

**BUILDING ENERGY AUDIT REPORT**

**NATIONAL ELECTRICITY REGULATOR  
526 VERMEULEN STREET, PRETORIA**

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## **EXECUTIVE SUMMARY**

The Department of Minerals and Energy (DME) is proactively investing in energy efficiency. Energy efficiency in buildings is one of many projects investigated by the DME. The National Electricity Regulatory (NER) building in Pretoria is a specific case study contracted to the Energy Research Institute (ERI).

This project is managed by COWI A/S as part of the DANCED funded programme: DME-DANCED Capacity Building In Energy Efficiency And Renewable Energy

It was found that the NER building in Pretoria incorporated both energy and cost efficiency in its original building design, including:

- Overhangs surrounding the building that reduce solar heat gain
- Tinted window glass
- Additional angled tinted windows on the northern overhangs
- Variable volume Heating, Ventilation & Air Conditioning (HVAC) system.

The HVAC equipment in the plant room is in a poor condition and the system cannot operate any where near to its design intent. The chillers and pumps do not operate at all. Consequently, energy consumption levels could not be measured. Similarly, figures shown in the electricity bills would not be indicative for the period that the plant has been out of proper operation. In addition, the NER has recently refurbished and changed the use of the building, which would mean that historical data from the previous tenants could not be used for energy comparison. The bulk of the audit, therefore, concentrates on the lighting system.

***The building holds the potential to be one of the most energy efficient buildings if attention is given to upgrading and maintaining the HVAC system, management of the building and its services, and upgrading the control system.***

The energy conservation opportunities (ECOs) recommended and described in this report are summarized in Table 1.

Economic savings presented address only energy and demand cost avoidance and reduction of present and future costs associated with energy usage. The savings given for each opportunity reflect the savings achievable when implementing each opportunity independently. Some of the recommended measures may interact. Therefore, actual cost savings may be less than indicated.

Note also that the estimates given for savings with respect to the air conditioning system are on the basis that the original system is restored to working order, as designed.

A strong recommendation is that an experienced consulting engineer be commissioned to evaluate the HVAC system, design (energy efficient) repairs and improvements, and call for firm tenders for implementation.

**Table 1: Potential Energy Savings**

<b>ECO</b>	<b>RECOMMENDATIONS</b>	<b>POTENTIAL SAVINGS (R/YR)</b>	<b>ESTIMATED IMPLEMENTATION COST (R)</b>	<b>SIMPLE PAYBACK (YRS)</b>
1	Reduce lighting hours	30 576	0	0
2	Replace light types	15 113	21 123	2.8
3	Add light switches	30 219	24 200	0.8
4	ECO 1 + 2 + 3	62 010	45 323	0.7
5	Adopt a good maintenance strategy	varies	varies	varies
6	Install BMS	54 – 108 000	300 000	5.55 -2.76
7	Improve HVAC controls	81 123	75 000	0.92

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**LIST OF ABBREVIATIONS**

°C	Degree Celsius
CF	Coincidence Factor
CFL	Compact Fluorescent Light
DCS	Demand Cost Reduction
DME	Department of Minerals and Energy
DR	Demand Reduction
DB/WB	Dry Bulb/Wet Bulb (temperature)
EC	Estimated Energy Conservation
ECO	Energy Conservation Opportunity
ECS	Energy Cost Saving
ERI	Energy Research Institute
HVAC	Heating, Ventilation and Air Conditioning System
NER	National Electricity Regulator
VAT	Value Added Tax
VAV	Variable Air Volume

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## 1. INTRODUCTION

This project is part of the DANCED funded programme for Capacity Building in the DME in Energy Efficiency and Renewable Energy. The project is managed by COWI A/S.

The project contributes to the overall goal of establishing a more sustainable energy sector in South Africa through an increased use of renewable energy and greater energy efficiency on the demand side. A more immediate goal is this specific building energy audit with recommendations for energy reductions in government buildings.

Cost savings normally drive investment in energy efficiency, although environmental reasons can be strong. The focus of this study is to realise cost effective efficiency measures. The recommended energy efficient measures can be grouped into three categories, namely, no cost or low cost measures requiring little or no investment, medium cost measures requiring only a simple payback calculation, and high capital cost measures requiring detailed design and a full investment appraisal.

The assessment takes into account the wider benefits such as improvements in comfort and the environment.

The ERI surveyed the building and its services during the period 22-26 August 2002.

South African, British and American literature was researched to determine whether there were any benchmark data for this sort of building. Only the British reference<sup>[1]</sup> gave useful details. The figures are quoted below.

	<b>GOOD PRACTICE</b>	<b>TYPICAL</b>
Overall	225 kWh/m <sup>2</sup>	400 kWh/m <sup>2</sup>
Office equipment	23	31
Hot water + HVAC	149	287
Lighting	27	54

Energy Cybernetics surveyed a similar building in Vermeulen Street about 6 years ago. The only specific energy consumption is the overall value at approximately 258 kWh/m<sup>2</sup> per year. This gives a context to the British figures and is the region of anecdotal values of around 300 kWh/m<sup>2</sup>.

It should be noted that these figures are for a geographic location of 51.5° north latitude with design conditions of 27.2/18.9°C DB/WB in summer and -3.6/-6.1°C DB/WB in winter, whereas the building in question is situated at 25.7° south latitude with design conditions of 31.7/17.8°C DB/WB in summer and 3.9/0.1°C DB/WB in winter. Pretoria is also at least 1300 m above sea level.

The NER owns and occupies the building. It is responsible for the cost of operating the building. It has recently occupied the building on floors 4 to 8, following refurbishment of these floors. Floors 2 and 3 are rented to others while floors 0 and 1 are unoccupied, save for a security person. There are 2 levels basement car parks.

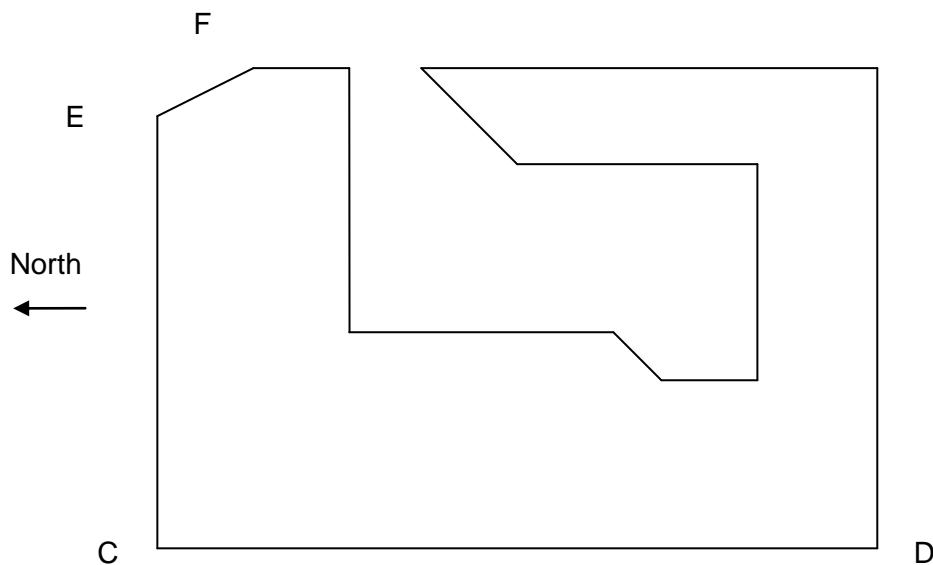
All bought energy is electric; there is no fossil fuel use on site.

## 2. BUILDING DESCRIPTION

The National Electricity Regulator (NER) building in Pretoria is approximately 20 years old. During the survey it was difficult to accurately determine the type of insulation or the wall construction of the building. (The NER was unable to provide architectural and services drawings as requested; we made educated judgments on what we were able to see)

It appears that the building has been designed to mitigate the effects of the sun. The building forms a C shape as indicated in Figure 1 below with tinted windows right around except along CD. Little or no direct sunlight reaches the inner part of the C due to the architectural design. The mitigation of solar gain in terms of building design is clearly evidenced here, especially in the morning when direct sunlight reaches this side of the building. As a result, heat transfers from the sun's radiation, into the building, is limited and controlled.

