at which the sun's rays enter the atmosphere. Therefore the angle of incidence, which is a function of both the earth's curvature and the declination angle, which has a 23.5º tilt, is an important factor when determining the solar radiation at a particular site because both absorption and reflection is a function thereof. The maximum and minimum value for incident solar energy corresponds to the tilt of the earth's axis, as shown in Figure 38.

Figure 38 The Earth's Declination Variation



4.3.3 Determining Solar Radiation Data

When determining solar radiation data on the surfaces of a building envelope, there will almost always be a reflected component which will have to be considered. Determining the direct component onto a flat surface normal to the suns rays is relatively simple. However, when the incident solar radiation on a building envelop is considered, reflected radiation can become a significant component as a result of the surrounding buildings and other surfaces. The diffuse component of solar radiation is seen by Eberhard to represent the largest potential for error. His data handbook on solar radiation for Southern Africa can be a useful tool for determining solar radiation data on buildings. However, it should be used in conjunction with more specific design methodologies.

4.3.4 Solar Design Principles

Passive solar designed buildings take careful planning and are based on the following design principles:

- Orientation
- Overhangs and shading
- Windows
- Thermal Mass
- Layout and configuration
- Daylighting

Of the above principles orientation, thermal mass and Layout and configuration have to be designed into the building from the onset. Overhangs and shading, insulation, day lighting and windows can either be part of the original design but can also be retrofitted and/or be part of an upgrade.

Orientation

In South Africa the most accepted building orientation is north facing to make use of the winter sun. The reference to north facing has to do with windows and window sizes. It is common practice to have more or larger windows on the north facing side of a building than the other sides. Unfortunately this can also create problems in summer with the result that more aggressive measures have to be taken to ensure adequate cooling in summer. However, this will be addressed and discussed.

Orientation combined with layout and configuration can also combine to make use of the natural air movement for cooling and ventilation.

Overhangs and shading

The most efficient way of protecting a building is to shade its windows and other openings from unwanted direct sunlight. The degree and type of shade necessary depends on the position of the sun and the position and geometry of the part of the building being shaded. In summer the sun is relatively high in the sky, which results in a small angle of incident radiation.

Therefore, any north facing apertures receive less solar radiation and it is easier to protect them. Shading of east and west facing windows, on the other hand, poses a greater problem because the sun is low in the sky when it is in the east or west and a greater amount of solar radiation reaches these windows. One solution, therefore, is to consider reducing as far as possible the area of east and west-facing glazing.

Overhangs and shading can be effective for limiting the heating effect of the sun as shown in Figure 39 and Figure 40.

Figure 39 Roof extension used for shading

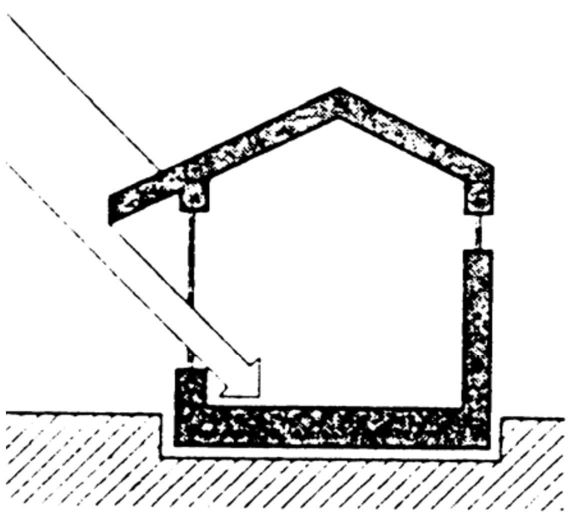
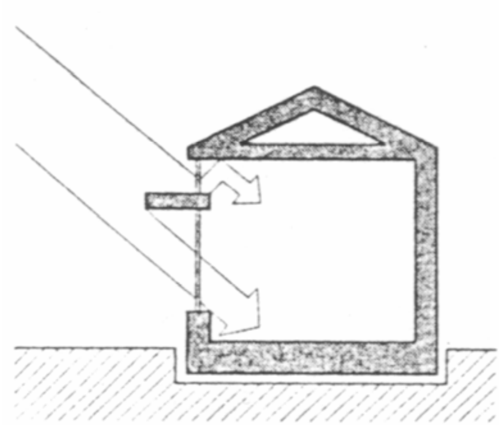


Figure 40 Window Overhang

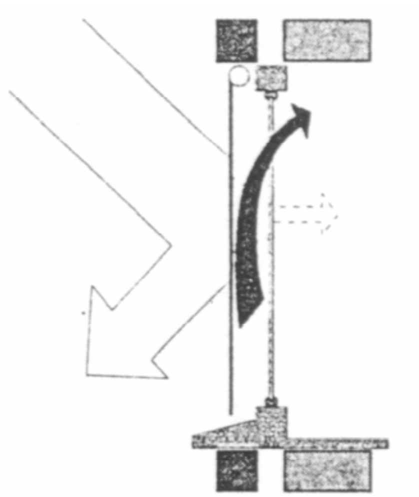


Shading can include trees as well as overhangs which form part of the building design. When overhangs and shading are used as part of the solar passive design process the difference in the position of the sun during winter and summer should be borne in mind. By doing this overhangs and shading can be very effective. Movable screens can also be an effective means controlling incident solar energy.

The design of a shading device, which is a fixed part of a building, is distinct from one which can be adjusted, must take into account the orientation of the aperture being protected. North facing windows may be shaded by an overhang above the glazed element. To obtain the maximum benefit from the sun's rays in winter, when they can make a useful contribution to heating requirements, it is sensible to locate the overhang in such a position that rays can pass through the opening when the sun is low in the sky. The depth of the overhang should take into account not only its distance above the window but also the aperture height. The length of the overhang is determined by the window width.

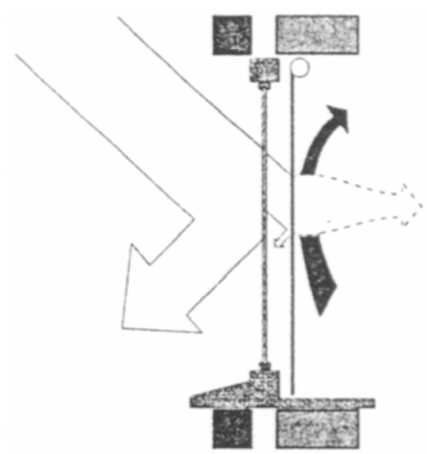
East and west facing windows can benefit from lateral shading. Because the sun’s position changes, a movable vertical screen can be the most effective way of providing this although it can pose problems of stability and maintenance. If a fixed screen is to be used, its dimensions should be determined from the width and height of the window and the distance of the screen from it. It can be useful to use sun path diagrams to estimate the amount of shadow thrown onto the window by the proposed screen.

Figure 41 Outside Screening



The effectiveness of fixed screens varies according to the seasonal changes in the position of the sun. Because climatic seasons do not correspond to solar seasons, it is preferable in regions with a long heating season to erect movable protection, which can be adjusted easily. Shutters, blinds, awnings and curtains are all examples of adjustable shading devices. They can also be used in winter to increase thermal insulation. The effectiveness of their shading is expressed by a shading coefficient, which is the ratio of the solar energy passing through a protected opening to the energy which would pass through the opening if it was unprotected. Usually, a simple window is taken as the reference.

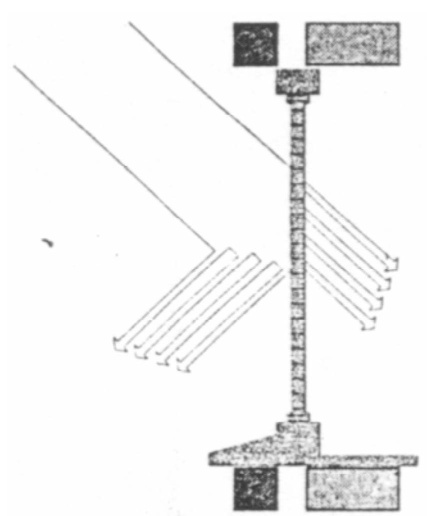
Figure 42 Inside Screening



In designing a shading system, the aim should be to minimize solar gains but not to darken the inside and as a result force occupants to use artificial lighting. It is preferable to place screens outside rather than inside the building so that most of the sunlight can be reflected before reaches the glazing as shown in Figure 41. Unless they are reflectant, internal screens do not stop the sun's rays until after they have passed through the window and in so doing heat the air between the window and the screen and the screen itself heat up as illustrated in Figure 42. The screen can be sandwiched between the two layers of glass in a double glazed unit, thus enabling the features of an external screen to be retained while avoiding maintenance problems.

The color and surface condition of a screen also play a role in determining its effectiveness. Their reflection and absorption properties have an effect on the amount of solar radiation entering the building as shown in Figure 43.

Figure 43 Surface Conditioning



It is also possible to plan and design a building so that it can benefit from shading by neighboring buildings. In this context, trees can play the same role.

Almost invariably, some shade will be thrown on a building by neighboring construction. This effect is frequently put to deliberate use in hot and dry climates where cities and towns may be planned and built in a very compact form with narrow streets so that all the buildings are shaded to some extent from the sun. In such situations, however, it is important that the buildings are not placed so close together that ventilation is difficult to achieve. Even in the design of individual buildings and their surrounding spaces, it is possible to use existing neighboring buildings to block off unwanted solar radiation.

The topography of a place, too, can often create shade. Therefore, when choosing a location for the building on a site in regions where overheating is likely, it is sensible to try to take advantage of this and construct the building in the most shaded area. The shadow cast by the topography will be a function of the path taken by the incident solar radiation, function of the sun path, the orientation and the tilt of the land.

Shading can also be provided by vegetation. If the planting is deciduous, a certain amount of advantage can be taken of the sun's rays in winter when the branches are bare but provide a progressively increasing amount of shade created from spring onwards as the leaves grow. It is best to choose plants with dense foliage but few branches so that maximum protection is provided in summer and minimum shade in winter. It should be noted that a bare tree will block out some 20-40% of the sun's rays.

Windows and special glazing

For windows which are difficult to shade, special glazing can be useful when trying to prevent unwanted heat gains while retaining the view and natural light. Absorbing glass reduces the overall transmission of solar radiation through the window by cutting down on direct transmission and increasing re-emission towards the exterior after absorption.

Reflecting glass is made by coating the glass with a thin layer of highly reflective metal oxide. Ideally, this should be on the outside of the window. This would, however, create durability problems and the film is as a result normally placed on the inside face of the outer layer of glass or the outside face of the inner layer (in the case of double glazing). If the reflective layer is placed on the inner glazing, care must be taken with the design of the double glazed unit to ensure that the air in the gap cannot heat up and thus cause loss of seal.

Absorbing or reflecting glasses, illustrated in Figure 44 and Figure 45, are recommended mainly for windows facing east or west. They are rarely used in domestic buildings at present but have good potential for the future, especially in hot climates.

In addition, while not yet commercial, there is considerable development in photochromic, thermochromic and electrochromic glasses which modify the incoming rays of the sun so that the optical properties of the glass change and, for instance, darkening of the glass can occur.

