

THE IMPACT OF
ENERGY CONSERVATION
ON THE
MANAGEMENT AND ADMINISTRATION
OF BUILDINGS

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Submitted to the University of Cape Town in partial fulfillment of the
requirements for the degree of Master in Industrial Administration.

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I, Stephen Carlin, submit this thesis for the degree of Master in Industrial Administration.

I claim that this is my original work and that it has not been submitted for a degree at any University.

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ABSTRACT

Rapidly rising energy prices have focussed attention on the operating costs of commercial buildings. In order to minimise energy use in new and existing buildings, an effective Energy Management Programme must be implemented.

Any Energy Management Programme should not conserve energy at the expense of a lowering of comfort standards and subsequent complaints from occupants. The comfort conditions are determined largely by the lighting and air conditioning systems, which are the two main users of energy in buildings.

A hypothetical model building was chosen as the base against which to evaluate measures to conserve energy. This building was based upon a typical modern South African commercial building. As the services systems on buildings are usually quite complex, the performance of each sub-system as well as the interaction between them was analysed using a systems engineering approach.

To this end, a comprehensive checklist of energy conservation measures was compiled and analysed. These measures include modifications and improvements to the illumination, air conditioning and hot water systems, as well as to the building itself. In addition, measures are proposed to ensure efficient maintenance and operation of these systems.

Energy surveys were carried out on several buildings using the Energy Management Programme guidelines. A comprehensive questionnaire was developed to assist in collecting only the most relevant information. The survey revealed that the standard of operation of many buildings was very poor and that energy was being needlessly wasted. Operators were inadequately trained, the operating instructions were not suited to them and there was very little supervision and monitoring of their tasks.

It was found that implementation of the energy conservation measures would generally result in the expected savings. On some buildings the cost of the modifications would result in a long payback period due to the existing building design. The guidelines would naturally be most effective if considered during the design of new buildings.

The analysis of the buildings surveyed indicated that considerable scope exists in South Africa for energy economy and efficiency in building design and operation. The wasteful situation that has generally prevailed due to the uncontrolled use of previously cheap energy should be reappraised as rising energy prices have more influence on building management and administrative methods.

CHAPTER ONE

INTRODUCTION

1.1 ENERGY

Energy, until recently, has been regarded as inexhaustible and expendible, as most forms of energy have been inexpensive and readily available.

Most modern commercial buildings have typically been designed and constructed on an initial-cost basis, without adequate consideration as to the life-cycle operating and maintenance costs.

This had led to the erection of many energy wasteful buildings.

1.1.1 Energy Sources

The main source of energy used today is fossil fuels. Although other sources are available or are developing on a smaller scale, (and in many cases, on a long term basis), at the current rate of consumption energy derived from fossil fuels will be exhausted before the end of the next century.

Thus the immediate challenge facing man is to make better and more economical use of energy, i.e. to minimize its use.

The world as a whole relies on oil for almost 50% of its total energy requirements, with oil and gas together accounting for 67%. In South Africa, coal or coal derived fuel accounts for about 75% of the primary energy, the remaining 25% being imported oil.⁽¹⁾

1.2 DESIGN OF BUILDINGS

Before the advent of air conditioning, large buildings were usually designed with courtyards and long and narrow office blocks. In these instances, to obtain ventilation in working areas, single width offices on either side of a central corridor were provided. Consequently, these buildings occupied large areas of land.

The introduction of air conditioning systems allowed the building shape to change. Large buildings became square or rectangular in shape, and had large facade areas, which were often glass-covered.

Air conditioning systems had to cope with a complex seasonal situation. In summer, an additional heat load was imposed by the office equipment, and in winter the interior zones had to be cooled rather than heated. Also, due to the glass facades, a perimeter area could change from a heating to a cooling requirement when the sun shone.

In order to cope with these problems, air conditioning engineers developed fresh-air supply systems that can either heat or cool. These systems consume a large amount of energy in a complex situation that is a function of the weather, the time of the year and the use of the space by the occupants.

It has been estimated that in European countries between 40%-50% of all energy is used for controlling the environment in buildings.⁽²⁾ This energy is mainly used for heating, cooling and lighting. Comparable values for South Africa are not available, but considering that South African buildings do not generally have the same heating requirements as their European counterparts, a reasonable estimate of the value of the total energy consumed in buildings is 20%-30%.

1.3 COST OF ENERGY

Energy costs have been increasing over the past few years, and building owners have been particularly severely affected.

Figure 1.1 shows the cost of crude oil for the period 1971 - 1975.