This single office block consists of 9 levels of office space and 3 underground parking bay levels with an office area of approximately 760 m<sup>2</sup> per floor (treated area, excluding kitchens and toilets). Overhangs of approximately 1,5 m exist along the outside of the building on each of the office levels (see Figure 2). Furthermore, along face EF of the building, additional tinted windows angled to filter the sun's radiation are fitted on the overhang of each level.



**Figure 1: Pictorial Diagram of Building Shape**

The building is used for administrative purposes only and is occupied Mondays to Fridays, usually between 8.00 am and 5.00 pm. Currently levels 2 to 8 are occupied. The two lower levels 2 and 3 are a good indicator of the previous usage of the building. Various companies occupy these levels. For this part of the building a central drop down ceiling is used to house the HVAC ducts that distribute air to offices on either side of the corridor. Many localized air conditioning systems were also used, probably as a result of the central system falling into disrepair.



**Figure 2: The Building Viewed from Vermeulen Street**

The layout is mainly open-plan for levels 4 to 6. Level 7 is divided into a number of private offices and level 8 has mainly conference rooms. Dropped ceilings have been added to the full width of the floors.

### 3. BUILDING SERVICES

#### 3.1 Lighting

The following description applies to the NER offices. Floors 2 and 3 have mainly the older type of fluorescent lamp fittings. Table 2 shows the type and number of light fittings.

Three types of light fittings are used in the building. These include the following:

- Halogen stream lights are installed along the longitudinal centreline of each of floors 4 to 8. Each of these fittings has its own 50 Watt, 12 Volt transformer. There is an average of 60 installations per floor.
- Fluorescent lights with three T8, 40 Watt tubes per fitting. Magnetic ballasts are used. There are approximately 50 of these fittings on each level. In the basement each fitting has two T12, 40 Watt tubes with a total of 82 fittings.
- Incandescent light fittings are mainly used on the outside of the building. Under the outside overhangs a total of 88 such fittings were counted. A further 17 of these fittings were counted in the centre garden and other outside areas.
- Other light fittings include the energy efficiency compact fluorescent lamps (CFL) with two 13 Watt bulbs in each fitting. Approximately 20 of these are installed per floor level

Two switches control the lights on each floor, one switch per wing on each level. These lights were found to be on day, night and over the weekend. The building is not used at night or at weekends.

**Table 2: Lighting Distribution**

TYPE OF FIXTURE	NUMBER OF LAMPS PER FIXTURE	WATTS PER LAMP	BALLAST TYPE	TOTAL NUMBER OF FIXTURES PER FLOOR	NUMBER OF FLOORS	TOTAL
Fluorescent Lights (T8)	3	40 W	Magnetic	50	7	1050
Fluorescent Lights (T12)	2	40 W	Magnetic			88
Incandescent	1	100 W				105
Halogen Stream Lights	1	50 W, 12 V		60	5	300
Compact Fluorescents	2	13 W		20	5	200

The total energy consumed by the above mentioned fittings is 418 114.8 kWh/yr, or 110 kWh/m<sup>2</sup> per yr. This compares with reference<sup>[1]</sup> 27-54 kWh/m<sup>2</sup> per yr for which the lights are only on during working hours.

### 3.2 Heating, Ventilation and Air Conditioning (HVAC)

The major components of the HVAC system are shown in Table 3.

**Table 3: Inventory of HVAC equipment**

DESCRIPTION	NO. OF COMPONENTS	MOTOR RATING	REMARKS
Chillers (UW80EGSYE)	3	60 kW	Rated capacity ~235kW ea.
Primary chilled water pump	3	3 kW	
Secondary chilled water pump	2	15 kW	
Condenser water pump	2	18.5 kW	
Return Air Fans	2	17 A	
Air Handling Unit 1	1	30 kW	Inlet guide vanes fully open
Air Handling Unit 2	1	11 kW	Inlet guide vanes fully open
Air Handling Unit 3	1	18.5 kW	Inlet guide vanes fully open
Air Handling Unit 4	1	15 kW	Inlet guide vanes fully open
Exhaust air fan	3	1.5 kW	
Exhaust air fan	1	3 kW	
Exhaust air fan	1	1.1 kW	
Cooling Tower	1	2 kW	Estimated
Roof Extract	1	3 kW	
Roof Extract	1	0.37 kW	

(It should be noted that heaters are indicated on the control panel but they could not be located in the air handling units or the plant room ducting)

It must also be noted that system drawings and manuals could not be made available to us. Comments are, therefore, based on experience and judgment of what could be seen.

We calculated the cooling requirements of the building based on our observations and the information the hand. The required cooling capacity is approximately 500 kW, or approximately 90W/m<sup>2</sup>, taken over seven floors. We examined the monthly load profile and concluded that that the equivalent hours of operation of the chillers at full load would be approximately 2200 per year. This results in a compressor energy consumption of about 50W/m<sup>2</sup> on the assumption that the coefficient of performance is 4. The installed chiller capacity is approximately 40% greater than the design cooling requirement.

#### 3.2.1 Description of System

The office space (floors 2 to 8) is served by a variable volume (VAV) air conditioning system, supplied by a central plant located in the lower basement.

Toilets are located on each landing of the stairs. The doors to the stairwell are louvered but there is no air extraction from the toilets, although there appears to be an extract fan at roof level drawing from the masonry shaft immediately adjacent to the toilets.

There are also disabled-person toilets on the recently refurbished floors which have no apparent extraction, neither are the doors louvered for inlet air.

There is a small fan at roof level at the top of the stairwell that was possibly intended for smoke extraction.

Some fume extraction fans remain at roof level. They are not operational and originally served the fume cupboards on level 2 used by previous occupants.

The cooking areas on the lower floors have extraction systems but these no longer function.

The original system air outlets are both of the ceiling diffuser and sidewall outlet type. There are no identifying labels, however, they appear to be of the type manufactured by Ventline. These units are still in place on levels 2 and 3 in general office areas that were not refurbished. Only a handful of people occupy levels 2 and 3 while the NER occupies levels 4 to 8. The refurbished (NER) offices have been fitted with Rickard VAV diffusers that are similar in principle to the original units manufactured by Ventline.

The air conditioning system that serves levels 2 and 3 is in poor condition. This would adversely affect the operation in the rest of the building.

The controls in the plant room have been mechanically disabled to the extent that the system can no longer function in its designed VAV mode. It is likely that the electrical side of the control system does not function, given the general state of decline in the plant room.

It is not possible to tell (there was no operational evidence and neither could drawings and manuals be made available to us) whether an "economy cycle" was designed into the original control philosophy. This is an aid to energy efficiency that removes the need for mechanical (refrigerated) cooling during times when the external air temperature is low enough to satisfy the building needs.

At present, the return air dampers are fixed in a position that allows only a little outdoor air into the building (see also section on occupant survey). It seems as if the dampers were set to minimize the cost of heating during the winter period.

The chillers never ran while we were present, yet there was clearly a demand in the building for cooling. However, the fans ran day, night and over the weekend.

The boardroom on level 8 had some air outlets directed vertically downwards. These are not conventional air outlets and would result in cold drafts once the chillers operate.

### **3.2.2 Room Conditions**

We measured a typical space temperature on the sixth level to find a variation between 25°C before lunch to about 27°C in the afternoon. The lower temperature is a little above the usual summer set point of 24°C while the higher one is reaching the limit of comfort, particularly in view of the low relative humidity which we estimated at below 25%.

At the time of testing, the external temperature remained constant at about 22°C. The supply air temperature from the diffusers was 24°C while the design temperature would have been about 13°C for a system without an economy cycle. Conditions on levels 2 and 3 were not measured, given that the system was visibly not in a good state.