Figure 44 Reflecting Glass - Coating on Inner Surface

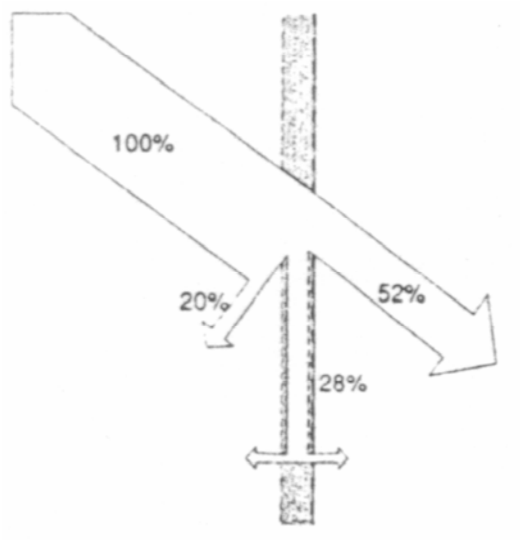
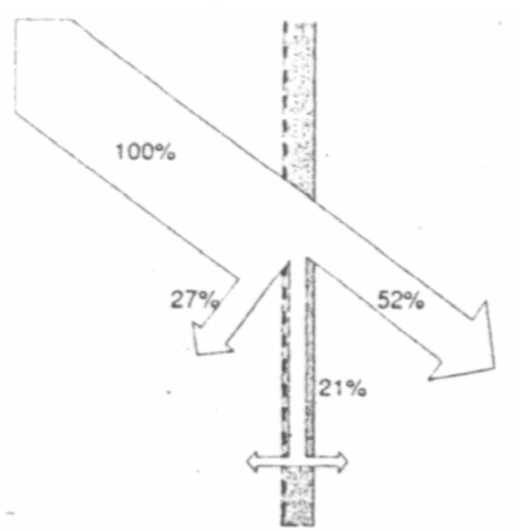


Figure 45 Reflecting Glass - Coating on Outer Surface



The diagrams shown in Figure 46 through Figure 50 give typical values for the proportions of solar radiation transmitted by a range of glazing systems.

Double glazing is also a very effective method of making windows more energy efficient and is very common in the colder parts of the world. Double glazing is not merely having two layers of glass in one window frame. The cavity between the to window panes is filled with an inert gas to reduce heat transmission through conduction to the inside. However, it does not stop radiated heat from passing from the outside to the inside. Figure 49 presents a typical example of how double glazing would react to incident solar radiation.

Figure 46 Reflecting glass with Coating on Outside

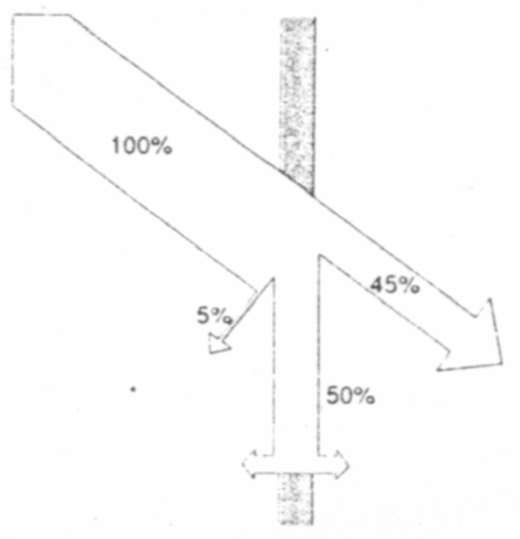


Figure 47 Absorbing Glass

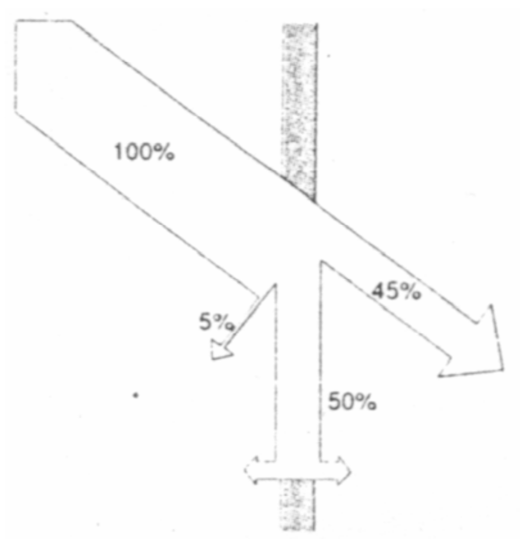


Figure 48 Reflecting Glass and Clear Glass

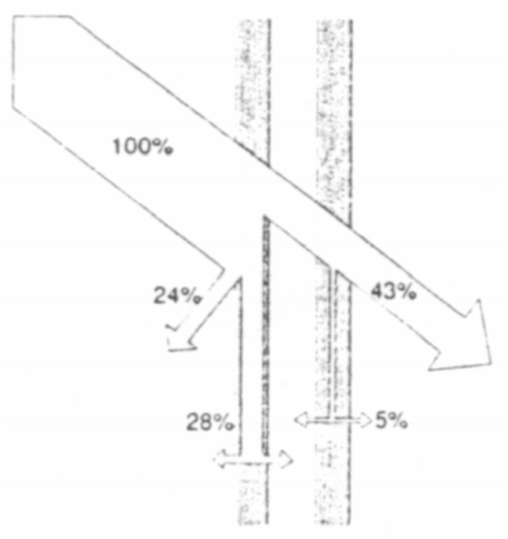


Figure 49 Reflecting Glass plus Reflecting Glass

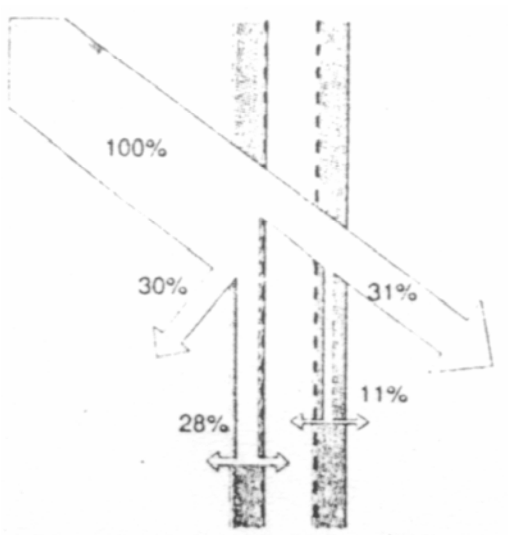
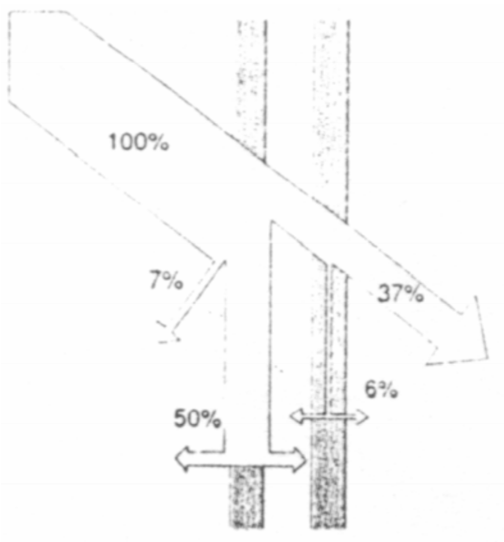


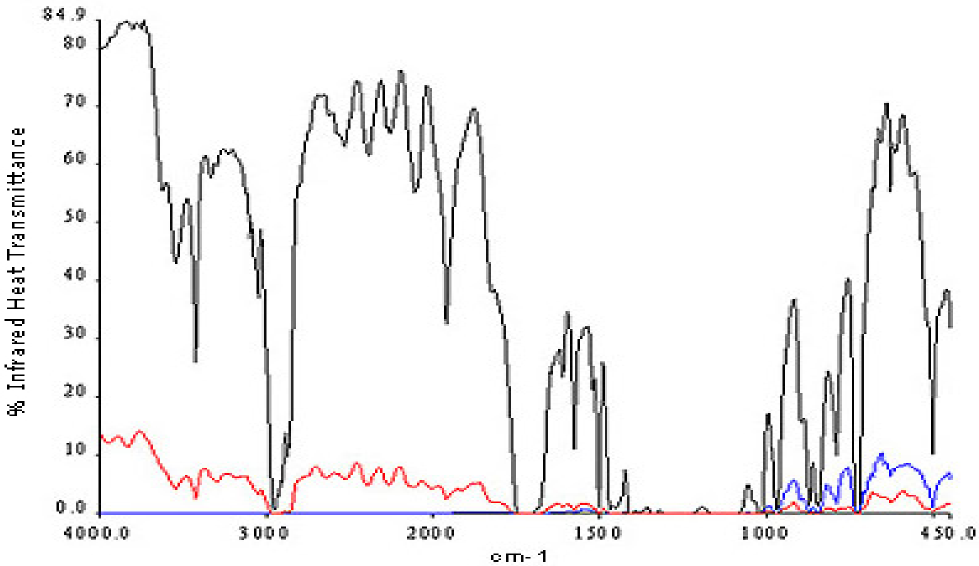
Figure 50 Absorbing Glass and Clear Glass



Window laminates

New generation films which can be applied to windows have become very efficient without having to be tinted. Most films, which have been applied to windows up to now, merely reduces the amount of light with the misconception that they keep out the heat energy. These films, because of their darker color, get hot and radiate large amounts of heat energy into the rooms which they are meant to keep cool.

Figure 51 Comparison of Window Tints



Black line: Smoke 05 UV window tint used in automotive, residential and commercial property applications.

Red line: Standard mirror-reflective UV window tint used in residential and commercial property applications.

Blue line: New generation high performance laminate for residential and commercial property applications (note: from 4 000 to 1 000 the infrared heat transmission is zero)

A

Thermal mass

Thermal mass refers to the mass of the building structure, floors and roof, should the roof be a concrete deck. The only way to achieve a high thermal mass is to design a building with a massive building structure. The objective is that the building mass would store heat energy in its structure, which would be released, e.g. the building would absorb the sun's energy during the day and release it during the night. However, the energy absorption process will take the whole day before the heat will be felt on the inside with the result that the inside temperature will remain relatively constant.

The concept of reducing heat flow through a building envelope by increasing the insulation is most commonly applied to heat conservation in cooler regions and can also effectively be used to prevent overheating by conduction in summer in hot parts of South Africa, in summer. During the summer months the heat flow is from the outside to the inside of the building i.e. the opposite direction of the winter heat flow. In addition to insulation, there are three other ways of reducing heat flow through the envelope. The first makes use of the thermal inertia of building envelope. The second involves provision of a barrier to reflect the radiation away from the building. In the third the building envelope is reduced by means of a compact layout.

The thermal inertia method is based on the fact that there is a time delay due to the thermal inertia of the walls and roof, etc., in the flow of heat through the building envelope which can be exploited in for cooling purposes. The concept is particularly helpful where there are significant daily variations in external temperature - in hot, dry parts of South Africa, for example.

When solar radiation strikes an opaque surface such as a wall or a roof the exterior surface absorbs part of the radiation and converts it to heat. Part of the heat is directly re-emitted to the outside. The remainder is conducted through the wall or roof at a rate which depends on the thermal diffusion characteristics of the material. When the temperature of the exterior surface drops because of a fall in ambient temperature part of the stored heat is emitted outside.