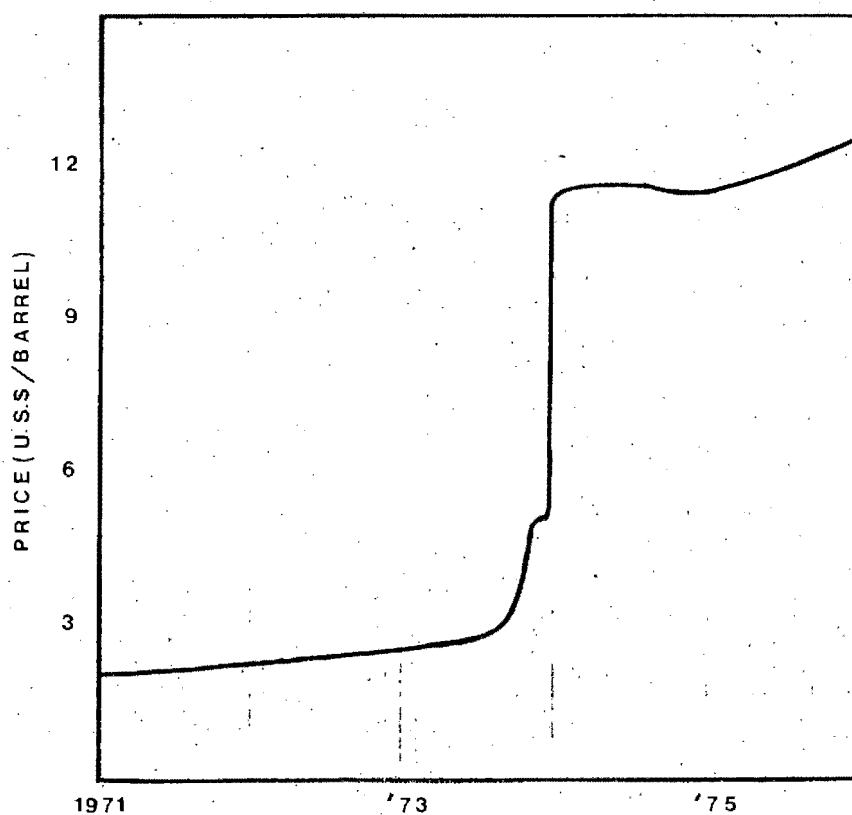


FIG. 1.1 : Price of crude oil 1971 - 1975

Although the Yom Kippur war of 1973 was the main cause of the "energy crisis", it is also argued that oil was underpriced in the past, and that the higher current prices reflect the real value of this form of energy.

Figure 1.2 shows the relative value of oil and gas compared to the general price inflation for the period 1961 - 1972.

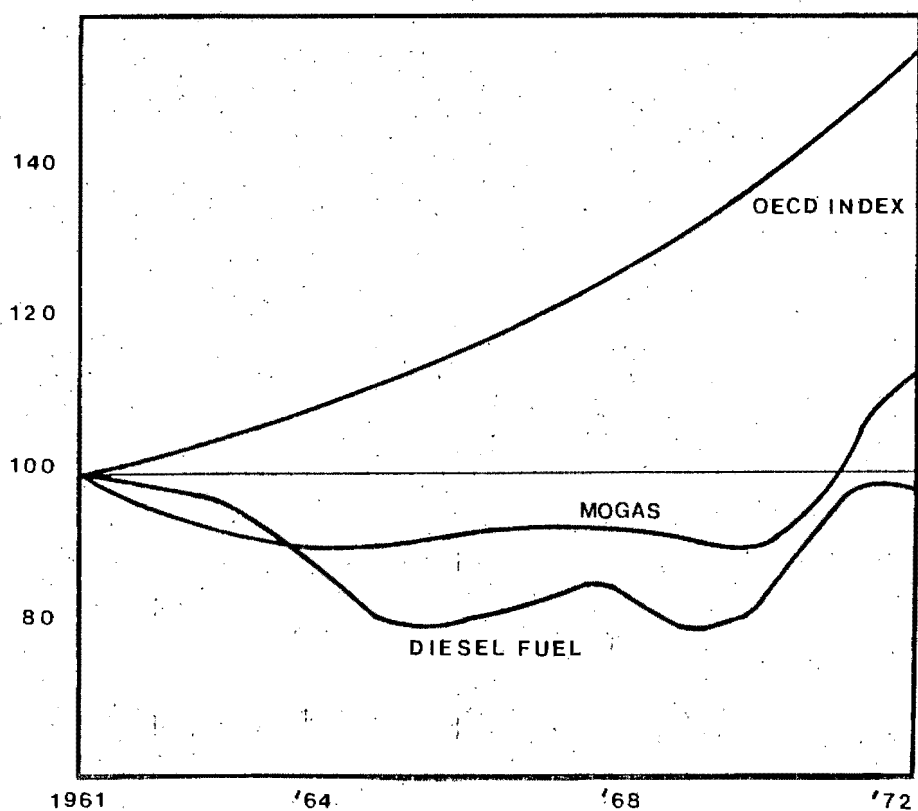


FIG. 1.2 : Price trends for main oil products with the OECD GNP deflation index as a crude indicator of general price inflation⁽³⁾

According to figures compiled by the Department of Planning, the price of electricity in South Africa is amongst the lowest in the world.

The average price of electricity from various supply authorities expressed as a percentage of 1977 Escom prices is shown below :

French Power Corporation	500%
Tokyo Electricity Power Corporation	420%
Electricity Council England and Wales	310%
State Electricity Council Queensland (Australia)	290%
Central Electricity Generating Board (U K)	240%
Nova Scotia Power (Canada)	230%
British Columbia Hydro and Power (Canada)	230%

It is possible that in future Escom will be forced to charge for electricity at the same rate as overseas supply authorities. This would mean rapid and large increases in cost within a few years.

This trend appears to be developing at present, as is evident from the curve of Figure 1.3 overleaf, which shows the cost of Escom electricity for the period 1950 - 1977.