The total connected power for these major items amounts to approximately 326 kW. The daily energy consumption would vary from about 3200 kWh in the height of summer to about 1400 kWh in mid winter (12 hour day).

### 3.3 Domestic Hot Water Heating

A D350 model geyser with an estimated capacity of over 1000 litres provides hot water for the whole building. This is an 18 kW, 40 A, three-phase geyser. The geyser and piping are insulated. However, the piping in the riser to the floors would benefit from re-insulation

### 3.4 Office Equipment

Table 4 shows the items on each floor. The Annual Hours of Usage column is an estimate of the use of each item.

**Table 4: List of Office Equipment and Staff count per level**

LEVEL	4	5	6	7	8	TOTAL	ANNUAL HOURS OF USAGE	ANNUAL KWH
Number of staff	28	20	19	18	3	88		
Printers (1 300 Watt)	0	5	0	2	0	7	2000	18 200
Photocopier (1000 Watt)	2	2	2	1	1	8	2000	16 000
Fax (655 Watt)	2	2	2	7	1	14	2000	18 340
Telephone	28	20	19	18	8	93		
PC (500 Watt)	28	20	27	18	5	98	2000	98 000
Scanner (250 Watt)	0	0	1	0	0	1	2000	500
Television (500 Watt)	0	0	1	0	0	1	100	50
Coffee Maker (1000 Watt)	1	1	1	1	1	5	2000	10 000
Microwave oven (900 Watt)	1	1	1	1	1	5	250	1 125
Fridge (250 Watt)	1	1	1	1	1	5	2000	2 500
Kettle (1000 Watt)	1	1	1	1	1	5	1000	5 000
Stove (3000 Watt)	0	0	0	1	1	2	100	600
Oven (3000 Watt)	0	0	0	1	1	2	100	600
<b>TOTAL</b>								<b>170 915</b>

The specific energy consumption for the above table is approximately 45 kWh/m<sup>2</sup>per yr and compares with the range 28–37 kWh/m<sup>2</sup> per yr<sup>[1]</sup>.

#### 4. **ENERGY ACCOUNTING**

##### 4.1 **Energy Management**

An essential component of any energy management program is a continuing account of energy use and its cost. Keeping up-to-date records of monthly energy consumption and associated costs can develop this. When utility bills are received, the energy use and costs should be recorded as soon as possible.

There was no maintenance or energy monitoring plan in place at the time of this audit. However, we know that the NER is moving in this direction.

Benchmark data for buildings in South is not in the public domain. Reference to (appropriate) foreign and local anecdotal data yield the following key figures as shown in Table 5 below.

**Table 5: Benchmark Energy Values (kWh/m<sup>2</sup>-yr)**

	<b>TYPICAL</b>	<b>GOOD PRACTICE</b>
Overall	258	Unknown
Lighting	54	27
Small power	31	23
Hot water	10	4

Note that the overall figure of 258 kWh/m<sup>2</sup> per year was obtained from a very similar building in the same street.

##### 4.2 **Electricity Bill**

The NER building is currently billed monthly using the rate schedule presented below:

R 296.47	Monthly customer charge
R 49.22	Capacity charge for each kW of billing demand
10.68 c	Energy charge per kWh

The electricity tariffs on the actual electricity account of the NER building are different to those specified on the Tshwane Metropolitan Municipality website (see Appendix 10.2). The reason for the discrepancy between published rates and actual account rates could not be established, despite the conversation described below. Our experience is that staff at the municipality are not able to explain their own tariff.

To get clarity on the matter, ERI contacted the Tshwane Metropolitan municipality<sup>[2]</sup> at (012) 308 8550. The person spoken to is Mr Rider Moyeni who was very helpful and patient throughout the conversation. The questions involved the account dated for July 2002. On his screen the following details are reflected:

- Energy consumption has two readings which amounts to 124 558 and 73 812 and adds to 198 370. The previous reading on the account is 174 528 and the current reading is 194 365 which amounts to a total consumption of 19 837.
- Basic fixed charges are R 114.38 and R 182.09, which amounts to R296.47 in total.

No demand or electricity unit charge reflects on the system. As this was the limit to which he could assist me in understanding the electricity consumption bill, he referred me to Ms Annetjie Engelbrecht at (012) 308 8240. This number just rings and since Ms Engelbrecht could not be reached, clarity on the outstanding issues cannot be deduced.

The following is an example of the determination of the electric charges at the building for the month of July 2002:

Billed Demand = 441 kVA  
 Energy Consumed = 198 370 kWh

Customer Charge:		R 296.47
Demand Charge:	441 kVA @ R 49.22/kVA	R 21 707.05
Energy Charge:	198370 kWh @ R 10.68c/kWh	R 21 194.68
14% VAT:		R 6 047.75
Total Electricity Charge:	Customer Charge + Demand Charges + Energy Charges + VAT	<b>R 49 245.95</b>

#### 4.3 Energy Usage and Cost

Electric energy usage, demand, and costs for April, May and July 2002 are presented in Table 6 below. These were the only accounts given to us.

**Table 6: Electric Usage, Demand and Cost Summary**

MONTH	ENERGY CONSUMED (kWh)	BILLED DEMAND (kVA)	POWER FACTOR (%)	ENERGY CHARGE (R)	DEMAND CHARGE (R)	VAT CHARGES (R)	TOTAL CHARGES (R)
April 2002	298,320	493	88.4	31,174.44	24,176.72	7,789.76	63,430.92
May 2002	137,440	438	87.1	14,362.48	21,479.52	5,058.48	41,198.49
July 2002	198,370	441	86.3	21,194.68	21,707.05	6,047.75	49,245.95
<b>TOTALS</b>	634,130	1,372		66,731.60	67,363.29	18,895.99	153,875.36
<b>AVERAGE</b>	211,376	457	87.0	22,243.87	22,454.43	6,298.66	51,291.79

#### 4.4 Avoided Cost of Electrical Energy

The avoided cost of electrical energy for this plant is: = **10.68c/kWh**

#### 4.5 Avoided Cost of Electrical Demand

The avoided cost of electrical demand for this plant is: = **R 49.22/kVA**

## 5. ENERGY CONSERVATION OPPORTUNITIES

### 5.1 Install High Efficiency Lighting

The methodology developed by the Industrial Assessment Centre is used here<sup>[3]</sup>.

#### **ECO 2: Case 1: Reduce operating hours of lights to 12 hours per day.**

Note that to implement this recommendation does not cost a cent. The lights can be switched off by the security personnel after hours and switched on by staff as they return to the office the following morning.

Estimated Electric Energy Conservation	= 286 277 kWh/yr
Estimated Electric Energy Cost Savings	= R 30 576/yr
Estimated Electric Demand Reduction	= 0 kW
Estimated Electric Demand Cost Savings	= R 0.00/yr
Estimated Total Cost Savings	= R 30 576/yr
Estimated Implementation Cost	= R 0.00
Simple Payback Period	= 0 years

#### **ECO 2: Case 2: Replace T-12 fluorescent lamps and incandescent lamps with T-8 fluorescent lamps and compact fluorescent lamps respectively.**

Note that this is a stand alone option which assumes that the lights remain on 24 hours per day.

Estimated Electric Energy Conservation	= 86 741 kWh/yr
Estimated Electric Energy Cost Savings	= R 9 264/yr
Estimated Electric Demand Reduction	= 9.9 kW
Estimated Electric Demand Cost Savings	= R 5 848/yr
Estimated Total Cost Savings	= R 15 113/yr
Estimated Implementation Cost	= R 21 123
Simple Payback Period	= 1.4 years

#### **ECO 3: Case 3: Switch off halogen stream lights.**

Note that this is a stand alone option which assumes that the lights remain on 24 hours per day.