At night, the air temperature inside the building is higher than the temperature outside. The heat flow to the outside therefore continues and the temperature of the wall or roof continues to decrease, thus eventually cooling the interior.

Light colors have the property of reflecting short wave solar radiation and it is for this reason that buildings in hot climates are often painted white.

In an air-filled cavity wall or roof space where the air is still and convection is therefore low, thermal radiation is the prime mechanism for transfer of heat. The thermal radiation can be reflected away from the occupied part of the building by coating the face of the partition separating the cavity from the occupied areas with a highly reflective material such as aluminum foil. Aluminum foil also increases the thermal resistance of an insulation layer if it is placed adjacent to the insulation with a small air space between the two.

Radiation barriers are recommended for those parts of lightweight buildings in hot and humid areas in South Africa, such as Durban, where it is difficult to provide protection from the heat. They are particularly effective in places where the heat flow is downwards, as in a basement in summer. Reduction of heat transmission can be as much as 90% when a simple reflective sheet is placed on the floor of a basement.

It is however important to remember that where insulation is also used there may be a risk of condensation in winter when the heat flow is reversed. The very compact urban layout sometimes found in hot, dry parts of South Africa help to maintain cooler temperatures in and around buildings. Compact designed buildings have smaller surface areas and this helps to reduce heat energy transmission losses. Dense urban planning also allows buildings to benefit from mutual shading.

Where diurnal temperature variations are significant (as they are for instance in the highveld) unwanted air infiltration should, if possible, be avoided during the day and the building ventilated at night so that any stored heat can be released from the thermal masses. In addition, steps should be taken to create a cool area round the building so as to reduce the temperature of the infiltration air and, where appropriate, to increase ground contact.

Layout and configuration design

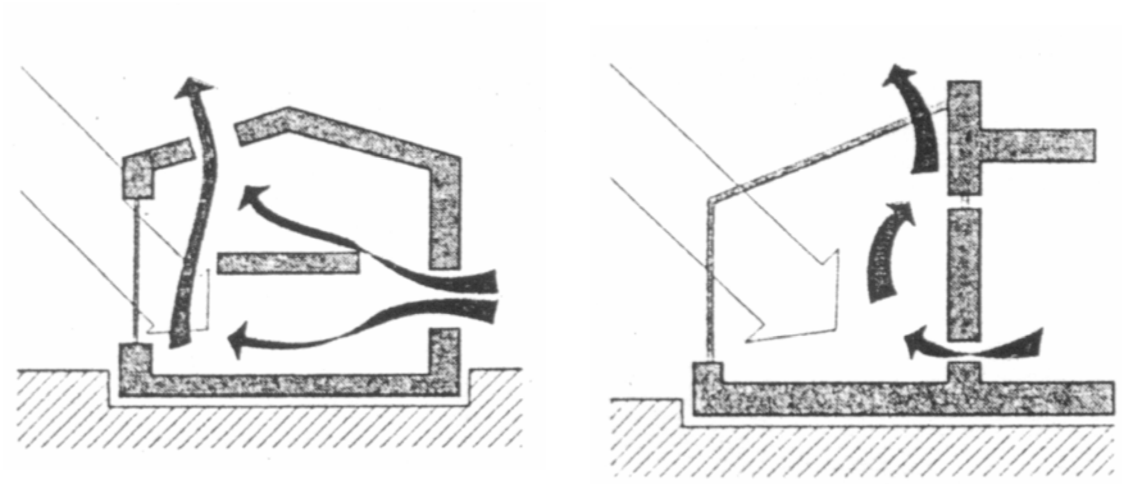
The general principles of circulation using temperature gradients can effectively be employed in situations where the air inside a building is warmer than ambient air and cooling is required, through the temperature gradient effect to expel the warm air from the building.

One way of doing this is to invoke the stack or chimney effect by providing openings at the top and bottom of the building as shown in Figure 52. The warm air will rise and naturally escape from the top outlet while cooled fresh air will enter through the openings at the base. The most thorough ventilation is achieved when the openings are placed vertically.

The chimney or stack effect can also be put to effective use to release unwanted heat from a building via an atrium. The air movement the atrium can give rise to an intake of air from the building into the atrium. This may in turn be dissipated to the outside.

Figure 52 Stack Effect

Figure 53 Cross Ventilation

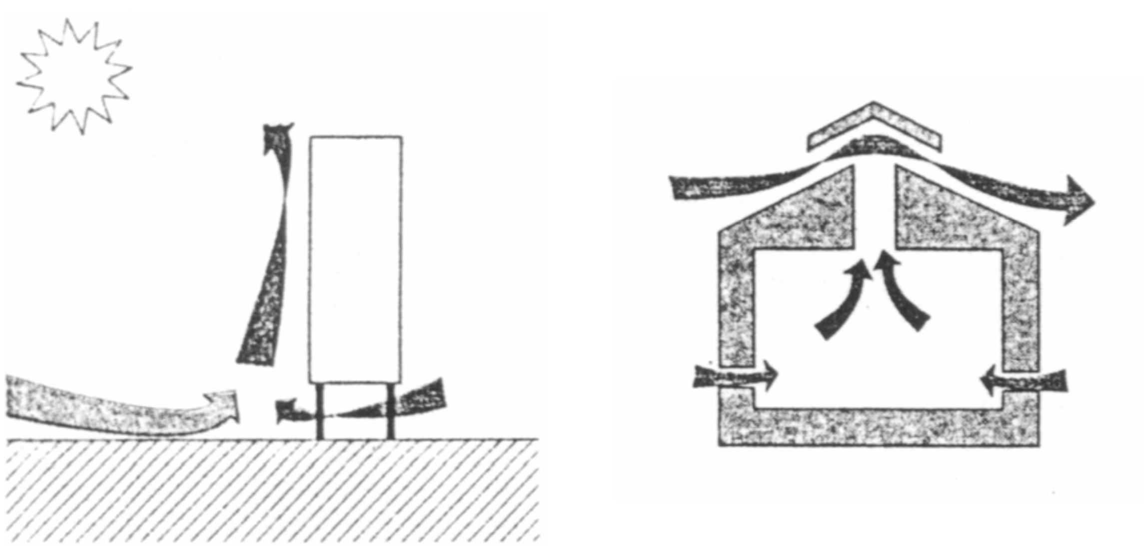


The same effect can be used to create cross ventilation, as shown in Figure 53. Here, air enters the building from cool pockets created in outside spaces on the buildings shady side and flows through the building towards the sunny side where it rises as it is exposed to the sun.

It is possible to increase the dissipation of heat from a building using the wind pressure effect, as shown in Figure 54. When wind strikes a building a high pressure on the exposed side a low pressure on the-opposite, sheltered face results. Usually, the speed and direction of local winds are variable.

At an individual site however, a building can often be positioned in relation to neighboring buildings, planted vegetation and other obstacles so that a wind is induced in a known constant direction at a reasonably steady rate. The conditions for ventilation are best when the wind strikes the building at an angle of up to 45 degrees.

Figure 54 Wind Effect



The movement of air across a site is from high pressure zones to low pressure zones, through openings in the building envelope. The size and position of the openings determines the speed and direction of air movement within the building. The air speed is greatest-when openings through which air leaves the building are bigger than the inlet openings, however inlet openings must be of an adequate area. The best distribution of fresh air throughout the building is achieved when the openings are diagonally opposite each other and air flows are not hindered excessively by partitions and other obstructions. Maximum ventilation should be provided during the day in occupied areas of the building at head height. In addition there should always be a good flow of fresh air along the building's most massive elements so that as much heat as possible is dissipated from them.

4.3.5 Solar Energy in Building Design

Solar energy applications in building design can be categorized as sources with a direct interaction with the building envelope and those which do not have a direct interaction.

- Daylighting
- Solar energy actively used for space heating
- Solar heating actively used to heat water and to drive processes
- Solar energy actively used for air-conditioning

Daylighting

Daylighting is using natural sunlight to light a building's interior. In addition to south-facing windows and skylights, clerestory windows – a row of windows near the peak of the roof – can let light into north-facing rooms and upper levels. An open floor plan allows the light to reach throughout the building. Daylighting in office buildings and shopping malls can result in substantial savings on electric bills, and not only provides a higher quality of light, but improves productivity and health. Daylighting in schools, friendly atmosphere it creates, can improve student grades and attendance.

Active solar design

"Active solar design" and "solar design principles" overlap to a large extent and as a result the following information is merely an elaboration of the aforegoing information. Active solar designs mainly focus on solar collectors. These include:

- Photovoltaic arrays

- Solar thermal collectors for water heating

- Solar thermal collectors for air heating

Photovoltaic arrays

Should photovoltaic arrays be used as a façade, they can result in a small reduction in the energy bill, assuming the capital cost of the array is not significantly greater than that of the material it replaces. It should be borne in mind that photovoltaics cannot compete economically with grid connected power.

Solar thermal collectors for water heating

The incident solar energy in South Africa is sufficient to make the use of solar thermal collectors for water heating economically viable. It is important to ensure that good quality systems are used because of the presence of hard water in some parts of the country as well as the possibility of water freezing in

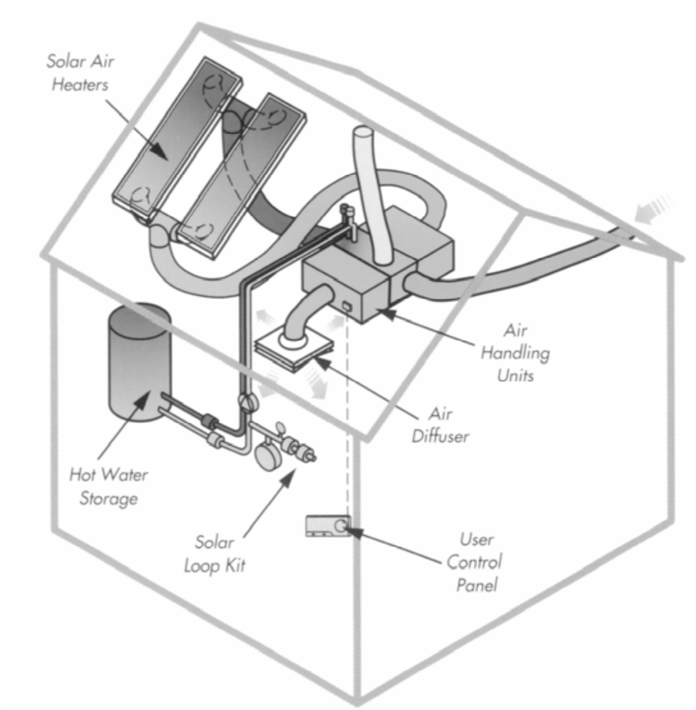
the capillaries. Collectors which are filled with an anti-freeze solution combined with a heat exchanger are ideal.

Heat pumps are very efficient devices for heating large quantities of water such as swimming pools and/or water for use at hotels, hostels etc. Heat pumps could be more efficient should the “cold” side capillary be manufactured into a solar collector.