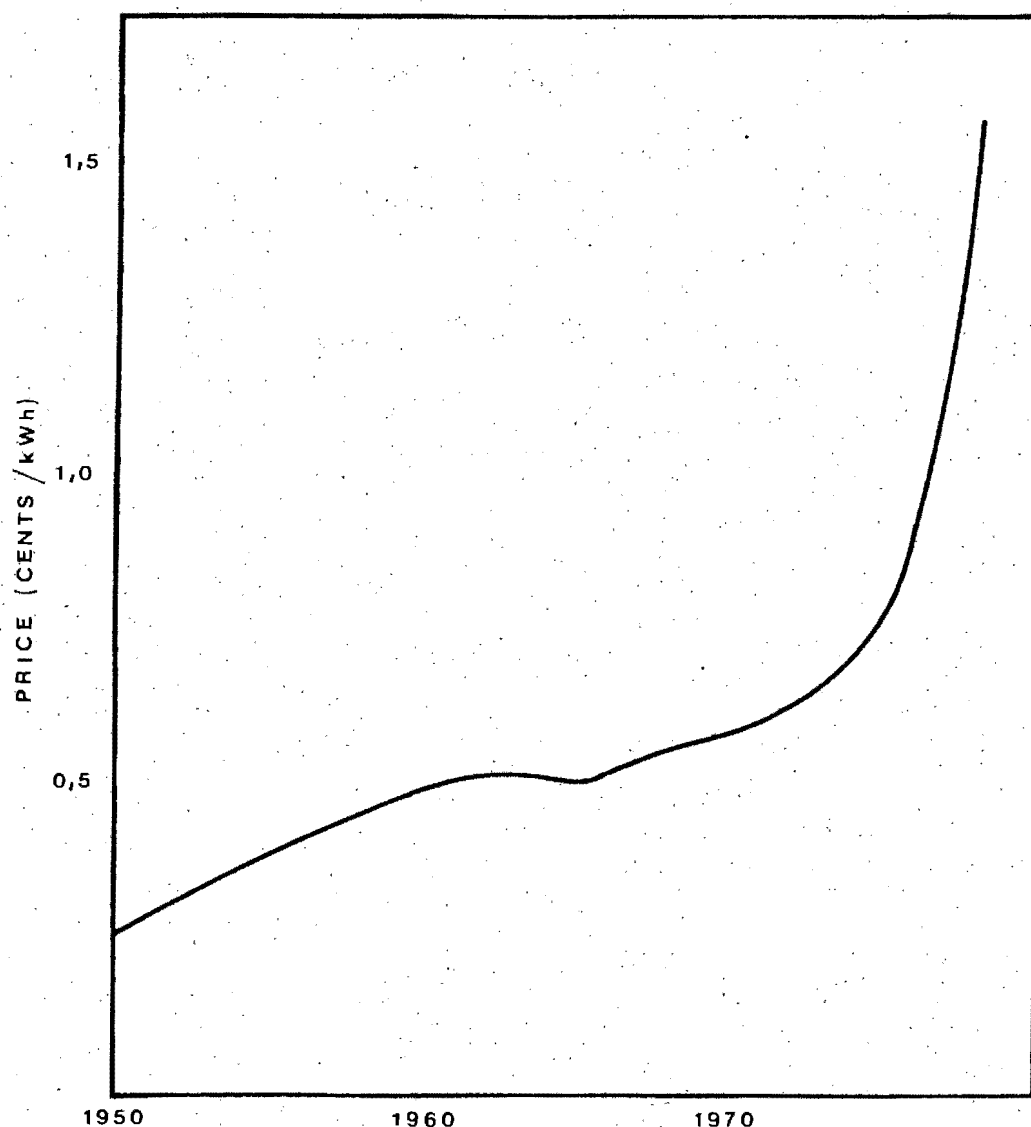


FIG. 1.3 : Cost of Escom Electricity 1950 - 1977⁽¹⁾

The installed capacity of the Escom grid in 1974 was 13.435 MW, and a total of 70.808 GWh was generated.

An increase of 20% in the number of units generated would add approximately R500m to the overall energy bill at today's costs.

1.4 FACTORS AFFECTING ENERGY COSTS IN BUILDINGS

1.4.1 Load Factor

A significant factor which has led to rising electricity tariffs has been the load factor of South African buildings. Load Factor is the ratio of average to peak demand supplied by the electricity authorities and is approximately 0,4 on many commercial office buildings.

A low load factor requires new generating facilities to be constructed to meet the peak load, but without adding proportionately to the revenue derived from the sale of energy.

1.4.2 Maximum Demand

Most large consumers are metered on a maximum demand plus energy consumption basis.

The maximum demand (usually measured in kVA) is the peak average consumption reached during a metering period. The metering period is usually between 15-30 minutes. The energy consumption is the straight forward units consumed (kWh)

Depending on the load factor of the building, considerable scope may exist to save costs without actually conserving energy. A low load factor implies that the energy consumption is occurring at an irregular and non-uniform rate. By varying the hours of operation, possibly with automatic controls, the consumption rate may be spread out more and the maximum demand will thus be reduced, leading to cost savings.

Conversely, the maximum demand can rise sharply due to inadvertent circumstances without a corresponding increase in units consumed, resulting in an unexpected increase in cost.