Estimated Electric Energy Conservation	= 173 448 kWh/yr
Estimated Electric Energy Cost Savings	= R 18 524/yr
Estimated Electric Demand Reduction	= 19.8 kW
Estimated Electric Demand Cost Savings	= R 11695/yr
Estimated Total Cost Savings	= R 30 219/yr
Estimated Implementation Cost	= R 24 200
Simple Payback Period	= 0.8 years

#### **ECO 4: Case 4: Case 1 + Case 2 + Case 3**

Note that the energy savings for Cases 2 and 3 must now be halved as they were based on 24 hour operation.

Estimated Electric Energy Conservation	= 416 372 kWh/yr
Estimated Electric Energy Cost Savings	= R 44 468/yr
Estimated Electric Demand Reduction	= 29.7 kW
Estimated Electric Demand Cost Savings	= R 17 542/yr
Estimated Total Cost Savings	= R 62 010/yr
Estimated Implementation Cost	= R 45 323
Simple Payback Period	= 0.7 years

#### **5.1.1 Recommended Action**

- (i) Replace the existing four-foot T-12 lamps and magnetic ballasts with high-efficiency (lower wattage) lamps and electronic ballasts. High efficiency lamps use less energy than standard lamps with comparable light output.
  - (ii) Replace the existing incandescent lamps with high-efficiency compact fluorescent lamps.
  - (iii) Switch off office lighting after hours and over weekends.
  - (iv) Install more switches per floor per wing.
- A switch for each side of the building on each floor for the stream lights, which amounts to two additional switches per floor. The luminance on floor levels 4 to 7 is significantly above the specified requirements. These stream lights can be switched off during the day and can be utilized as passage lights after hours.
  - A switch for the fluorescent fixtures on each side of the passage per wing per floor, which amounts to four additional switches per floor. This allows control of the floor lighting as required.
  - A switch for the lights in each conference room. Additional switches can be added if different types of light fixtures exist in a unit.
  - A switch for each set of compact fluorescent lights.

#### **5.1.2 Background**

- (i) Electronic ballasts are currently available which when used with the proper 32W T-8 fluorescent lamps (the T rating refers to lamp tube diameter in 1/8ths of an inch) provide a very high quality light while using significantly less energy than the existing magnetic ballasts and 40W T-12 fluorescent lamps. The T-8 lamps provide a high quality light that renders colour significantly better than the existing T-12 lamps thus providing excellent lighting for offices. All of the four-foot fluorescent lamps and ballasts in the office space could be replaced with T-8 lamps and electronic ballasts. An added benefit of electronic ballasts is the high frequency at which they operate, eliminating the flicker often associated with standard fluorescent lighting. In addition, electronic ballasts are available that operate four lamps; therefore, a four lamp fixture that previously required two magnetic ballasts operating two T-12 lamps each can utilize a single electronic ballast operating all four T-8 lamps.

- (ii) Incandescent lamps are thermal radiators. In an enclosed bulb filled with gas, an electric current is passed through a filament of tungsten wire to make it glow. Approximately 5% of the energy consumed is converted into light; the rest is lost to heat. Incandescent lights can last up to 1000 hours on average. Fluorescent lights consume approximately a fifth of the electricity that an incandescent lamp uses. Furthermore, compact fluorescent lamps have a life span of almost 12 000 hours.

### 5.1.3 Anticipated Savings

Lighting fixture identification codes and corresponding fixture specifications are given in Table 7. The power ratings used in the following equations are found in the "Fixture Power" column. The fixture power is the combined ballast and lamp power draw. Table 8 provides the existing lighting characteristics as determined from the lighting survey conducted during the audit visit. The values in Table 9 are projections based on the replacement of these lamp/ballast combinations with suitable high efficiency lamp/ballast combinations.

**Table 7: Lighting Fixture Codes and Specifications**

BALLAST/ LAMP CODE	LAMPS PER FIXTURE	LAMP POWER (W)	LAMP WIDTH	BALLASTS PER FIXTURE	BALLAST TYPE	FIXTURE POWER (W)	LAMP LIFE (HOURS)	TOTAL LAMP COST
1	2	40	T12	1	Magnetic	87	12000	R 35.00
2	3	40	T8	2	Magnetic	120	12000	R 40.00
3	2	13	CFL		N/A	26	12000	R 30.00
4	2	32	T8	1	Electronic	61	12000	R 40.00

The estimated energy conservation, EC, and energy cost savings, ECS, for replacement of the lamp/ballasts in a specific area are given by the following relations:

$$EC = \frac{N \times (CFW - PFW) \times H}{C_1}$$

$$ECS = EC \times \text{effective energy rate}$$

where,

- N = number of fixtures in area
- CFW = power rating of current fixtures in area, W
- PFW = power rating of proposed fixtures in area, W
- H = operating hours of lamp in area, h/yr
- C<sub>1</sub> = conversion constant, 1,000 W/kW

As an example, the estimated energy savings and energy cost savings for replacing all the 40W T-12 lamps and magnetic ballasts in the parking area with 32W T-8 lamps and electronic ballasts are calculated as follows:

$$EC = \frac{(82)(87 - 61)(8760)}{1,000} = 18,676.32 \text{ kWh/yr}$$

$$ECS = (18,676.32 \text{ kWh/yr})(10.68\text{c/kWh}) = \text{R}1994.63/\text{yr}$$

The energy conservation for reducing the operating hours of the T12-lamp is as follows:

$$EC = \frac{(82)(87)(8760 - 4380)}{1,000} = 31,246 \text{ kWh/yr}$$

$$ECS = (31,246 \text{ kWh/yr})(10.68\text{c/kWh}) = \text{R}3337.17/\text{yr}$$

Suppose the T12-lamps are replaced and the operating hours are reduced simultaneously then the total energy conservation amounts to 40,584.16 kWh/yr and energy cost savings of R 4 334.39 in total.

The following relations give the demand reduction, DR, and demand cost savings, DCS, associated with replacement of the lamp/ballasts in a specific area:

$$DR = \frac{N \times (CFW - PFW) \times CF}{C_1}$$

$$DCS = DR \times C_2 \times \text{effective demand rate}$$

where,

- CF = coincidence factor - probability that the equipment contributes to the facility peak demand, per month
- C<sub>2</sub> = conversion constant, 12 months/yr

Continuing the example above, the lights will likely be operating at their rated power when the peak demand is set each month, so CF = 1.0/month. Thus, the demand reduction and demand cost savings for the receiving area are calculated as follows:

$$DR = \frac{(82)(87 - 61)(1.0)}{1,000} = 2.13 \text{ kW/mo}$$

$$DCS = (2.13 \text{ kW/yr})(12\text{mo/yr})(\text{R}49.22/\text{kW}) = \text{R}1,259.24/\text{yr}$$

Energy conservation and demand reduction for lamp/ballast combinations in the other plant areas are given in Table 8. Energy cost savings, demand cost savings and total cost savings are given in Table 9.