Solar thermal collectors for air heating

New products are emerging all the time and one of these is a solar collector designed for heating air. Air heated in this way can reach temperatures in excess of 100ºC. At these temperatures air can be used to heat water and if mixed with cooler air can make a significant contribution to heating of buildings as shown in Figure 55. Unfortunately systems such as the one shown are still relatively expensive and a specific business case would have to be derived for each design in order to evaluate its economic viability. However, the potential for preheating ventilation air is significant.

Figure 55 Solar Air Heater



Solar energy used for air-conditioning

Although the direct use of solar energy for air-conditioning is receiving attention the consensus is that a significant amount of work still needs to be carried out to make it economically viable.

4.3.6 Other Technologies

- Wind turbines
- Sunspaces/atria
- Trombe walls

Wind turbines

Wind turbines, to some, appear to be natural energy source for installation on buildings. However, wind turbines cannot compete with grid connected power on an economical basis. A further problem is that turbulence will render such wind turbines inefficient and will also result in them being damaged.

Sunspaces/atria

A sunspace is another passive solar heating design feature. A sunspace is much like a greenhouse and is built on the north side of a building. As sunlight passes through glass or other glazing, it warms the sunspace. Proper ventilation allows the heat to circulate into the building.

Trombe walls

A trombe wall is a very thick, north-facing wall, which is painted black and made of a material that readily absorbs heat. A pane of glass or plastic glazing, installed a few inches in front of the wall and this helps hold in the heat. The wall heats up slowly during the day. Then as it cools gradually during the night, it gives off its heat inside the building.

Aquifers and other sources of water

If sufficient water is available it can be used towards making chiller plant more effective. An example of this is a large commercial building in Rosebank, which is built on an aquifer which could be used for this purpose.

4.3.7 Preliminary Perspectives on Energy Efficient Lighting Options

Economical energy efficiency of lighting in commercial buildings is based on two factors:

- Efficiency of the luminaire itself at converting electrical energy to light, and durability of the selected device

- Appropriateness of the fitting for the lighting setting and the selected luminaire.

Through discussion with industry representatives and experts on energy efficient lighting, the project learned of an Australian initiative which is currently being considered for adaptation to South Africa through the Eskom-sponsored Demand Side Management (DSM) programme, in collaboration with Osram, a supplier of energy efficient lighting solutions. This programme involves a labelling initiative similar to the appliance labelling scheme currently being rolled out by DME in South Africa. Through discussion with SABS, it has been agreed that the project will pursue the development of a dual set of recommendations:

- Point of sale measures (i.e. labelling of energy efficiency rating on the luminaire)

- Point of application measures (i.e. implementation of a mechanism for requiring compliance with an existing legal framework, such as the OHS Act.)

This latter measure would be aimed at the design and installation of the fitting.

The point of application measure could extend well beyond lighting, and could be used as a mechanism for approval of e.g. building finance. Care would have to be taken in designing such a mechanism to ensure that it functions more as an incentive to selecting energy efficient options rather than as a mechanism for vested interests to slow implementation of worthwhile projects.

4.4 Current Practice in South African Energy Efficient Commercial Building Design

TIASA (Thermal Insulation Association of South Africa) has done a fair amount of work on developing insulation requirements for commercial buildings. TIASA have based the new thermal requirements on Australian current practice - BCA 2005 Section J (Building Code Australia).

The basic assumption is that all walls, floors & roofs must comply with a minimum R-Value, comprising the base brickwork and additional insulation to achieve the required thermal resistance. TIASA have carried out the analysis based on the six climate zones identified under SAEDES.

Hot dry areas need different amounts of insulation when compared to cold, windy and wet (where condensation is likely) areas. TIASA have prepared a brochure which they intend distributing to building professionals in the near future to "desensitize" or "inform" all concerned of the future requirements.

The Australian approach to Energy Efficiency for commercial buildings is to define the orientation of the building, and treating each elevation differently, depending on its orientation. Obviously North facing facades need the most attention, while South facing facades generally have less onerous requirements. For each elevation, the BCA 2005 allows for any particular glazing system, a set area of vision glass for a particular overhang (sunscreen) size. The bigger the overhang, the more glass area is allowed and the better the glass is at eliminating solar gains the more area you are allowed. All the options that one is allowed to choose add up to the same number or energy usage. The same applies for the wall insulation – depending on the climate zone and the elevation orientation, one must include "x" thickness of insulation.

The insulation required on solid walls is defined by a series of standard details, which TIASA have adopted in their brochure. The critical aspect is that the insulation must be continuous around the envelope of the building. No thermal breaks are allowed.

European requirements are more stringent due to their adverse weather conditions and extreme cold during the winter months. The approach in the UK (Building Regulations Part L), for example, is to define maximum U-Values for each type of facade (solid, vision, roof – flat or pitched, floor, skylights, etc). The building team must then prove compliance by calculation and/or thermal imaging. These requirements have been in force for many years now, and the requirements have become more stringent lately, with further revisions due later this year.

5 Conclusions and Recommendations

5.1 Conclusions

Energy efficiency scenarios were developed for the building envelope followed by quantification of the energy consumption impact of these scenarios. Next, life cycle costs (in Rands) were mapped against energy efficiency levels for walls, roofs and windows. This allowed a tabulation of the energy efficiency scenario with the lowest life cycle cost to be made for each notional building in each of the three climate zones included in the scope of the study, presented again for convenience in Table 104.

Table 104 Summary of Cost Effective Thermal Performance Levels (RSI)

Building	Envelope	South Cape (RSI)			Highveld/Interior (RSI)			Lowveld/Mpumalanga (RSI)		
		Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC	Base Case	Lowest LCC	Best Performance + 5% LCC
Hospital	Wall	0.68	0.68	2.35	0.42	0.68	2.09	0.42	0.42	2.09
	Roof	1.27	1.27	1.27	1.27	1.27	1.96	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Low Rise Campus Office	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	3.35	1.27	1.27	3.35	1.27	1.27	1.96
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Large Office	Wall	1.72	1.72	2.79	1.72	1.72	2.79	1.72	1.72	2.79
	Roof	1.67	3.75	3.75	1.67	3.05	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.39	0.17	0.17	0.39	0.17	0.17	0.17
Hotel	Wall	0.68	2.9	2.9	0.42	2.09	2.64	0.42	1.05	2.64
	Roof	1.67	1.67	3.75	1.67	1.67	3.75	1.67	1.67	3.75
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Regional Shopping Centre	Wall	0.68	1.31	2.9	0.42	0.68	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	2.65
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Strip Mall	Wall	0.68	1.75	2.9	0.42	1.49	2.64	0.42	0.42	2.64
	Roof	1.27	1.27	2.65	1.27	1.27	3.35	1.27	1.27	1.27
	Window	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

A sensitivity analysis was carried out on future electricity prices as well as certain assumptions concerning windows, and the results showed the initial analysis to provide a clear and robust reference point for suggested changes to performance levels contained in SANS 204.

In general, comparative analysis of energy consumption in similar building types of both existing buildings and notional buildings indicated energy consumption in the notional buildings to be lower. Thus, the hypothesis that energy intensity in older buildings would be lower than those in new commercial buildings due to increased use glazing and other systems is not validated. Potential interventions made in large office building office in Johannesburg indicated a potential energy saving of about 25%.

5.2 Recommendations

In light of the above, recommendations on design guidelines that can be incorporated into SANS 204 have been developed and are presented below.

5.2.1 Introduction

This section provides information on:

- Design guidelines for building air-tightness;
- Design guidelines for minimum ventilation rates to maintain adequate indoor air quality;
- Performance criteria for lighting systems;
- Performance criteria for HVAC equipment;
- Performance criteria for service hot water equipment;
- Design guidelines for renewable energy technologies and
- Approach for energy efficiency assessment for existing buildings.

The intent of this section is to provide recommendations that can be incorporated into SANS 204. Each of the following sections contains background information and specific recommendations.

In order to develop the material in this document, various standards for commercial buildings were researched. These included:

- South Africa Energy and Demand Efficiency Guidelines (SAEDES), published in 1999;
- ASHRAE 90.1 (1989);
- ASHRAE 90.1 (2001);
- ASHRAE 90.1 (2004); and
- Model National Energy Code of Canada for Buildings (MNECB), published in 1997.

In addition, the UK Building Regulation L2 and ISO/TC 163/SC were briefly reviewed.

5.2.2 Design Guidelines for Building Air-Tightness

Background
Performance criteria windows and doors in commercial buildings were reviewed from the following standards:

- SAEDES
- ASHRAE 90.1 (2004)
- Model National Energy Code of Canada for Buildings (MNECB), published in 1997

It should be noted that both AHRAE 90.1 and MNECB require vestibules on many exterior doors in commercial buildings, depending on weather conditions. For all of the three South African regions considered in this report, ASHRAE 90.1 requires such vestibules.

A summary of the air tightness guidelines contained in the above standards is provided in Table 105 below.

Table 105 Window and Door Infiltration Levels

	SAEDES	ASHRAE 90.1 (2004)	MNECB
Windows	Less than 0.8 m/w per linear metre		
Aluminium prime windows and sliding glass doors	According to ANSI/AAM A 101-1988		
Wood window units (improved performance rating only)	According to ASTM D 4099-89		
Commercial entrance swinging and sliding doors	1.25 cfm/ft2 when tested with ASTM E283-84		
Glazed swinging entrance doors and revolving doors		5.0 L/s-m^2	
All other products except for field-fabricated windows and doors and garage doors.		2.0 L/s-m^2	
Windows			A2 rating according to CAN/CSA-A440-M
Swinging doors for dwellings and hotels/motels			0.82 L/s per linear metre when tested with ASTM E 283 OR weather-stripped on all edges
Sliding doors			A2 rating according to CAN/CGSB-82.1-M
Pre-hung insulated steel doors			According to CAN/CGSB-82.5-M
All other doors except for those used for vehicles or handling of materials			17.0 L/s per metre of door crack when tested with ASTM E 283

Recommendations

ASHRAE 90.1 (2004) door and window infiltration guidelines are clear and concise; consequently, the ASHRAE 90.1 (2004) guidelines and infiltration values shown in the preceding Table 105 are recommended for SANS 204.

It is also recommended that consideration be given to requiring vestibules on some categories of exterior doors, following the guidelines in ASHRAE 90.1. In South Africa, these categories would include all the doors except the followings: doors in buildings less than four stories above grade; doors not intended to be used as a building entrance door (such as mechanical or electrical equipment rooms); doors opening directly from a dwelling unit; doors that open directly from a space less than 300 m^2 in area; doors in building entrances with revolving doors; doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

5.2.3 Minimum Ventilation Rates to Maintain Adequate Indoor Air Quality

Background

The topic of minimum ventilation rates for adequate indoor air is both complicated and controversial. The definition of "adequate" ventilation rates is not clear-cut, and, even when defined, "adequate" rates depend on a wide variety of factors. The issue is further complicated by the development of new techniques and technologies to reduce the energy impact of providing adequate fresh air.

This topic is thoroughly covered in ASHRAE 62.1. This standard is considered "in continuous review" by ASHRAE, however the latest publication of the full standard was in 2004. The complexity of the topic precludes extracting simplified tables from this standard.

The Model National Energy Code of Canada for Buildings (MNECB) provides design ventilation rates for various building and space types. However, Canadian designers are finding that these recommendations have been superseded by ASHRAE 90.1 (2004).