The maximum demand curve of an office building during working hours is practically flat, apart from the cooling and heating loads, as there is little variation in the loads of lifts, lights, water heaters, or of the air conditioning ancillaries such as fans and compressors. Therefore, those components of air conditioning load which react to varying conditions, i.e. cooling and heating plants, are the main variables affecting the cost of energy.

The following further points should also be borne in mind :

- a) If any of the non-variable or "base" load components mentioned above could be permanently reduced without repercussions, this would automatically reduce the maximum demand by lowering the "base line" above which the variable components rise. This approach can apply particularly to the air conditioning ancillaries.
- b) The maximum demand of the cooling plant (water chiller, pumps and cooling tower fans) does not vary in a linear manner with the cooling load. This demand will naturally be 100% at full load, but only decrease to approximately 50% at the lowest load (15-20%) which the chiller can achieve continuously. If the cooling load is below that level, the chiller will "cycle", i.e. stop for 20 to 30 minutes and then restart, and it will then initially assume the maximum capacity for which it has been pre-set manually.

In this manner, whilst the cooling load is only 10% of maximum capacity, one could easily get a maximum demand reading of 75% of full load of the cooling plant which would, under the conditions described (small need for cooling) coincide with a high heating load.

- c) The response of the maximum demand meter installed by the Authority is normally not linear. For example, a load of 100 kVA working during 15 minutes will give a higher reading than would 50 kVA acting during a full 30 minute metering period, and this effect worsens that described in (b).
- d) Any temptation to reduce heating in winter in order to reduce power consumption and maximum demand must be resisted. This will lead to occupants installing electric heaters, and the maximum demand will not be possible to control.
- e) Often there is an aspect of power consumption which can be tackled to reduce maximum demand. This is the difference between kVA's (on which the charge is based), kilowatts (representing useful power) and the relationship between these two, called the Power Factor. In most buildings, equipment can be installed to maintain this Power Factor near Unity.

1.5 BUILDING ECONOMY

Acceptable working conditions in terms of standards of heating, ventilation, lighting and acoustics have been comprehensively analysed by numbers of workers in different countries and form the basis for the satisfactory engineering design of services in buildings. On the basis of these standards it is the architect's and engineer's responsibility to provide the most economical solution.

There are certain initial criteria to be met:

- a) Fuel and energy conservation must be profitable
- b) Resources must not be devoted to energy savings which could be employed advantageously in more profitable activities
- c) It is necessary to consider the economics of the complete system associated with a proposed new building
- d) The location should be designed for the most economical use of transport for workers, supplies and products.

The building construction should be as economical as possible in the usage of materials and energy and the operation and maintenance of the buildings should require the most economical use of labour, materials and energy.

To attain the least cost for the sum of transport, of buildings and of operation and maintenance, it may be necessary to compromise on the cost of one or more of the elements. The greatest economic advantage may not result in the least use of energy, but nonetheless in reaching an overall compromise it is necessary to reduce the energy demands of each element to a practicable minimum.

1.6 ENERGY CONSUMPTION IN BUILDINGS

In considering an energy management programme for buildings, two energy conservation methods have been advanced.

The first method involves the implementation of specific conservation steps in buildings. These "end-use" restrictions are simple and easy to implement and include such items as adjustment of the thermostats to predetermined levels to use less heating and cooling energy, or removal of lamps to reduce consumption of lighting energy.

A disadvantage of this method of conservation is that the extent to which a system is used has no bearing on its efficiency. If a system is inherently inefficient, it will waste energy every time it is used. The "end-use" conservation steps do not take into account the systems which actually produce the environmental conditions, such as the heating, cooling or lighting systems.

Considerable savings may be possible by making the systems operate as efficiently as possible rather than by implementing "end-use" restrictions only.

Each building is to a certain extent a unique system with many inter-relating elements. As a result, removing lamps and luminaires can sometimes cause consumption of more energy.

Thus "end-use" restrictions are most suitable for very short-term applications.

The second energy conservation approach is a Total Energy Management one. This method recognises that each building is a unique and complex system.

In order to conserve energy, one must first understand :

- a) how the building consumes energy
- b) how user's needs are met
- c) how the system's elements interrelate, and
- d) how the external environment affects the building

Any energy conservation modifications or improvements can thus be integrated into the overall system, and each "end use" restriction, when analysed on this basis, and applied with flexibility, would result in maximum savings.

The development of an overall Energy Management Programme requires a lot of time and effort in the beginning in order to establish the programme elements.

Significant savings can also subsequently be obtained through operational changes, improved maintenance and repair of faulty equipment.

This project develops guidelines for an effective Energy Management Programme for new and existing buildings. The programme elements are analysed to establish the potential savings, and the results of steps that have been implemented are discussed.

CHAPTER TWO

REVIEW OF DEVELOPMENTS IN ENERGY CONSERVATION

Energy conservation has become a very topical issue, and a mass of literature has proliferated dealing with energy utilisation in buildings.

In America, Britain and in several European countries many research studies have been commissioned and sponsored by government agencies, and the results of these studies have provided a wealth of information for building engineers.