**Table 8: Annual Energy Usage**

Level	Type of Lighting	Replacement light	Power	Number Of Fixtures	Power	Current Usage time	12-hour Usage time	Potential Demand Reduction	Current Energy usage	12-hour Energy usage
			(W)		(kW)	(h/yr)	(h/yr)	kW/mo	(kWh/yr)	(kWh/yr)
8	Fluorescent (T8)		120	35	4.2	8760	4380		36792	18,396
	Halogen Stream Lights		50	140	7	8760	4380	7	61320	30,660
	Compact Fluorescent		26	18	0.47	8760	4380		4099.68	2,050
7	Fluorescent (T8)		120	32	3.84	8760	4380		33638.4	16,819
	Halogen Stream Lights		50	65	3.25	8760	4380	3.25	28470	14,235
	Compact Fluorescent		26	28	0.73	8760	4380		6377.28	3,189
6	Fluorescent (T8)		120	50	6	8760	4380		52560	26,280
	Halogen Stream Lights		50	61	3.05	8760	4380	3.05	26718	13,359
	Compact Fluorescent		26	17	0.44	8760	4380		3871.92	1,936
5	Fluorescent (T8)		120	42	5.04	8760	4380		44150.4	22,075
	Halogen Stream Lights		50	62	3.1	8760	4380	37.2	27156	13,578
	Compact Fluorescent		26	20	0.52	8760	4380		4555.2	2,278
4	Fluorescent (T8)		120	54	6.48	8760	4380		56764.8	28,382
	Halogen Stream Lights		50	68	3.4	8760	4380	3.4	29784	14,892
	Compact Fluorescent		26	8	0.21	8760	4380		1822.08	911
Parking	Fluorescent (T12)	Fluorescent (T8) with Electronic Ballast	87	82	7.134	8760	4380	2.13	62493.84	31,247
Outside	Incandescent	CFL	100	105	10.5	8760	4,380	7.7	91 980	45,990
	<b>TOTALS</b>				<b>65.36</b>				<b>572 553</b>	<b>286 277</b>

**Table 9: Cost Reduction**

Level	Type of Lighting	Replacement Light	<sup>1</sup> Case 1	<sup>2</sup> Case 2			<sup>3</sup> Case 3		
			Energy Cost Reduction (ZAR)	Energy Cost Reduction (ZAR)	Demand Cost Saving (ZAR)	Total Cost Savings (ZAR)	Energy Cost Reduction (ZAR)	Demand Cost Saving (ZAR)	Total Cost Saving (ZAR)
8	Fluorescent (T8)		1964.69						
	Halogen Stream Lights		3274.49				6548.98	4134.48	10683.46
	Compact Fluorescent		219.86						
7	Fluorescent (T8)		1796.29						
	Halogen Stream Lights		1520.30				3040.60	1919.58	4960.18
	Compact Fluorescent		341.48						
6	Fluorescent (T8)		2806.70						
	Halogen Stream Lights		1426.74				2853.48	1801.45	4654.93
	Compact Fluorescent		205.82						
5	Fluorescent (T8)		2357.63						
	Halogen Stream Lights		1450.13				2900.26	1830.98	4731.24
	Compact Fluorescent		243.25						
4	Fluorescent (T8)		3031.24						
	Halogen Stream Lights		1590.47				3180.93	2008.18	5189.11
	Compact Fluorescent		98.23						
Parking	Fluorescent (T12)	Fluorescent (T8) with Electronic Ballast	3337.18	1994.63	1259.24	3253.87			
Outside	Incandescent	CFL	4911.73	7269.36	4589.27	11858.63			
	<b>TOTALS</b>		<b>30576.23</b>	<b>9263.99</b>	<b>5 848.51</b>	<b>15112.50</b>	<b>18524.25</b>	<b>11694.67</b>	<b>30218.92</b>

<sup>1</sup> Case 1: From the energy audit it was found that the lights are on 24 hours a day including weekends. Case 1 proposes that lights should be switch off after hours. The calculations are based on a 12-hour period for lights to be on.

<sup>2</sup> Case 2: Replace incandescent light fixtures and T-12 fluorescent lights with compact fluorescent lights and T-8 fluorescent lights respectively.

<sup>3</sup> Case 3: Switch off halogen lamps.

#### 5.1.4 Implementation Costs

##### Case 2:

The implementation cost for this recommendation includes the equipment and labour costs required for the new lamps. Labour costs for replacing the T-12s with T-8s are estimated at 6 minutes per lamp at a rate of R140/hour. The cost of the lamp is estimated at R40 each.

*Resulting Implementation Cost:*

$$\begin{aligned} &= 164 \text{ lamps} \times R40 + 6/60 \text{ hour} \times 164 \times R140/\text{hour} \\ &= R 6 560 + R 2 296 \\ &= R 8 856 \end{aligned}$$

Labour costs for replacing the 105 incandescent fixtures with 2 times 13 W compact fluorescent lamps per fixture are estimated at 6 minutes per lamp and 30 min per fixture at a rate of R140/hour. The cost of the lamp is estimated at R30 each and fixture R160.

*Resulting Implementation Cost:*

$$\begin{aligned} &= 105 \times 2 \times R30 + 6/60 \times 210 \times R140 + 105 \times R160 + 0.5 \times 105 \times R140 \\ &= R 6 300 + R 2 940 + R 16 800 + R 7 350 \\ &= R 33 390 \end{aligned}$$

It is reasonable to assume that lamps would be replaced as a matter of course in a maintenance programme and that all the replacement cost should not be borne by the energy efficiency exercise. An equal split between these two costs centres gives a

$$\underline{\underline{\text{Total Implementation Cost} = 0.5 \times (R 8 856 + R 33 390) = R 21 123}}$$

##### Case 3:

A labour cost for installing light switches is estimated at 1 1/2 hour per switch at a rate of R140 /hour. It is estimated that approximately 110 switches are required. The cost of the switch is estimated at R10.

*Resulting Implementation Cost*

$$\begin{aligned} &= 110 \times R10 + 110 \times 1.5 \times R140 \\ &= R 1 100 + R 23 100 \\ &= R 24 200 \end{aligned}$$

## 5.2 Adopt a Good Building Maintenance Strategy

Effective maintenance contributes to the realization of an energy efficient building by ensuring the efficient operation of systems and equipment. In addition it improves the useful life of the plant. The maintenance of the NER building requires a great deal of attention. The following is recommended to improve the maintenance of the building.

- Develop a maintenance policy. This should be co-ordinated with the support of top management.

- Consider good practice measures for reactive and planned preventative maintenance.
- If building maintenance is contracted out then the maintenance contract should include clear explanations of operational responsibilities and standards.
- The performance specification should include budgets, levels of service, responsibilities, reporting procedures and policies such as energy, health and safety.
- Monitoring maintenance is important to ensure value for money and to identify any changes in the policy that need to be made.

A maintenance strategy is not an additional cost item. It is a discipline that ensures that sufficient correct procedures are carried out timeously to protect an expensive asset.

### **5.3 Implement a Building Management System**

Estimated Electric Energy Conservation	= 250 – 500 000 kWh/yr
Estimated Electric Energy Cost Savings	= R 27 – 54 000/yr
Estimated Electric Demand Reduction	= 548.4 kW/yr
Estimated Electric Demand Cost Savings	= R 26 992.25/yr
Estimated Total Cost Savings	= R 54 – 108 000/yr
Estimated Implementation Cost	= R 300 000
Simple Payback	= 5.55 – 2.78 years

A building management system (BMS) can significantly improve the overall management and performance of the building, promoting a holistic approach to controls and providing operational feedback. Energy savings of 10–20%<sup>[4]</sup> can be achieved by installing a BMS compared with independent controllers for each system.

The monitoring facilities of a BMS allow building status, environmental conditions and energy to be monitored, providing the building operator with a real-time understanding of how the building is operating. This can often lead to the identification of problems that may have gone unnoticed, for example, high energy usage. Energy meters connected to the BMS system allow real-time energy consumption to be monitored and tracked. This provides a historical record of the building's energy performance that can be logged and analysed as required both numerically and graphically.

The BMS can improve management information by trend logging performance, benefiting forward planning and costing. This can also encourage greater awareness of energy efficiency among staff.

Alarms are also monitored providing instantaneous indications and records that the plant (HVAC) has shut down, maintenance is required, or environmental conditions are outside specified limits.

BMS that integrate security, access control and lighting control are now available. These can, where appropriate, reduce the total cost of incorporating a range of services and hence assist to justify additional cost.

A building management system can cost between R 50 000 and R 100 000, depending on the functionality required.

#### 5.4 Upgrading and Tuning HVAC Controls

Estimated Electric Energy Conservation	= 380 476.80 kWh/yr
Estimated Electric Energy Cost Savings	= R 40 634.92/yr
Estimated Electric Demand Reduction	= 822.6 kW/yr
Estimated Electric Demand Cost Savings	= R 40 488.37/yr
Estimated Total Cost Savings	= R 81 123.29/yr
Estimated Implementation Cost	= R 75 000
Simple Payback	= 0.92 years

Important control functions are listed below.