Recommendations

Adoption of ASHRAE 62.1 is recommended for SANS 204. This will allow South Africa to take advantage of the extensive ongoing effort and expense invested in this international standard.

5.2.4 Performance Criteria for Lighting Systems

Background

Efficient lighting design includes the following:

- Use of appropriate energy efficiency technologies, including task lighting;
- Design using appropriate light levels;
- Incorporation of appropriate lighting controls; and
- Consideration of use of daylighting (while controlling solar gains).

The lighting sections of several energy efficiency standards were reviewed. Information contained in these standards is briefly summarized below:

- SAEDES refers to the Occupational Health and Safety Act and related SABS codes for minimum lighting levels, and gives common (but not necessarily efficient) lighting levels and power densities. It provides quantitative information on daylighting, but does not provide information on appropriate technologies or controls.

- ASHRAE 90.1 (2004) provides several methods of complying with lighting standards, ranging from simple but constrained, to more complicated but flexible methods. It lists control requirements, and allowable lighting power densities. It does not discuss appropriate technologies or daylighting.

- The Model National Energy Code of Canada for Buildings also provides control requirements and allowable lighting power densities. It also does not discuss appropriate technologies or daylighting.

5.2.5 Recommendations

The lighting level and control guidelines from ASHRAE 90.1 2004 (Section 9) are recommended for SANS 204. Some of the information in this standard is detailed below:

General

Once the interior and exterior lighting power allowance for a building has been determined, the designer should strive to design the lighting system that will provide an effective and pleasing visual environment in accordance with the use of the space without exceeding the lighting power densities (LPD) outlined below.

Lighting Power Densities

The recommended maximum lighting power densities at the whole building level (building area method) should not exceed the values shown in Table 106.

In addition, the maximum lighting power densities for individual spaces can be determined using the space-by-space method. (Different spaces in one building will have different LPD requirements.)

Table 106 Lighting Power Density

Building Area Type	**(W/m2)** [12]
Automotive Facility	10
Convention Centre	13
Court House	13
Dining: Bar Lounge/Leisure	14
Dining: Cafeteria/Fast Food	15
Dining: Family	17
Dormitory	11
Exercise Centre	11
Gymnasium	12
Healthcare-Clinic	11
Hospital	13
Hotel	11
Library	14
Manufacturing Facility	14
Motel	11
Motion Picture Theatre	13
Multi-Family	8
Museum	12
Office	11
Parking Garage	3
Penitentiary	11
Performing Arts Theatre	17
Police/Fire Station	11
Post Office	12
Religious Building	14
Retail	16
School/University	13
Sports Arena	12
Town Hall	12
Transportation	11
Warehouse	9
Workshop	15

Lighting Controls

All lighting systems, except those required for emergency or exit lighting should be provided with manual, automatic or programmable controls.

Interior lighting in buildings larger that 465 m^2 should be controlled with an automatic control device to shut off building lighting in all spaces.

Each space enclosed by walls including ceiling height partitions, shall be provided with controls that together or singly are capable of turning of all the lights within that space.

[12] Source:ASHRAE Standard 90.1 – 2004, Table 9.5.1, Page 64

Lighting for most exterior applications should have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during night time hours. (ASHRAE 90.1 provides some exceptions to this requirement.)

5.2.6 Performance Criteria for HVAC Equipment

Background

Performance criteria for HVAC equipment in commercial buildings were reviewed from the following standards:

- SAEDES;
- ASHRAE 90.1 (1989);
- ASHRAE 90.1 (2001);
- ASHRAE 90.1 (2004); and
- Model National Energy Code of Canada for Buildings (MNECB), published in 1997.

A summary of this review is presented in Table 107 overleaf.

Examination of Table 107 reveals that the current SAEDES performance levels are identical to those of ASHRAE 90.1 (1989), as stated in the SAEDES Guidelines. Table 107 also reveals that ASHRAE 90.1 versions 2001 and 2004 have set higher levels, and that the Model National Energy Code of Canada for Buildings (MNECB) has been surpassed by the most recent version of ASHRAE 90.1.

5.2.7 Recommendations

Subject to confirmation of the availability of HVAC equipment with the required performance levels in South Africa, it is recommended that the ASHRAE 90.1 (2004) HVAC equipment performance values shown in Table 107 of this report and Table 6.8.1 of the standard be adopted by SANS 204. Although not in the original scope of this project, but recognizing that HVAC equipment performance is only one factor in HVAC system energy efficiency, it is also recommended that the entire Section 6 of ASHRAE 90.1 be adopted to provide additional guidance on HVAC control, duct and pipe insulation and sealing, humidification and dehumidification, economizers, heat recovery, balancing and commissioning.

ASHRAE 90.1 is now being revised continuously; however, it will be published in its entirety every three years. SANS 204 performance criteria should be compared to ASHRAE 90.1 with each new publication and consideration should be given to revising the SANS 204 HVAC performance criteria.

Table 107 Summary of HVAC Performance Requirements

Equipment	Category	SAEDES	ASHRAE 90.1 (1989)		ASHRAE 90.1 (2001)		ASHRAE 90.1 (2004)	MNECB (1997)	
		COP	EER	COP	EER	COP	COP	EER	COP
Air conditioners (Air cooled)	<19 kW (split system)	2.93	10	2.93	10	2.93	**3.52**		
	<19 kW (single package)	2.84	9.7	2.84	9.7	2.84	**3.52**		
	19kW -- 40kW	2.61	8.9	2.61	10.1	2.96	**2.96**		
	40kW -- 70 kW	2.49			9.5	2.78	**2.78**		
	70kW -- 223 kW	2.49			9.3	2.73	**2.72**	8.5	2.49
	>223 kW	2.4			9	2.64	**2.64**	8.2	2.40
Room air conditioners (without louvered sides)	<1.8 kW	2.34	8	2.34	9	2.64	**2.64**	8.5	2.49
	1.8 kW -- 5.9 kW	2.49	8.5	2.49	8.5	2.49	**2.49**	8.5	2.49
	>5.9 kW	2.4	8.2	2.40	8.5	2.49	**2.49**	8.5	2.49
Room air conditioner heat pump with louvered sides	<5.9 kW	2.49	8.5	2.49	9	2.64	**2.65**	8.5	2.49
	> 5.9 kW	2.49	8.5	2.49	8.5	2.49	**2.49**	9.5	2.49
Water chilling package (water-cooled, electrically operated), Positive displacement	<528 kW	3.8		3.8		4.45	**4.45**		
	528 kW -- 1055 kW	4.2		4.2		4.9	**4.9**		
	>1055 kW	5.2		5.2		5.5	**5.5**		
Water chilling package (water-cooled, electrically operated), Centrifugal	<528 kW	3.8		3.8		5	**5**		
	528 kW -- 1055 kW	4.2		4.2		5.55	**5.55**		
	>1055 kW	5.2		5.2		6.1	**6.1**		

5.2.8 Performance Criteria for Service Hot Water Equipment

Background

Performance criteria for service hot water (SHW) equipment in commercial buildings were reviewed from the following standards:

- SAEDES;
- ASHRAE 90.1 (1989);
- ASHRAE 90.1 (2004); and
- Model National Energy Code of Canada for Buildings (MNECB), published in 1997.

The SAEDES Guidelines provide performance criteria for heat pumps based on ASHRAE 90A-1989 efficiencies) and provide qualitative recommendations for hot water boilers. More comprehensive performance criteria for SHW equipment, drawn from ASHRAE 90.1 (1989R) is given in a table in the appendix, however it is not clear that SAEDES actually requires adherence to this table.

Comparison of the SHW performance criteria in the various versions of ASHRAE indicate that ASHRAE 90.1 (2004) is more stringent than ASHRAE 90.1 (1989).

Performance criteria for SHW equipment in MNECB refers to a variety of standards, such as CAN/CSA-C745, ANSI Z21.10.3 and CGA CAN1-4.1-M. For this reason, this standard is less useful as a reference.

Recommendations

Subject to confirmation of the availability of equipment with the required performance levels in South Africa, it is recommended that the ASHRAE 90.1 (2004) water heating equipment performance values, shown in Table 108, be adopted by SANS 204. Because equipment performance levels are only one factor in the total SHW system performance, it is recommended that the entire Section 7 of ASHRAE 90.1 (2004) be adopted to provide guidance on additional factors influencing SHW system energy efficiency, such as pipe insulation, controls, and heat traps

ASHRAE 90.1 is now being revised continuously; however, it will be published in its entirety every three years. SANS 204 performance criteria should be compared to ASHRAE 90.1 with each new publication and consideration should be given to revising the SANS 204 HVAC performance criteria.

Table 108 Performance Requirements for Water Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required [a]	Test Procedure [b]
Electric Water Heaters	≤12 kW	Resistance ≥75.7 L	0.93-0.00132V EF	DOE 10 CFR Part 430
	>12 kW	Resistance ≥75.7 L	20 + 35 √V SL, W	ANSI Z21.10.3
	≤24 Amps and ≤250 Volts	Heat Pump	0.93-0.00132V EF	DOE 10 CFR Part 430
Gas Storage Water Heaters	≤22.98 kW	≥75.7 L	0.62-0.0019V EF	DOE 10 CFR Part 430
	>22.98 kW	<309.75 W/L	80% E_t (Q/800 + 110 √V) SL, W	ANSI Z21.10.3
Gas Instantaneous Water Heaters	>14.66 kW and <58.62 kW	≥309.75 W/L and <7.57 L	0.62-0.0019V EF	DOE 10 CFR Part 430
	≥58.62 kW [c]	≥309.75 W/L and <37.85 L	80% *E t*	ANSI Z21.10.3
	≥58.62 kW	≥309.75 W/L and ≥37.85 L	80% *E t* (Q/800 + 110 √V) SL, W	
Oil Storage Water Heaters	≤30.78 kW	≥75.7 L	0.59-0.0019V EF	DOE 10 CFR Part 430
	>30.78 kW	<309.75 W/L	78% *E t* (Q/800 + 110 √V) SL, W	ANSI Z21.10.3
Oil Instantaneous Water Heaters	≤61.55 kW	≥309.75 W/L and <7.57 L	0.59-0.0019V EF	DOE 10 CFR
	>61.55 kW	≥309.75 W/L and <37.85 L	80% *E t*	ANSI Z21.10.3
	>61.55 kW	≥309.75 W/L and <37.85 L	78% *E t* (Q/800 + 110 √V) SL, W	
Hot Water Supply Boilers, Gas and Oil	≥61.55 kW and <3663.8 kW	≥309.75 W/L and <37.85 L	80% *E t*	ANSI Z21.10.3
Hot Water Supply Boilers, Gas		≥309.75 W/L and ≥37.85 L	80% *E t* (Q/800 + 110 √V) SL, W	
Hot Water Supply Boilers, Oil		309.75 W/L and ≥37.85 L	78% *E t* (Q/800 + 110 √V) SL, W	
Pool Heaters Oil and Gas	All		78% E_t	ASHRAE 146
Heat Pump Pool Heaters	All		4.0 COP	ASHRAE 146
Unfired Storage Tanks	All		R-2.2	(none)

[a] Energy factor (EF) thermal efficiency (Et) are minimum requirements, while standby loss (SL) is maximum W based on a 38.90C temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. In the SL equation, V is the rated volume I gallons and Q is the nameplate input rate in W.