In 1974 V L Sailor published a paper on "Conservation of Energy in Buildings" which analyzed the energy situation in the United States and its relationship to commercial buildings. A study of the distribution of energy usage in a 50 storey modern office building revealed the following breakdown⁽⁴⁾:

Lighting	47,0%
Air conditioning	34,3%
Pumps and accessories	10,5%
Elevators	6,1%
Miscellaneous	2,3%

A feature of American buildings is their high lighting levels (700-1000 lux) and the subsequent increase in the air conditioning load. The situation in South Africa is slightly different in that lighting levels are generally lower (500-700 lux).

Sailor lists several methods for conserving energy in buildings, and points out that the time had arrived when fairly expensive modifications will be economically justified. Architects and engineers will be required to consider low energy designs and operating systems.

Current trends in South Africa are generally proceeding along the above lines, despite the obstacles of convention.

The United States Federal Energy Administration produced a series of Energy Conservation papers in 1975. Paper No 18 deals with office lighting and makes recommendations for changes to lighting design in order to reduce energy consumption without reducing visual comfort.⁽⁵⁾

The main recommendations are :

- a) Illumination for office tasks should be 500 lux,
and for surrounding areas 300 lux
- b) Local switches should be provided as necessary
to control the lighting
- c) More use should be made of daylight

These recommendations have been analysed in the South African context and are included in Chapter 4.

At a symposium on "Air conditioning and the Built Environment" in 1976, H J Spoormaker suggested that "adaptable" air conditioning and illumination systems should be introduced to South African buildings.⁽⁶⁾ This would result in a modern building illumination system average power demand reduction of approximately 40%, with a resulting reduction in the air conditioning energy consumption as well.

The suggestions and guidelines contained in this paper have been found to be very applicable to the situations encountered on this project, and have been developed further.

The Department of Planning and the Environment have published a series of papers on energy conservation.^(7,8,9) On a national and industrial level these papers contain many facts and figures, particularly with regard to estimated future needs. On the subject of Conservation in buildings, the guidelines are fairly general and deal more with statements of suggested policy and planning strategy than with specific recommendations. Areas requiring further attention are identified and the guidelines are formulated to provide a general review of the various factors involved and their relevant importance.

It is unfortunate that a more detailed analysis of energy consumption in buildings has not been undertaken by South African Government Departments. This would have resulted in more detailed energy conservation recommendations as well as target consumption figures, and, perhaps, a more consistent composition, interpretation and application of building by-laws by local authorities.

In 1976 M Caratsch published a paper on "Swiss Examples of Energy Saving in Existing Buildings".⁽¹⁰⁾ This paper described modifications carried out on buildings in Switzerland. These modifications were concerned mainly with insulation of the facade and it does not appear that a detailed analysis of the energy efficiency of the various building systems was carried out.

One of the most valuable contributions to the field of energy conservation in buildings was a conference held on "Energy - Key Factor in Property Development and Management" in Pretoria in April 1978. In a paper entitled "Building Systems and Space Efficiency", B Klevansky proposed some general guidelines to be used in building design for energy efficiency. These include the design of lighting for specific tasks, control of solar gain, etc. and have generally been included and analysed in this project.⁽¹¹⁾

In South Africa there is generally a noticeable lack of a specific magazine or publication dealing solely with all building services, with particular emphasis on operation, maintenance and energy consumption.

As energy costs continue to rise, it is expected that the need to examine building services systematically, with particular attention being paid to the interrelationship between systems, will assume more importance. This will lead to a departure from the present clear cut distinction between electrical and mechanical building engineers to an integrated approach that will contribute to energy economy and will result in a dissemination of applicable information.

CHAPTER THREE

ANALYSIS OF ENERGY CONSUMPTION IN BUILDINGS

3.1 OFFICE BUILDINGS

An office building can be described as part of an information processing system, containing :

- a) the building itself
- b) people
- c) rules
- d) energy for operation

An analysis by the General Services Administration in America, who operate about 10.000 buildings, shows that the life costs of the system over 40 years are approximately :

- i) 92% - cost of people to process information (salaries)
- ii) 6% - maintenance of facilities
- iii) 2% - first cost of the buildings

"It is evident that building cost reductions can have only limited benefits, while a more thorough analysis of user's needs and, ultimately, behaviour, is potentially the more beneficial".⁽¹²⁾

Preliminary research has found that increases in productivity are influenced by the personal satisfaction of the worker as well as by the working conditions. (According to Frederick Herzberg's Two-Factor Theory of Motivation, when people are dissatisfied, these bad feelings are generally associated with the environment in which they are working).⁽¹³⁾

On a technical level, the lighting and air conditioning facilities are amongst the most important components that comprise a pleasant working environment. It is thus evident that in analysing possible changes to the above systems, with the aim of conserving energy, the effect on the performance of the "information processing system" must be considered.

Modifications to these systems should not conserve energy at the expense of a larger loss in worker performance.

3.1.1 Lighting System

Typically, modern office buildings usually have a modular pattern of light fittings. In large areas this will provide a relatively high lighting level. In smaller areas, with partition dividers, the level will be lower. This is due to the loss of light contribution from nearby fittings, and because a percentage of the light is absorbed by the vertical surfaces. In many cases, the lighting level will be based on the maximum requirement.