- Time Controls:
  - Set time switches in relation to occupancy and use of the service.
  - Introduce time switches on energy using equipment as required.
- Plant capacity controls:
  - Introduce sequence controls where appropriate and check that the sequence selection of the heaters and chillers provides a minimum output matched to the load.
  - Introduce standard controls to reduce excessive plant cycling.
  - Introduce variable speed drives where appropriate for central plant fans and pumps.

##### 5.4.1 Background

The choice of controls has a direct effect on the operation and energy consumption of a building. Pneumatic controls were used widely in large buildings until the early 1980s. At that time they could provide relatively complex control strategies at low cost. They are still common, however with recent applications they are likely to have been replaced.

In the case of the NER building little or no controls exist. The potential energy savings of between 15–25%<sup>[4]</sup> can be obtained if proper controls are installed within the building.

#### 5.5 Air Conditioning System

The condition of the system is such that an energy audit is not possible. The control philosophy is not known and can only be assumed. In addition, lack of operation of the chillers and other elements in the plant room mean that the building has, in all probability, been operating *below* its expected energy consumption, despite a control system that is clearly not providing energy efficient operation.

However, we must point out that the VAV system is potentially a very energy efficient central system and would readily lend itself to fine-tuning to bring about still more efficiency if this has not been built in from the start.

The CSIR and Richard Pearce & Partners have indicated that a standard building in the Gauteng region would have a design cooling load of around  $100\text{W/m}^2$  while an energy efficient one would be approximately  $80\text{W/m}^2$ . Preliminary calculations for the Vermeulen Street building result in a cooling load of close to  $90\text{W/m}^2$ , indicating the inherent good qualities of the building and its system. A good control system would translate this power requirement into economical energy operation.

It is recommended that an experienced consulting engineer be appointed to evaluate the HVAC system, including the controls. The engineer should be asked to provide a design and costs for repair and upgrade, with due regard for energy efficient operation.

### **5.6 Domestic Hot Water Heating**

The hot water to the taps is currently supplied from an electrically heated storage vessel in the basement. The electrical energy appears to be available at all times, i.e. there is no arrangement to heat the water with a cheap night tariff.

The capacity of the vessels appears to be in excess of 1000 litres, which is much more than that needed by 100 office staff. The latest tariff option for night operation is 6.36 cents per kilowatt-hour, or 60% of the day rate. In addition, the Tshwane tariff rules give them the option to impose a conversion charge, should their study confirm a financial gain to the customer, and there is an increase of tariff to 24.38 cents per kilowatt-hour during the hours 07.00 to 10.00. The fans and pumps operating during this time require more than 100 kW.

British Gas research shows that office workers require approximately 10 litres of hot water each per day, excluding catering. One hundred people drawing this volume for 250 working days per year would require 250 000 litres per annum. This costs approximately R1500 per year and is not worth considering further since much more would be lost on operating fans and pumps during the high rate period.

### **5.7 Variable Speed Drivers**

The major fans are of the variable speed type while the compressors load and unload according to the capacity requirements induced by the weather. Exhaust and extract air fans are required to run at a constant speed which leaves only the secondary chilled water pump (15 kW) and the condenser water pump (18.5 kW) as possible opportunities for variable speed drives. Taken together these motors would absorb less than 400 kWh per day, or less than 80 000 kWh per year. A 20% reduction in energy would amount to about R 1 700 saving per year, an insufficient amount to consider changing motors before they fail.

## **6. COMFORT AUDIT**

Personnel comfort plays an integral role in the productivity levels of any company. Comfort in itself is described as the state in which the average person expresses satisfaction with the working environment. The field of ergonomics focuses a great deal on personnel comfort. In

particular, poor indoor conditions are one of the main contributors of Sick Building Syndrome (SBS). The World Health Organisation (WHO) defines this as “ailments that are suffered while people are inside a particular building and which eases as they leave”.

A building is the cause of SBS if many of the occupants experience one or more of the following symptoms: headache, runny nose, fatigue, eye irritation, difficult breathing, sinus problems, congestion, sneezing, nausea, sore throat and stuffy smells.

These symptoms are the result of one or a combination of factors such as inadequate indoor air temperatures, inadequate relative humidity levels, poor indoor air quality, and insufficient lighting. Other factor such as work stress and personal problems can also contribute to these symptoms. It is therefore necessary to take measurement in order to assess indoor comfort levels.

Personnel comfort is an ancillary of an energy audit and for the above reasons it is seen fit to include it as part of this building energy audit. A quantitative approach was adopted to asses comfort levels within the building. This included the distribution of a questionnaire and other appropriate measurement of the indoor light intensity levels and temperatures.

## 6.1 **Results**

Questionnaires (see Appendix 10.4) were distributed to all staff members with a total head count of 88. A total of 35 questionnaires were returned which amounts to approximately 40%. Of these 60% were returned by female staff members and 40% by male staff members.

### 6.1.1 **Indoor Temperatures**

The results from the questionnaire with respect to indoor temperatures experienced by staff members are reflected in Table 10 below. Relative to the day the questionnaire was distributed it is found that 51% found the indoor temperature to be hot, 31% found it to be acceptable 11% indicated that it is hot and cold, and 7% found it to be cold. The 11% that indicated that it was both hot and cold, said that it was hot in summer and cold in winter. This is in line with the expected outcome if the study were to be conducted for each season.

The actual measured temperatures (Table 11) ranged from 25°C at noon to 27°C at approximately 15h00. This is above the generally accepted comfortable indoor temperature range of between 22°C and 24°C.

**Table 10: Comfort Audit - Temperature**

	<b>COLD</b>	<b>HOT</b>	<b>BOTH</b>	<b>ACCEPTABLE</b>
Female	0	13	1	7
Male	2	5	3	4
Total	2	18	4	11
Percentage	7%	51%	11%	31%

**Table 11: Measured Temperatures**

	<b>TEMPERATURE (°C)</b>	<b>TIME</b>
External Shade Air Temperature	22°C	12:15
External Shade Air Temperature	22°C	15:10
6 <sup>th</sup> Floor Room	25°C	12:25
6 <sup>th</sup> Floor Supply Air	24°C	12:25
6 <sup>th</sup> Floor Supply Air	26°C	13:00
8 <sup>th</sup> Floor Room	25°C	13:10
8 <sup>th</sup> Floor Room	27°C	14:55

### 6.1.2 Relative Humidity

Humidity gives an indication of the moisture level of the air. It is found that humidity levels below 40% are associated with bacteria growth, respiratory infections and increased allergic reactions. Humidity levels above 60% cause an increase in mould, dust mites, allergic reactions and chemical interactions. The humidity comfort zone is set between 40% and 60%.

From Table 12 below it can be seen that 46% experience the air to be dry and 40% found the humidity acceptable.

**Table 12: Comfort Audit - Humidity**

	<b>DRY</b>	<b>ACCEPTABLE</b>	<b>HUMID</b>
Female	11	8	4
Male	5	6	1
Total	16	14	5
<b>Percentage</b>	46%	40%	14%

### 6.1.3 Light Intensity Levels

Almost 80% of our sensory information at work is through our eyes. It is therefore necessary to have good lighting. The lighting intensity must be around 300 to 500 Lux. From Table 13 below it can be seen that 89% of the building occupants find the lighting level acceptable.

From the measurements it can be seen that the light intensity within the building is above that normally recommended. This is also true for the case where all the blinds are closed and all lights are switched off. Table 14 gives the measured values under different conditions.