[b] [ASHRAE 90.1] Section 12 contains a complete specification, including the year version, of the referenced test procedure.

[c] Instantaneous water heaters with input rates below 58.62 W must comply with these requirements if the water heater is designed to heat water to temperatures 82.2^0 C or higher.

5.2.9 Design Guidelines for Renewable Energy Technologies

Background
The use of renewable energy technologies to reduce dependence on fossil fuels is unanimously supported. However, specific requirements are rarely found in building standards. The following standards were examined for renewable technology specifications:

- SAEDES;
- ASHRAE 90.1 (2004); and
- Model National Energy Code of Canada for Buildings (MNECB), published in 1997.

Specific standards or recommendations for the use of renewable technologies are not given in any of these standards. This is most likely because renewable technologies are widely varied, usually have to be custom-designed for a particular building and location, and are generally not well-understood or often used by most design professionals.

Several tools have been developed to facilitate the screening and modelling of renewable energy technologies. One popular free computer program is RETScreen, developed by Natural Resources Canada and available at www.retscreen.net. RETScreen can be used to assist in the development of feasibility studies for a wide range of renewable energy technologies. In addition to the software, the RETScreen website includes a wealth of information on renewable energy technologies and applications.

Recommendations
The following renewable energy guidelines are recommended for SANS 204.

Renewable technologies should be considered whenever the end-use or application could benefit in a cost effective matter and the local climate can support the technology.

Technologies that should be considered include:

- Domestic Solar Water Heating
- Solar space heating using transpired solar collectors (*Solarwall* is one brand name)
- Photovoltaic collectors for onsite electricity generation

Domestic Hot Water Heating
Buildings with large DHW loads (such as hotels and restaurants) in geographic locations with a high percentage of sunshine should consider the use of solar assisted hot water heating to reduce the use of conventional energy supplies.

Solar Space Heating Using Transpired Solar Collectors
Low-rise buildings that require significant volumes of outside air (such as airplane hangers, certain types of warehouses, automotive garages and big box retail buildings) in locations with high percent winter sunshine should consider the use of transpired solar collectors. These collectors can help meet a portion of the space heating loads.

Photovoltaic Collectors
While still expensive, PV collectors make sense in regions with high electricity costs and high percentage sunshine values. Low-rise buildings with large surface areas are ideally suited for installation of PV systems. Because electricity costs in South Africa are currently relatively low by international standards, PV installations are appropriate now only for demonstration and remote (off-grid) installations. As electricity prices increase, the appropriateness of PV installations should be reviewed.

5.2.10 Approach for Existing Buildings

It is recommended that the Energy Use Intensities (EUIs) developed for each notional building be used as benchmarks within the framework of a clearly defined monitoring and verification programme commissioned by the DME. Each benchmark would represent a maximum energy consumption level not to be exceeded should a building undergo a retrofit of one or more of the identified components. It is also recommended that consideration be given to making building finance contingent on an energy efficiency evaluation to be carried out by a Certified Building Energy Auditor.

5.2.11 Recommendation Summary

Recommendations for SANS 204 are summarized in Table 109.

Table 109 Summary of Recommendations

Design/Performance Area	Recommendation
Building Air-Tightness	ASHRAE 90.1 (2004) Section 5.4.3.2 with consideration of also including Section 5.4.3.4 (vestibules)
Outdoor Air Ventilation	ASHRAE 62.1 (2004)
Lighting Systems	ASHRAE 90.1 (2004) Section 9
HVAC Equipment	ASHRAE 90.1 (2004) Table 6.81 with consideration of incorporating the entire Section 6
Service Hot Water Equipment	ASHRAE 90.1 (2004) Table 7.8 with consideration of incorporating the entire Section 7
Renewable Energy Technologies	Provided in this report

6 References

1 Krenz, J.H., 1996. Energy Conversion and Utilisation. Alan and Bacon, Inc. Boston, London and Sydney
2 Eberhard, A.A., Solar Radiation Data Handbook for Southern Africa. Elan Press. Cape Town.
3 Tripp, D., 2005. Buildings Energy Audit Manual. CBLA.
4 Goulding, J.R., 1992. Energy Conscious Design. A Primer For Architects. B.T. Batsford Ltd. London.
5 Thomas, R. et al, 1997. Environmental Design. E & FN Spon. London.
6 Edwards, B. 1999. Sustainable Architecture. EU Directives & Building Design. 2nd Ed. Architectural Press. Oxford.
7 ASHRAE 90.1 (1989)
8 ASHRAE 90.1 (2001)
9 ASHRAE 90.1 (2004)
10 Model National Energy Code of Canada for Buildings (MNECB)

Information on lighting technologies can be found at the Lighting Research Centre's website: www.lrc.rpi.edu.

A comprehensive daylighting resource can be found at the Daylighting Collaboratives website: www.daylighting.org.

RETScreen is a renewable energy assessment computer program. It was developed by Natural Resources Canada and is available free of charge at www.retscreen.net.

Annexes

Annex 1

Preliminary Base Energy Consumption Analysis

1 Regional shopping centres/malls
2 Suburban strip shopping/value centres
3 Low rise /campus style office park developments
4 High rise office blocks
5 Hotels & resorts
6 Hospitals

Provided on enclosed floppy disk

Annex 2

Sample Existing Building Energy Audit Output

Johannesburg Large Office Building

Description	Rating (W)	Total rating	Quantity		Total load W	Est Hours per day		Est.kWh per day	Intervention	Potential Saving kWhrs per day	Potential Saving kVA
3 Tube Fluorescent (Refl)	55	165	648	3 Tube Fluorescent (Refl)	106,920	11	3 Tube Fluorescent (Refl)	1,176	Electronic balast	118	11
3 Tube Fluorescent (Acryl)	36	108	213	3 Tube Fluorescent (Acryl)	23,004	11	3 Tube Fluorescent (Acryl)	253	Replacement & management	84	8
1 Tube Fluorescent (Open)	36	36	15	1 Tube Fluorescent (Open)	540	11	1 Tube Fluorescent (Open)	6	Replacement & management	2	0
2 Tube Fluorescent (Acryl)	55	110	12	2 Tube Fluorescent (Acryl)	1,320	11	2 Tube Fluorescent (Acryl)	15	Replacement & management	5	0
2 Tube Fluorescent (Acryl)	36	72	2	2 Tube Fluorescent (Acryl)	144	11	2 Tube Fluorescent (Acryl)	2	Replacement & management	1	0
3 Tube Fluorescent (Refl)	36	108	66	3 Tube Fluorescent (Refl)	7,128	11	3 Tube Fluorescent (Refl)	78	Electronic balast	8	1
3 Tube Fluorescent (Refl)	58	174	166	3 Tube Fluorescent (Refl)	28,884	11	3 Tube Fluorescent (Refl)	318	Electronic balast	32	3
1 Tube Fluorescent (Open)	56	56	508	1 Tube Fluorescent (Open)	28,448	11	1 Tube Fluorescent (Open)	313	Replacement & management	103	9
2 Tube Fluorescent (Open)	58	116	32	2 Tube Fluorescent (Open)	3,712	11	2 Tube Fluorescent (Open)	41	Replacement & management	13	1
Low voltage halogen	50	50	2,956	Low voltage halogen	147,800	11	Low voltage halogen	1,626	Replacement & management	1,171	106
Diffuser heaters(500W to 1500W)	750	750	739	Diffuser heaters(500W to 1500W)	554,250	6	Diffuser heaters(500W to 1500W)	3,326	Modify & management	831	139
Duct heaters	36,000	36,000	8	Duct heaters	288,000	6	Duct heaters	1,728	Modify & management	432	72
Water cooled chillers	750,000	750,000	2	Water cooled chillers	1,500,000	12	Water cooled chillers	18,000	Modify & management	1,800	150
Air cooled chillers	530,000	530,000	1	Air cooled chillers	530,000	12	Air cooled chillers	6,360	Modify & management	636	53
Chilled water pumps	22,500	22,500	2	Chilled water pumps	45,000	12	Chilled water pumps	540	Modify & management	54	5
Chilled water pumps	7,500	7,500	1	Chilled water pumps	7,500	12	Chilled water pumps	90	Modify & management	9	1
Cooling tower fan	18,500	18,500	1	Cooling tower fan	18,500	12	Cooling tower fan	222	Modify & management	22	2
Condenser water pumps	18,500	18,500	1	Condenser water pumps	18,500	12	Condenser water pumps	222	Modify & management	22	2
Air compressor	10,000	10,000	3	Air compressor	30,000	12	Air compressor	360	Modify & management	36	3
Water conservation/booster pumps	9,000	9,000	4	Water conservation/booster pumps	36,000	12	Water conservation/booster pumps	432	Modify & management	43	4
Carpark ventilation fans	60,000	60,000	10	Carpark ventilation fans	600,000	12	Carpark ventilation fans	7,200	Modify & management	5,760	360
General ventilation fans(25X)	20,000	20,000	1	General ventilation fans(25X)	20,000	12	General ventilation fans(25X)	240	Modify & management	24	2
Air handling plantfans(16X)	138,000	138,000	1	Air handling plantfans(16X)	138,000	12	Air handling plantfans(16X)	1,656	Modify & management	166	14
Comp room aircon(5X)	156,000	156,000	1	Comp room aircon(5X)	156,000	12	Comp room aircon(5X)	1,872	Modify & management	187	16
Main control centre	35,000	35,000	1	Main control centre	35,000	12	Main control centre	420	Modify & management	42	4
General aircons(9X)	98,000	98,000	1	General aircons(9X)	98,000	12	General aircons(9X)	1,176	Modify & management	118	10
General ventilation fans(10X)	26,000	26,000	1	General ventilation fans(10X)	26,000	12	General ventilation fans(10X)	312	Modify & management	31	3
Heat energy from halogen lights eliminated								47,982		1,171	106
					4,448,650					11,749	976

Annex 3

AAAMSA Test Performance Criteria

The requirements laid down in the Table below shall be the AAAMSA Test Performance Requirements to test and classify the products presented for testing:

AAAMSA Test Performance Requirements

Test	Class Designation					
	A0	A1	A2	A3	A4	Requirement
Deflection (positive and negative) under uniform loading Pa	600 Pa	1000 Pa	1500 Pa	2000 Pa	2500 Pa	Maximum deflection 1/175 of span or 20mm, whichever is less (2)
Structural proof loading 1.5 x Uniform loading	900 Pa	1500 Pa	2250 Pa	3000 Pa	3750 Pa	No failure allowed
Water resistance under a pressure of x Pa	x = 120 Pa	x = 200 Pa	x = 300 Pa	x = 400 Pa	x = 500 Pa	No leakage when subjected to a flow of 0.05 $l/(s.m^2)$
Air leakage through specimen under a pressure difference of 75 Pa	Y = 2.5	y = 2.0	y = 1.5	y = 0.75	y = 0.5	Not more than y l/s per m of mating length (1)

(1) Mating length: The length of the mating surfaces on opening lites and the fixed frames.
(2) Maximum deflection for the framing using SIGU's is 1/300 of span of member supporting SIGU's or 8mm whichever is less.

2.1 Products such as curtain walling, window walling and shopfronts shall include expansion joints and/or crucifix connections and shall have an average air flow rate not exceeding 0.306 $l/s/m^2$ at 75 Pa.