This arrangement has the following advantages :

- a) Occupants can put desks and other office furniture anywhere in the space and still achieve satisfactory lighting conditions.
- b) Large spaces can be sub-divided into any reasonable size and pattern, and still maintain the minimum required lighting level.
- c) Once the initial installation is complete, it can often remain unaltered, although the use of the space may change. Problems of faulty workmanship arising from cheap and unsupervised alterations are thus avoided.
- d) The time needed to implement tenant's requirements (for both new and existing tenants) is reduced, as alterations to the lighting system are unnecessary.

Although the capital cost of providing a modular lighting system may be justifiable in terms of the advantages listed above, the energy that the "additional" lights consume is an ongoing cost and is continually increasing.

3.1.2 Air Conditioning Systems

Modern office air conditioning systems must cater for the heat generated by the occupants of the space, by the office equipment and machinery, and by the sun. The light fittings also generate a large amount of heat into the space, thus imposing an additional load on the air conditioning system.

In winter, heating is mainly required at the perimeter office areas, especially in the morning as the building cools down overnight.

The air conditioning supply air diffusers are often integrated with the light fittings to allow them to be easily installed and repositioned. Figure 3.1 below illustrates the typical installation of a modular lighting system and an integrated air conditioning system.

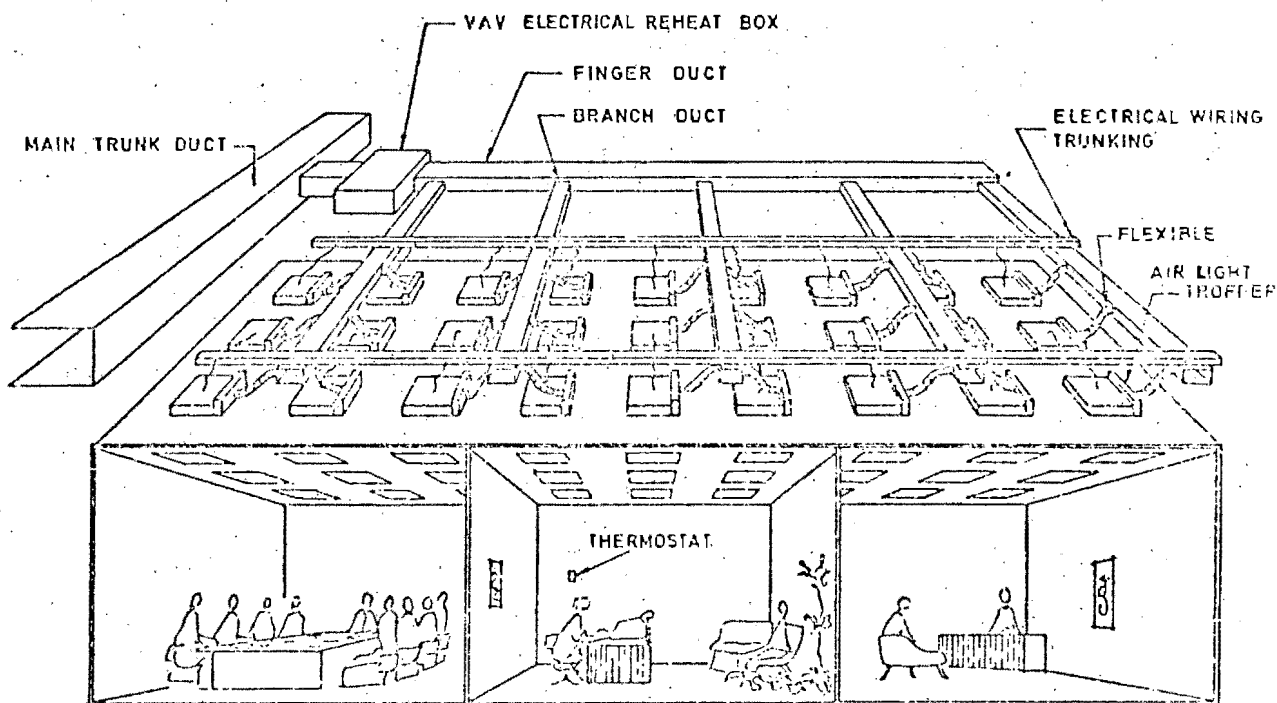


FIG. 3.1 : Modular lighting and air conditioning system⁽¹⁴⁾

The energy costs associated with good comfort standards have increased rapidly over the past 5-10 years. In addition, building owners and operators have been faced with the additional problem of oversupply of office accommodation. In South Africa's major cities there is a saturation of high quality office space. It is estimated that the overall surplus space available today is sufficient to meet the projected requirements of the next 20 years.

Building owners are thus in a situation where they are neither able to demand higher rentals, nor able to fully let buildings, and yet are faced with ever-increasing energy bills. This has resulted in some buildings operating at a negative cash flow.

Ways and means have therefore to be found to reduce energy consumption of office buildings, while at the same time maintaining the comfort standards as far as possible.

Many studies have been undertaken in this field and the results have often been incorporated in current building design. This chapter analyses the approach to be followed in investigating possible savings in energy consumption that may be achieved using these and other suggested techniques.