**Table 13: Comfort Audit - Lighting**

	<b>DIM</b>	<b>ACCEPTABLE</b>	<b>BRIGHT</b>
Female	0	18	3
Male	1	13	0
Total	1	31	3
<b>Percentage</b>	2%	89%	9%

**Table 14: Light Intensity Measurements**

<b>DISTANCE FROM WINDOW (M)</b>	<b>LIGHT INTENSITY (LUX) UNDER LIGHT FIXTURE BLINDS CLOSED</b>	<b>LIGHT INTENSITY (LUX) UNDER LIGHT FIXTURE BLINDS OPEN</b>	<b>LIGHT INTENSITY (LUX) BETWEEN LIGHT FIXTURES BLINDS CLOSED</b>	<b>LIGHT INTENSITY (LUX) BETWEEN LIGHT FIXTURES BLINDS OPEN</b>	<b>LIGHT INTENSITY (LUX) BLINDS OPEN LIGHTS OFF</b>	<b>LIGHT INTENSITY (LUX) BLINDS CLOSED LIGHTS OFF</b>
1	780	>1000	500	>1000	>1000	>1000
1.8	720	>1000	420	>1000	>1000	>1000
4.5	400	760	500	640	640	380

#### 6.1.4 Air Movement

The air movement within the building plays an important role in maintaining thermal comfort as it influences the rate of evaporation on the skin of occupants. Air movement that is too high causes unpleasant draughts. Acceptable airflow rates for office buildings are between 4 to 6 l/s/m<sup>2</sup>. Table 15 below shows 80% of the building occupants found the airflow to be low. This is in line with the results with regard to lack of fresh air where 77% of the occupants found that there is a lack of fresh air, as detailed in Table 16.

**Table 15: Comfort Audit - Air Movement**

	<b>LOW</b>	<b>ACCEPTABLE</b>	<b>HIGH</b>
Female	19	2	0
Male	9	4	1
Total	28	6	1
<b>Percentage</b>	80%	17%	3%

**Table 16: Comfort Audit - Lack of Fresh Air**

	<b>YES</b>	<b>NO</b>
Female	16	5
Male	11	3
Total	27	8
<b>Percentage</b>	77%	23%

## **7. DISCUSSION, RECOMMENDATIONS AND FURTHER ACTIONS**

The calculations in this report are based on estimated costs from know reputable suppliers. They do not reflect amounts tendered in competition against detailed specifications and it is therefore recommended that, before any of these energy conservation opportunities are implemented, actual quotations from different relevant companies be obtained to establish actual implementation cost.

In particular for the maintenance and upgrading of the HVAC, controls and building management system it is recommended that a suitably experienced consulting engineer be appointed to cost and design improvements with due regard to energy efficiency.

For the replacement of lights, light fixtures and additional switches it is further recommended to get quotations from an electrical company or to renegotiate contract with the current company responsible for the renovations.

Budgets might already exist for the implementation for some or all of the ECO's via the renovation budget. Thus before requesting funding for the implementation phase, make sure that possible available funds do not exist.

Clearly the current building renovation plan plays a vital role in the future building upgrade plan. It is therefore important to communicate the current energy efficiency opportunity findings with the renovators.

Our research has shown a significant lack in useful data for rapidly benchmarking building energy use. It is recommended that the DME extend this study to develop a comprehensive database of buildings throughout the country, which can be used to quantify energy consumption. The findings can be evaluated to produce a set of "best practice" notes for building professionals.

Unfortunately the NER building is not yet in a state where it can be used as a model. However, as has been mentioned, the basic building and system are reasonably sound and would be suitable for repairs that would demonstrate energy efficient techniques.

Levels 2 and 3 need immediate attention to the HVAC system to prevent wasteful discharge of conditioned air to the unoccupied offices, as well as via broken horizontal ducts and vertical risers.

We recommended, as a first and early step, that an appropriately experienced consulting engineer be engaged to evaluate the HVAC system and detail proposals for repair with due regard for energy efficiency.

Section 5 details the energy conservation opportunities that should be investigated. The savings and costs are summarized in Table 1 in the Executive Summary. Derived and calculated energy key figures are shown below in Table 17.

**Table 17: Derived and Calculated Energy Key Figures**

<b>SERVICE</b>	<b>kWh/person-yr</b>	<b>kWh/m<sup>2</sup>-yr</b>
HVAC	5710	134
Lighting	4688	110 [27 – 54]
Small power	1918	45 [23 – 31]
Hot water	639	15 [4 – 10]
<b>OVERALL</b>	12 955	304 [258]

The figures in square brackets [...] are from Section 1. It can be seen that, if the lights were switched off for half the day, then the overall figure would be very close to the monitored figure for the similar nearby building. The estimate for small power is admittedly high in an attempt to be conservative. We believe that, with well controlled lighting and HVAC, the building and services as designed would achieve better than average energy consumption, thereby bearing out our early assessment of the building.

Finally, if energy consumption does not have a responsible person (“champion”), then it will soon be disregarded. We recommend the appointment of an Energy Management Officer whose function would be the active promotion and maintenance of energy efficient practices.

## **8. REFERENCES**

- [1] Energy Consumption Guide 19, Energy Use in Offices, Energy Efficiency Office, Best Practice Programme, UK, 2000.
- [2] <http://www.tshwane.gov.za/muninfo/electricity/tariffs.pdf>
- [3] Industrial Assessment Centre programme, University City Science Centre, Philadelphia, USA.
- [4] CIBSE Guide F, Energy Efficiency in Buildings, September 1998.
- [5] Department of Minerals and Energy, Report No. ED9501, September 1996.

## **9. BIBLIOGRAPHY**

- (a) North American Measurement And Verification Protocol, US Department Of Energy, 1996
- (b) Energy Savings Potential and Guidelines for Effective Energy Use in Office Buildings, Report Number ED9309, Department Of Minerals and Energy, 1997.
- (c) Good Practice Guide 287, The Design Team’s Guide to Environmentally Smart Buildings, Energy Efficiency Office, Best Practice Programme, UK, 2000.
- (d) <http://www.energy-efficiency.gov.uk/>

## **10. APPENDICES**

### **10.1 Methodology**

A consistent systematic approach was adopted and implemented by using the guidelines as set out by the CIBSE and DME studies.<sup>[4,5]</sup>

#### **10.1.1 Principles of Energy Efficiency**

An energy efficient building provides the required internal environment and services with minimum energy use in a cost effective and environmentally sensitive manner.

#### **10.1.2 Managing the Building**

The energy used by a building is determined by three factors, namely, the building fabric, building services and, most importantly, the management of the building. Management of the building is normally underrated. The reason for its importance is that it has a direct impact on the day-to-day energy consumption. The key to energy efficient management is to:

- Gain a sound understanding of how the building is meant to work, both at a strategic and at a detailed level.
- Set out a clear energy management policy alongside a clear maintenance policy for the building and its services.
- Involve both management and occupants in the process. That is, arrange organizational structures to ensure that responsibilities are clear, regular reporting or feedback as appropriate, and necessary resources are made available.
- Encourage and reward occupants to use the building correctly and motivate them to reduce energy consumption.
- Set energy targets and continually monitor performance in order to keep consumption under control.

#### **10.1.3 Retrofitting Energy Saving Measures**

##### ***Planning:***

First, a fully costed plan of action should be produced. Thereafter agreement should be obtained to proceed with the entire programme or in stages. The action plan should include

- Preparation of a more detailed energy audit and building survey.
- Identification of measures where energy savings could be made.
- The effects of energy saving measures on the internal environment and activities within the building.
- Cost-benefit assessment of proposed measures.
- A list of priorities for the proposal.

##### ***Identifying or surveying:***

An energy audit is an attempt to allocate a value to each item of energy consumption over a given period, and to balance these against overall energy use. The survey should cover the main items affecting energy use, including the following

- The building: levels of insulation, ventilation, air infiltration etc.

- The pattern of use: periods of occupancy, the types of control, the temperature and humidity maintained, the use of electric lighting, the activities and processes being undertaken, including their operating temperatures, insulation etc.
- The main building service: primary heating, cooling and air handling plant.
- Electric lighting: quality, luminance, luminaire efficiency, extent to which daylight could reduce energy use, flexibility of control etc.
- The transport of energy within the building: fans and pumps, insulation of hot water and steam pipes and air ducts, evidence of leakage etc.
- The plant room: state and condition, insulation of boilers, tanks, pipe work, recovery of condensate, plant efficiency checks etc.