It is suggested that the test pressure of 75 Pa be increased to at least 300 Pa to make the facades 6 times airtight than current practice**.**

Annex 4

Energy Consumption Data of Existing Buildings

Existing Building Energy Consumption Survey Form

COMPANY	:	
CONTACT PERSON	:	
CONTACT NUMBERS	:	
DATE OF MEETING / DISCUSSION	:	
FILE REF	:	……………………… / GEN
Notes:		
COMPLEX DATA		
COMPLEX TYPE		
LOCATION		
AREA (m2)		
PARKING		
LETTABLE AREA		
OTHER:		
OTHER:		
OTHER:		
OTHER:		
CONNECTED ELECT LOAD (kVA)		
HVAC: Central / Package Units / Individual		
Hot Water System		
Other:		

Notional Building		**Base Loads & Power Consumption**		**Comment**
Month (20_ _)		**Max Demand (kVA)**	**kWh/month**	
1	January			
2	February			
3	March			
4	April			
5	May			
6	June			
7	July			
8	August			
9	September			
10	October			
11	November			
12	December			
Notes:				

Actual Buildings	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Shopping centres/malls												
Brooklyn Mall												
Lettable Area (m²):	18000											
Consumption (kWh)	4,035,320	2,694,970	2,032,600	2,610,990	1,601,970	2,099,090	2,294,080	2,209,590	2,475,030	2,642,820	2,367,870	1,597,310
Consumption (kWh/m²)	224.2	149.7	112.9	145.1	89.0	116.6	127.4	122.8	137.5	146.8	131.5	88.7
Suburban strip mall												
Glen Village North												
Lettable Area (m²):	7000											
Consumption (kWh)	460,490	443,410	401,460	366,230	412,250	364,260	438,910	381,900	388,960	423,140	408,760	398,620
Consumption (kWh/m²)	65.8	63.3	57.4	52.3	58.9	52.0	62.7	54.6	55.6	60.4	58.4	56.9
Glen Village South												
Lettable Area (m²):	5800											
Consumption (kWh)	250,000	240,000	224,664	210,796	229,123	197,831	248,711	220,000	220,000	240,000	230,000	220,000
Consumption (kWh/m²)	43.1	41.4	38.7	36.3	39.5	34.1	42.9	37.9	37.9	41.4	39.7	37.9
Hotels and Resorts												
Montecasino												
Lettable Area (m²):	15000											
Consumption (kWh)	45,369	44,100	44,309	42,794	41,775	44,020	45,302	45,761	44,205	42,193	42,419	39,225
Consumption (kWh/m²)	3.0	2.9	3.0	2.9	2.8	2.9	3.0	3.1	2.9	2.8	2.8	2.6
Hospitals												
Pretoria East Hospital												
Lettable Area (m²):	19369											
Consumption (kWh)	796,000	746,000	582,000	820,000	612,000	606,000	686,000	748,000	704,000	690,000		
Consumption (kWh/m²)	41.1	38.5	30.0	42.3	31.6	31.3	35.4	38.6	36.3	35.6		

Annex 5 Green Building Profiles

Megawatt Park
CSIR Conference Centre
Old Mutual Centre, Pretoria

MEGAWATT PARK: A GREEN BUILDING PROFILE

The introduction of energy cost saving measures saved R9.2-million or 32 percent between 1991 and 1999!

"Automated lighting system has been a shining example of energy management for Megawatt Park.."
- William Smith, Manager, Megawatt Park Facilities Maintenance Manager

Since 1991, Eskom has introduced measures to reduce the energy at its headquarters, Megawatt Park. Their efforts have made Megawatt Park one of South Africa's most efficient buildings.

Eskom undertook these efforts to demonstrate that investing in energy management is profitable. This initiative also is part of Eskom's national demand side management programme (DSM) that encourages property owners to introduce energy-efficiency, load-shifting and load-shedding options into their buildings.

Megawatt Park is a practical example of what no-cost and low-cost activities can achieve. Simply by implementing the proper control practices and an aggressive maintenance strategy, the building's annual energy fell 34 % from 1991 to 1997, resulting in savings of nearly R6-million! The measures also improved indoor comfort, with occupant complaints dropping by nearly 80 percent.

BUILDING AT A GLANCE

Building Type:	Commercial office building. Large open plan with small number of enclosed cellular offices. Small businesses on the ground floor.
Location:	Sandton, Johannesburg
Size:	100,000 m^2 main building, ~25,000 m^2 underground parking, 30,000m^2 outdoor parking
Year Built:	1978 - 1983
Owner:	Eskom

During 1998 Megawatt Park had a major energy-efficiency upgrade. The complete lighting system was replaced with a more efficient system and variable speed drives were installed on the supply fans of the air handling units. This again resulted in significant savings.

Megawatt Park's maintenance department created a win-win-win solution—a comfortable building with satisfied occupants that operates with less energy. As a Showcase Partner in the Green Buildings for Africa programme, Eskom is

also proud of the pollution prevented through reduced energy consumption.

Original Design

Megawatt Park is a four-storey building with a total floor area of about 100 000 m^2. It was constructed in two phases. Phase 1 was built in 1978 and then linked to the newly completed phase 2 via a link block in 1983. Each phase is built around an atrium with an indoor garden.

The building has a variable air volume (VAV) air-conditioning system that supplies air at a constant temperature. This building is divided into 14 air-conditioning zones each with its own air-handling units. These units are situated in 8 plant rooms.

Two water-cooled chilled water systems, one for each phase, cool the supply air. Hot-water boilers heat the supply air when necessary. The same hot water is also used for perimeter heating during winter.

18 462 double-tube luminaries (65 watts per tube) lighted Phase 1 while Phase 2, which has the same floor area, was lit by 9 760 single-tube light fittings (also 65 watts per tube). This complete lighting system was replaced at the end 1998.

The building has a building management system that controls the lights and air-conditioning system. A network of meters monitors the building's energy use, maximum demand and power factor.

Upgrades

Some of the various options Eskom implemented between 1991 and 1999 are given below:

- Upgrade of the building management system (BMS).
- Installation of energy monitoring meters and integration of these measures with the BMS.
- Optimisation of the operating hours of the air-conditioning systems.
- Automation of the lighting control systems.
- Upgrade of pneumatic control of the air-handling plants to direct digital control.
- Replacement of the lighting system with more efficient lighting system.
- Installation of variable speed drives to the supply fans of the air handling units.

As a result of these measures, from 1991 to 1999 Megawatt Park's energy use fell by 21 998 MWh from 54 658 MWh per year to 32 660 MWh per year. This represents a total reduction of 40 percent!

The lighting retrofit reduced the monthly demand by about 1 900 kW. This represents a maximum demand reduction of 22 percent!

During 1999 Megawatt Park saved about R2 480 000 in contrast to what it would have paid if no energy saving measures were introduced. This represents annual cost savings of 32 percent!

The accumulated saving between 1991 and 1999 was nearly R9.2-million! See Figure 1.

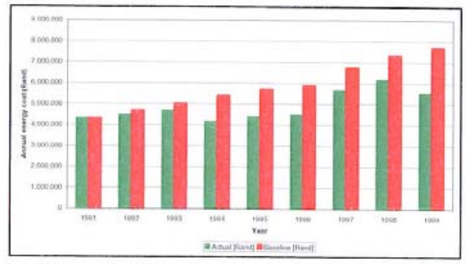


Figure 1 Comparisson of actual energy cost with the cost Megawatt would have paid if they did not improve its efficiency

Figure 2 illustrates the annual emission savings of SO_2, NO_x and particulates at the power station due to the saving in energy use.

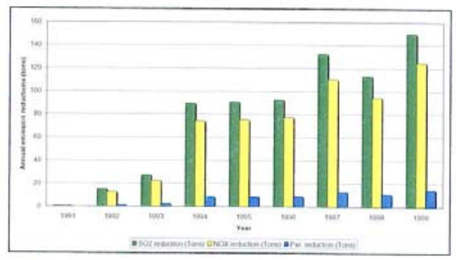


Figure 2 Annual emission savings of SO_2, NO_x and particulates

Figure 3 illustrates the annual emission saving of the greenhouse gas CO_2. The emission saving was achieved because the power stations needed to generate less power, thus burning less coal.

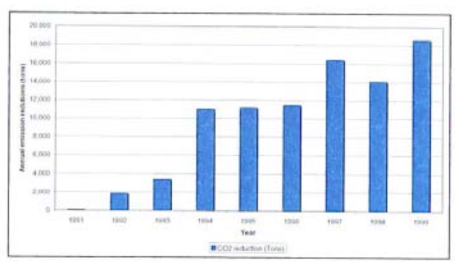


Figure 3 Annual emission saving of CO_2

For 1999 the emission savings was respectively the following:

- SO_2 158 ton
- NO_x 132 ton
- Particulates 15 ton
- CO_2 19 622 ton

The increase in emission savings for 1999 compared to that of 1998 was more than 26

percent. This clearly shows the environmental benefit also associated with reduction in the energy use.

New Paths to Profits

As a *Green Buildings for Africa* Partner, Eskom is committed to finding and implementing new opportunities for saving energy and improving occupant comfort.

Despite all these efforts there are still opportunities for more cost savings. Options that were recommended and still have to be introduced are:

- Changing of the tariff from Standard Rate to Megaflex.
- Installation of power factor correction together with the tariff change.

Analyses showed that an additional saving of R700 000 should be achieved if these two options are implemented. Megawatt Park is planning to introduce these measures during 2000.

Financial Viability

A financial analysis was performed to determine the overall cost-effectiveness of all the energy saving measures that were introduced since 1991.

By the end of 1999 Megawatt Park will have achieved the following since 1991:

Total energy upgrade costs	R 7 492 553
Total energy cost savings	R 9 200 056
Net energy cost savings	R 1 707 503

This means that by the end of 1999 the energy cost savings paid for all the energy measures introduced between 1991 and 1999. It also included the lighting and variable speed drive retrofits that were performed at the end of 1998.

All the further energy cost savings over the life of the installed equipment will therefore go straight to the bottom line, thus improving the competitiveness and financial performance of Megawatt Park.

It was assumed that the new lighting system and variable speed drives would have an expected lifetime of at least ten years. Based on the savings till the end of 1999 and the expected savings that will be realised when the outstanding measures are implemented forecasts of future savings were made for the next ten years.

Figure 4 illustrates the energy cost Megawatt Park would be avoiding between 1991 and 2008. The avoided energy costs are the costs Megawatt Park avoided due to the implementation of energy cost saving measures. The total avoided energy cost will be nearly R47.5-million!