3.2 REFERENCE BUILDING

To measure and estimate possible energy savings, a reference building has been selected as a base against which to evaluate the merits of implementing the energy conservation proposals. This reference building is equivalent to the typical modern office buildings that have been constructed in the past few years in South Africa. Examples are :

Shell House - Cape Town
B P Centre - Cape Town
Carlton Centre - Johannesburg

The hypothetical building has the following parameters:

- underground parking
- ground floor shopping podium
- multi-storey office tower
- modular uniform lighting layout
(lighting level between 500-1000 lux)
- fully air-conditioned offices
served by a central plant

Electrical consumption values have been developed for this reference building. The data is shown in Table 3.1 below:

<u>ENERGY CONSUMPTION DATA:</u>	
Connected load (entire building) :	117 W/m ²
Connected load - office lighting :	40 W/m ²
Connected load - small power :	5 W/m ²
Annual operating hours :	3000 hours
Annual energy consumption :	250 kWh/m ² /a
Average monthly consumption :	800.000 kWh
<u>ANNUAL ENERGY CONSUMPTION ALLOCATION:</u>	
Lights	42%
Air Conditioning : Fans 6	
Cooling 16	
Heating 11	33%
Ventilation Fans	6%
Small Power	5%
Lifts	3%
Hot Water	2%
Miscellaneous	9%
	100%
<u>AREA:</u>	
Offices (net usable)	23,000 m ²
Shopping	2,000 m ²
Parking	8,000 m ²
Service/Plant rooms	7,000 m ²
	40,000 m ²

TABLE 3.1 : Model building consumption data

3.3 SYSTEMS ANALYSIS

As modern building systems have become increasingly complex, the performance of each sub-system as well as their inter-action must be fully analysed. If this approach is not adopted, the objective of energy conservation will not be met, and a further increase in energy consumption could result.

Some examples of steps taken to conserve energy, but which did not do so, are given below :

- a) To reduce electricity consumption in an office building, lamps were removed from light fittings. This did not, however, result in less overall electricity consumption. The air conditioning system had electrical reheat coils which were automatically switched on by the room thermostat when the light fittings were switched off, and the heat from the fittings no longer generated to the space.
- b) During winter, room thermostats were reduced from 24°C to 20°C to conserve energy. Energy consumption actually increased. The building zones had high internal heat gains and this, together with solar loads, caused the air conditioning system to actually reduce the room temperature to 20°C.

These examples illustrate how simple explanations and immediate responses are not valid to deal with the rapidly changing energy technology and complex systems that exist in modern buildings today. Therefore, a systems engineering approach, which takes into consideration the inter-relationship between systems, must be followed.

3.3.1 Systems Behaviour

A system is a set of inter-related elements whose parts are connected together in an organized way, are affected by being in the system, and are changed by leaving it. The stages involved in a systems engineering approach are described below.⁽¹⁵⁾

3.3.1.1 Systems Analysis - The question of what is going on, and why, and whether it may be done better, is analysed. The system and its objectives can then be defined, and data is gathered about the likely performance.

3.3.1.2 Systems Design - Different ways of operating the system are investigated and the best ones are chosen, thus optimising its potential.

3.3.1.3 Implementation - The optimised system will then have to be built. After it has been constructed, it must be checked for performance and reliability.

3.3.1.4 Operation - The system must be handed over to the people who have to operate it on a routine basis. This is an area where misunderstanding and inefficiency must be avoided and where great care should be taken.

The effectiveness of the operational system must be assessed and improved if possible.

Analysis of a building ("the system") and its sub-systems ("the components") using the systems engineering approach described above will ensure that the optimum Energy Management Programme is produced.

3.4 DEVELOPMENT OF ENERGY SURVEY CHECKLIST

As mentioned in Item 1.4.2, electricity tariffs for large consumers are normally based on a 2-part structure :

- a) The maximum demand (kVA), which reflects the generating capacity that the local authority has to provide in order to cope with the building load, and
- b) the consumption, measured in kilowatt hours (kWh), which reflects the rate at which electricity is consumed by the building.

Thus for a building owner to reduce the electricity cost, there are three possibilities :

- i) Reduce the demand
- ii) Reduce the consumption
- iii) Increase the amount recovered from tenants

To achieve the above goals the owner may modify and improve the building and its sub-systems, and can improve the operation and maintenance of these systems.

This is illustrated Figure 3.2 overleaf :