***Measurement and calculation:***

Good instrumentation and measurement is an essential part of investigating and implementing retrofit measures. Portable instrumentation is the best option.

***Assessing Measures and savings:***

It is important to consider all the possible available options before making a change to an existing system. This is particularly important where major investments are involved, such as replacing of chillers. A full option appraisal will ensure that the most cost-effective and efficient plant is chosen. The option appraisal can provide a number of benefits such as:

- Correct sizing of the plant to meet real demands of the building may lead to lower capital cost.
- Lower running costs through increased levels of control taking account of the needs of staff.
- Improved comfort levels through increased levels of control taking account of the needs of staff.
- Higher environmental standards by considering the environmental benefits of each option.
- A formal justification for the recommendation made, including a well researched fallback option in case management rejects the recommendation.

#### **10.1.4 Specific Energy Saving Measures**

***Controls:***

Upgrading of the controls is often the single biggest improvement that can be made to enhance the energy efficiency of existing buildings. It should be noted that well-designed building services would perform badly if controls are inadequate, incorrectly installed or misunderstood by the building operators. Many problems with building services can be traced back to poor control of the systems.

***HVAC:***

Ventilation is often responsible for the largest energy loss in well-insulated buildings. Therefore it offers significant scope for retrofit energy saving measures.

**Refrigeration:**

Cooling of buildings is generally required for only parts of the year. It is often found that the plant is operating unnecessarily or inefficiently to supply small loads. Thus significant energy saving potential exists in upgrading the refrigeration system and controls, or installing smaller plant to serve such loads.

**Lighting:**

In most buildings, lighting is a significant component of the electrical consumption. In the case of offices it is normally the biggest energy cost, after the air conditioning. Upgrading lamps, luminaires, ballasts and lighting controls, can reduce the energy consumption of the lighting.

**Motors and Transportation Systems:**

Significant energy savings can be realized by upgrading motors and motor controls. Particular options for motors are as follows

- Higher efficiency motors should always be considered as they often have no additional capital cost and offer efficiency and economic benefit in virtually all situations.
- Motors should be sized correctly to avoid the increased losses resulting from part-load operation.
- Use direct drives rather than belt drives where practicable.
- Where belt drives are used, consider modern flat, synchronous, or ribbed-belt drives rather than traditional V-belts, to reduce drive losses.
- Systems should be carefully designed to minimize pressure loss and hence reduce energy consumption.
- Efficient system regulation, achieved by matching fan and pump characteristics to the system, normally by means of speed change, can provide significant energy savings compared with increased system resistance. Energy savings are typically 20% for 10% flow regulation and 40% for 20% regulation.
- Variable flow control can provide significant opportunities for energy saving. Building services are designed for peak loads and, for most of their working life, operate well below their full output. Typically 20% of full volume energy is required to move air and water at 50% of maximum volume.
- The use of variable speed drives should always be considered for efficient system regulation and variable flow.

**General electrical power measures:**

Small power loads are an increasingly significant component of the total energy use in buildings. In particular, they have an important effect on the energy consumed in air conditioning and can influence the need to upgrade air conditioning due to increased internal heat gains. General electrical power measures can be achieved by:

- Reducing energy consumption of small power loads
- Reducing cooling loads
- Information technology measures

### **10.1.5 Monitoring and Targeting**

Good monitoring and targeting should aim to:

- (i) Establish current consumption.
- (ii) Compare current consumption with historical data and benchmarks
- (iii) Set future targets.
- (iv) Compare current consumption with targets
- (v) Identify trends in consumption

Quick action is required where consumption is abnormal or excessive.

### **10.1.6 Maintaining the Savings**

Following the implementation of energy saving measures, post project evaluation is desirable to establish that measures have been correctly installed and are achieving the predicted savings. Note that small measures may require only a cursory check but larger projects, for example those involving combined heat and power, require a thorough assessment.

Evaluations should establish:

- (i) Actual savings
- (ii) Final capital cost
- (iii) Impact on occupants
- (iv) Management implications
- (v) Maintenance issues
- (vi) Other benefits achieved
- (vii) Practical pitfalls

It may be possible to compare actual savings with the savings achieved in published case study material.

### **10.1.7 Environmental Impact**

Man-made greenhouse gasses, released into the atmosphere, are disturbing the natural balance resulting in rising global temperatures. Unless action is taken now, the emission of greenhouse gases through man's activities will increase and accelerate the rise of global temperatures. The following steps are recommended to reduce global warming:

- (i) Consider the relative merits of alternative energy sources in the light of their greenhouse gas emissions.
- (ii) Advise clients and the professional team on the selection of the best design solution for energy efficient structures, plant and systems using environmentally friendly resources.
- (iii) Advise clients on modifications to existing plant to incorporate developments with improved performance.
- (iv) Review operating and maintenance procedures to limit progressive deterioration of plant performance and building conditions.
- (v) Examine standard specification and remove features now recognised as hazards.
- (vi) Remain vigilant to the possibilities of eliminating chlorofluorocarbons.
- (vii) Promote the use of air conditioning only where necessary.

- (viii) Optimise building orientation, form, façade design, thermal insulation and passive energy utilisation to conserve energy.
- (ix) Consider all the available alternative energy sources.
- (x) Specify efficient plant, accurately sized for the optimum duty.
- (xi) Design buildings for good access to plant for maintenance.
- (xii) Recognize opportunities for using combined heat and power generation plant.

## 10.2 Tshwane Metropolitan Municipality Electricity Tariffs

The electricity tariffs for an 11 kV supply scale as of 1<sup>st</sup> of July 2002 is as follows:

- (i) A fixed charge whether or not electricity is consumed, per metering point R 307,40.
- (ii) A demand charge per kVA of half-hourly maximum demand provided that the amount payable in respect of the maximum demand in any month will not be less than the prevailing tariff multiplied by 70% of the highest demand recorded during the preceding twelve months. R 49,53
- (iii) An energy charge for all kWh consumed since the previous meter reading, per kWh of 11.08 c,
- (iv) Provided that in the case of a consumer who is not supplied with electricity under the Off-peak Supply Scale, the said energy charge will be reduced if the average daily consumption in any month is equal to or greater than 13 kWh per kVA of the maximum demand in that month, to 10.28 c
- (v) Maximum energy charge if the sum of the demand charge and the energy charge, divided by the total kWh consumed during the month, is more than 59.36c/kWh, the consumer will pay a constant energy rate only, for all kWh consumed since the previous meter reading, per kWh 59.36 c.

## 10.3 Comparative Evaluation: Incandescent and Compact Fluorescent Lamps

	12 WATT COMPACT FLUORESCENT LAMP	60 WATT INCANDESCENT LAMP
<b>Basic Information:</b>		
Unit Cost	R 56.50 /lamp	R 2.20 /lamp
Expected Life	10 000	1 000
Energy Rating	12 Watts	60 Watts
<b>Consumption:</b>		
Energy Consumption (Life)	120 kW hours	60 kW hours
Energy Tariff (R/kW hour inclusive VAT)	R 0.25 / kW hr	R 0.25 / kW hr
<b>Cost:</b>		
Energy Cost (Total over expected life)	R 30.10	R 15.05
Total Cost (Total over expected life)	R 86.60	R 17.25
Total Cost per 1000 hours	R 8.66	R 17.25
<b>Emissions:</b>		
Greenhouse Gas Equivalent, kg per 1000 hours (CO <sub>2</sub> kg)	21.53 kg	107.63 kg
Acidification Equivalent, kg per 1000 hours (SO <sub>2</sub> kg)	0.09 kg	0.46 kg
Carbon particulate, grams per 1000 hours	8.20 g	41.01 g

[Source: Green Buildings for Africa]