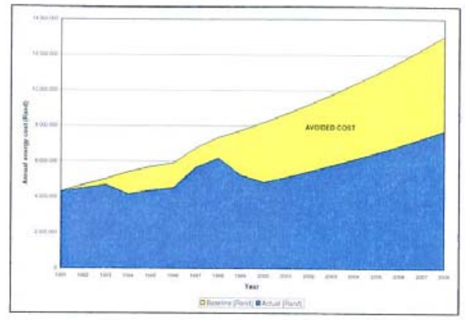


Figure 4 Avoided energy cost over the life of the project

A financial analysis was also performed to determine the cost-effectiveness of all the implemented energy measures between 1991 and 2008. Table 1 gives a summary of the financial indicators:

FINANCIAL SUMMARY - Megawatt Park		
Years 1991 to 2008		
Annual energy cost increase from 2000 to 2008		6%
Discount rate		18%
Internal Rate of Return		128%
Net Present Value - January 1991	R	5,524,979
Net Present Value - December 1999	R	20,767,618
Total investment - January 1991 to December 1999	R	7,492,553
Total savings - January 1991 to December 1999	R	9,200,055
Total savings - January 1991 to December 2008	R	47,492,435
Net savings - January 1991 to December 1999	R	1,707,502
Net savings - January 1991 to December 2008	R	39,739,882

Table 1: Financial summary of Megawatt Park

The analysis showed that all the measures had a Net Present Value of nearly R21-million by the end of 1999. The overall internal rate of return was 128 percent. By the end of 2008 Megawatt Park would have achieved net energy savings of nearly R40-million!

The initiatives at Megawatt Park demonstrated the financial benefits of energy management. The money that will be saved over this period will be enough to power the building (using 1999 consumption figures) for an additional 8 years!

For more information on the Green Buildings for Africa programme, please contact:

Green Buildings for Africa Division of Building and Construction Technology	CSIR P.O. Box 395 Pretoria 0001 South Africa	Tel: 012-841-2524 Fax: 012-841-3504 E-Mail: greenbld@csir.co.za

Your Technology Partner

CSIR CONFERENCE CENTRE: A GREEN BUILDING PROFILE

Getting peak performance (comfort and efficiency) from the building management system is critical for this conference centre's ability to attract customers.

"Comfort levels have increased markedly since the control changes were made in 1998; temperatures are much more stable."

—Raymond Gourley
Building Operations

The CSIR Conference Centre plays a crucial role on the CSIR campus in serving as the primary conference facility of Africa's leading technology organization. The Centre is also a highly lettable asset and strategic meeting venue for other leading organizations, both from South Africa and abroad. With the capacity to accommodate 450 people, the facility hosts over 800 national and international events per annum and also displays numerous CSIR products, services, and accomplishments.

As the agency managing the *Green Buildings for Africa* programme and a recognized leader in building and energy technologies for the African environment, the CSIR has committed itself to optimizing energy efficiency/pollution prevention in its own buildings throughout its campus. After a thorough energy audit of the Conference Centre in 1997, it was determined that the building could potentially decrease its total energy bill by approximately 44% with energy efficiency upgrades. The CSIR is now well on the way to realizing the full savings potential of upgrades to this high-profile facility. In addition, CSIR is improving building comfort for its customers and the overall marketability of this asset.

BUILDING AT A GLANCE

Building Type:	Conference Centre with lecture halls, banquet hall, main lobby offices, and waiting rooms
Location:	CSIR Campus, Pretoria
Size:	5 492 m^2
Year Built:	1977
Owner:	CSIR
Architect:	Burg, Doherty, Bryant & Partners
Construction:	Concrete frame. Two floors with one basement. Curtain walls and structural glass walls. Single glazed, bronze-tinted windows. Mechanical rooms in basement.
Building Systems:	Constant volume air supply HVAC system. Electric resistance heat. Two reciprocating chillers. Mostly incandescent lighting. 100 kw geyser for domestic hot water.

Original Design and Systems

When built over 20 years ago, the Conference Centre incorporated a number of traditional technologies that make it a ripe candidate for energy and cost savings today.

The heating, ventilation and air-conditioning (HVAC) system is constant volume. Perimeter heating is provided by electric resistance coils, and hot water heating coils serve the central zones from an electric boiler. Two reciprocating chillers supply the air handlers. The heating and cooling systems both operate during the winter and summer, inefficiently cooling and heating each zone simultaneously.

Interior lighting in the building is almost exclusively incandescent, with 500, 250, 60 and 40 Watt incandescent bulbs, which are replaced individually upon burnout. A 100 kW geyser heats the domestic hot water.

Initial Upgrades

A Building Management System (BMS) was installed and commissioned at the Conference Centre in October 1995. The system, however, never worked properly and did not produce any savings. In 1996, the system was recommended for re-commissioning.

In 1998, preliminary changes were made to the BMS, which reduced the amount of simultaneous heating and cooling and stabilized room temperatures throughout the Conference Centre.

Significant Energy Savings Already Being Achieved:

- R80 000/year lower energy costs
- 700 000/year kWh savings
- R5 000 investment, yielding a simple payback of less than 0.1 years

New Paths to Profits

CSIR continues to implement further recommended energy efficiency measures as part of the Green Buildings for Africa Programme. These measures include:

Additional Controls Upgrades. This includes: eliminating unnecessary reheat of cool air; adding demand-shedding capability; preventing undesired operation of extractors; adding temperature resets for chilled and hot water; turning off pumps when not needed; and optimizing fan operations.

Occupancy Sensors. Because the majority of the rooms are only occupied 50% of the time, occupancy sensors can reduce the operating hours of lighting and cooling systems.

In-Line Geysers. The installation of new in-line geysers can eliminate the use of (and energy losses associated with) the existing 100 KW central geyser.

Recommended Upgrades				
Energy Efficiency Measure	Demand Savings (kW)	Energy Savings (kWh)	Annual Cost Savings	Estimated Project Cost
New Controls Upgrades	105	320 000	R51 000	R44 000
Occupancy Sensors	50	225 000	R36 000	R76 000
In-Line Geysers	15	57 000	R10 000	R11 000
Operable Dampers	20	35 000	R10 000	R14 000
All Measures Combined	190	637 000	R107 000	R145 000

Operable Outside Air Dampers. Current dampers allow only a fixed quantity of air into the building. Adding controls to the dampers could allow more air to be brought in for cooling when outside conditions are right.

CSIR management considers its Conference Centre a strategic, revenue-generating asset where the customer comes first. Stabilizing room temperatures, through optimization of its BMS, is only one measure implemented in a series of planned upgrades. Through its leadership in and commitment to the Green Buildings for Africa programme, the CSIR has recognized that the profitability of a building can be significantly improved by reducing utility costs and increasing customer comfort.

For more information on the Green Buildings for Africa programme, please contact:

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CSIR
Your Technology Partner

GREEN BUILDINGS FOR AFRICA

OLD MUTUAL CENTRE - PRETORIA: A GREEN BUILDING PROFILE

Treating energy management as an investment opportunity would realise savings of more than R4-million over the next 10 years

"Old Mutual Properties is busy with various energy-efficiency projects to reduce the energy cost of their tenants"
— ***Richard Murphy, Technical facilities manager, Old Mutual Properties***

OLD MUTUAL Properties

Old Mutual is pro-actively investing in energy efficiency. The company recently permitted the CSIR to investigate the energy savings potential of the Old Mutual Centre (OMC) facility in Pretoria. The results were astonishing. The report by the CSIR's identified several upgrades with internal rates of return in excess of 129 percent! And several additional upgrades had internal rates of return of at least 60 percent.

The chilled water used for cooling the building is supplied by two chillers that use R-11 as a refrigerant. R-11, a chloro-fluorocarbon (CFC), is an ozone-depleting chemical and is being phased out of production. Due to the envisaged future scarcity of R-11, the replacement of the chillers is imminent.

BUILDING AT A GLANCE

Building Type:	Commercial office building. Small businesses on the ground floor.
Location:	CBD, Pretoria
Size:	24,000 m² main building, app. 4,500 m² parking (underground), 15,000m² lettable office area, 3,000 m² shopping area
Year Built:	1976
Owner:	Old Mutual Properties
Construction:	Concrete frame. Twenty floors of lettable space.

New chillers, on their own, are not an attractive investment, but when coupled with several energy efficiency upgrades, it becomes financially viable. So what initially seemed like a capital expenditure with no hope of recovery was transformed into an investment through pro-active energy efficient considerations.

Original Design

OMC is a twenty-storey building with a total floor area of about 24 000 m². It is a multi-tenanted and accommodates about 800 people. The building consists of about 15 000 m² of lettable office area, 3 000 m² of shop area with the balance being parking and common areas.

The building has a variable air volume (VAV) air-conditioning system that supplies air at a constant temperature. OMC has a total of five air handling units (AHUs). Three large AHUs serve the office areas, and 2 small units serve the shopping areas.

Two 1200 kW centrifugal chillers supply the chilled water that cools the supply air. Two 108 kW hot-water boilers heat the supply air when necessary.

Fluorescent tubes, 4-foot T12 (40 W), light the office areas. The parking area and plant rooms are equipped with 8-foot T12 (75 W) lights.

The facility does not have a building management system.

Upgrades

The energy audit showed that the operating times of the AHUs were not properly controlled. AHUs operated 24 hours per day including weekends. This finding surprised the maintenance staff.

The first upgrade was to change and reset the AHUs timers. This simple measure realised annual savings of R39 160.

New Paths to Profits

The study also identified several additional low-cost upgrades. Old Mutual is implementing these upgrades and include:

- Installing permanent metering to determine where, when and how energy is used in the building.
- Upgrading the AHU timers.
- Improving the operation of the power factor control equipment.
- Installing a maximum demand control system.

As a *Green Buildings for Africa* Partner, Old Mutual Properties is committed to identifying and implementing measures to realise more energy savings and improved occupancy comfort at OMC.

A recent study identified various profitable energy efficient upgrades that are more capital intensive. These upgrades are currently being investigated, and include:

- Lighting retrofits.
- Installing variable speed drives for air supply fans.
- A combination of the above-mentioned options with the installation of new chillers.

The chillers currently in use are outdated, using R-11 as a refrigerant. Sometime in near future these chillers will have to be replaced as the production of R-11 is phased out. By implementing the above mentioned upgrades, the building's cooling load will fall, allowing OMC to purchase a smaller (less expensive) chiller when it is time for replacement.

From a financial perspective, the combination of measures is much more attractive. Table 1 provides more details on the improved finances that result from tying the chiller replacement to the lighting and VSD measures.

Recommended upgrades						
Option	Description	Initial capital cost (R)	Savings/ year (R)	IRR (%)	NPV (R)	Payback (year)
1	Lighting upgrade	110,658	94,968	92	409,951	1.
2	VSDs	101,262	26,376	28	43,330	3.
3	VSDs and lights	211,920	125,104	64	473,892	1.
4	Smaller chiller with VSD's and lights	1,096,920	129,442	8	-387,327	8.

Table 1: Investment worth analysis of recommended upgrades.

The total savings in energy over a 10-year period are R4.2-million. This includes the savings from the no- and low-cost upgrades as well as those from the envisaged upgrade of the lighting system and the installation of VSD.

The projected savings in energy costs are illustrated in Figure 1.

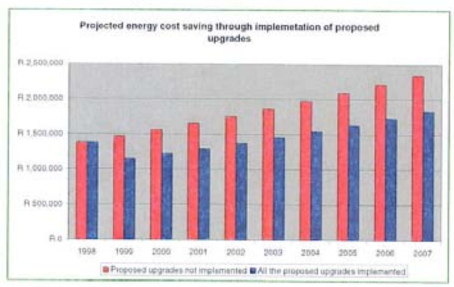

Figure 1: Projected savings through implementation of proposed upgrades.

For more information on the Green Buildings for Africa programme, please contact:

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