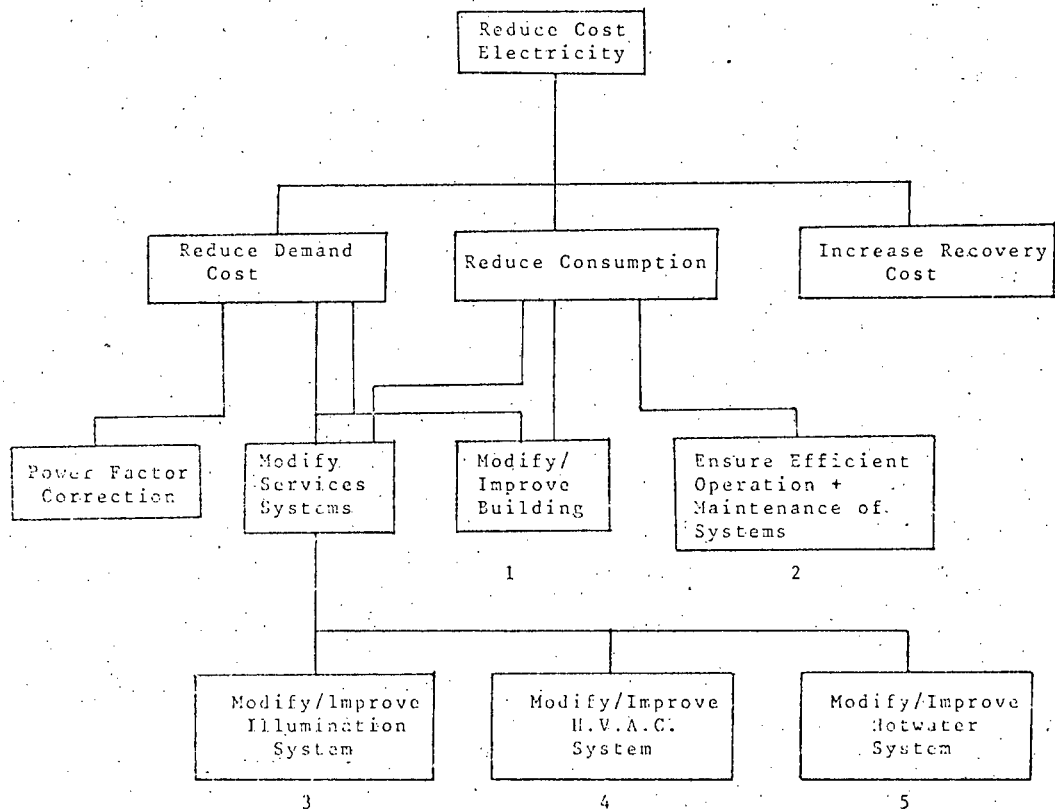


FIG. 3.2 : Energy economy diagram

For each of blocks 1-5 in Figure 3.2 a checklist has been developed. This step by step approach makes it possible to systematically evaluate the cost benefit of implementing the energy conserving modifications and improvements. The checklist is included in Appendix A.

Each system is investigated and the cost of the modifications and improvements and the resulting energy savings are assessed. Many simple modifications may have a 2-3 year payback period, while other more complicated and costly ones will fall into a longer payback period category.

The steps of the checklist are described and analysed in Chapter 4.

CHAPTER FOUR

ENERGY CONSERVATION MEASURES - MODIFICATIONS AND IMPROVEMENTS

A comprehensive list of possible modifications and improvements that may be carried out on buildings and their systems is included in Appendix A.

Each of these items is described in further detail in this chapter.

4.1 MODIFY AND IMPROVE THE ILLUMINATION SYSTEM

A - USE MORE EFFICIENT SYSTEM

B - OPERATE SYSTEM EFFICIENTLY

A - USE MORE EFFICIENT SYSTEM

4.1.1 Select Efficient Light Fittings

The efficiency of a light fitting will be determined by the characteristics of the following components :

- lamp length and wattage
- type of ballast
- type of diffuser
- physical construction of light fitting body
- colour rendering of the lamp

The most widely used light fitting in modern offices today is a 4-lamp 40 watt recessed fluorescent fitting.

It is 1,2 m long and is usually fitted with a prismatic diffuser.

In the reference building these luminaires will provide an even level of illumination and low glare discomfort.

By replacing these light fittings with the most modern ones available, an increase in the efficiency of the lighting system of 32% can be

achieved while providing the same illumination level and a lower glare index.

These new modern luminaires are called "low brightness reflector" luminaires. Instead of prismatic diffusers they have a highly polished aluminium reflector scientifically designed to control the light distribution and to reduce the glare.

The technical evaluation of this energy conserving step is given in Appendix B.

4.1.2 Introduce Task Lighting and Concentrate the Light on Work Surfaces

The lighting system using an overall uniform pattern of light fittings has been found, in many cases, to require alterations as tenancies change, and as the use of the space varies.

This occurs even though the uniform system was originally selected to avoid such alterations being required. It is extremely difficult to arrive at an optimum system of a reasonably uniform lighting layout that will require minimum post-installation alterations, while at the same time consuming the minimum of energy.

The uniform lighting system is wasteful, not only in energy required for lighting, but also for the consequent increased heat-load from the light fittings that the air conditioning system must cope with.

If lighting could be designed specifically for the nature of the task and the location of the "work station" in the area, energy reductions of up to 30%-40% could be achieved.

The lighting layout would be planned around the requirements of the user in the area, and it would naturally have to be a relatively simple matter to reposition lights as the work station is relocated.

The use of such an adaptable, non-uniform lighting system, (also called task lighting), of putting light where and when it is needed, is becoming more common today.

Non uniform lighting can also provide better quality lighting in a given area as there is more control in locating the light fittings in relation to the task. This reduces visual discomfort caused by direct glare and veiling reflections.

The quantity of light fittings and lamps required for task lighting instead of uniform lighting is reduced, resulting in less initial equipment, material and labour costs.

Less light fitting and lamp maintenance is required. However, greater dependence on fewer light fittings increases the importance of proper maintenance.

There are two basic systems of task lighting, namely :

- a) Ceiling mounted, and
- b) Furniture mounted.

4.1.2.1 Ceiling Mounted Task Lighting System

An illustration of this system is shown in Figure 4.1 below :

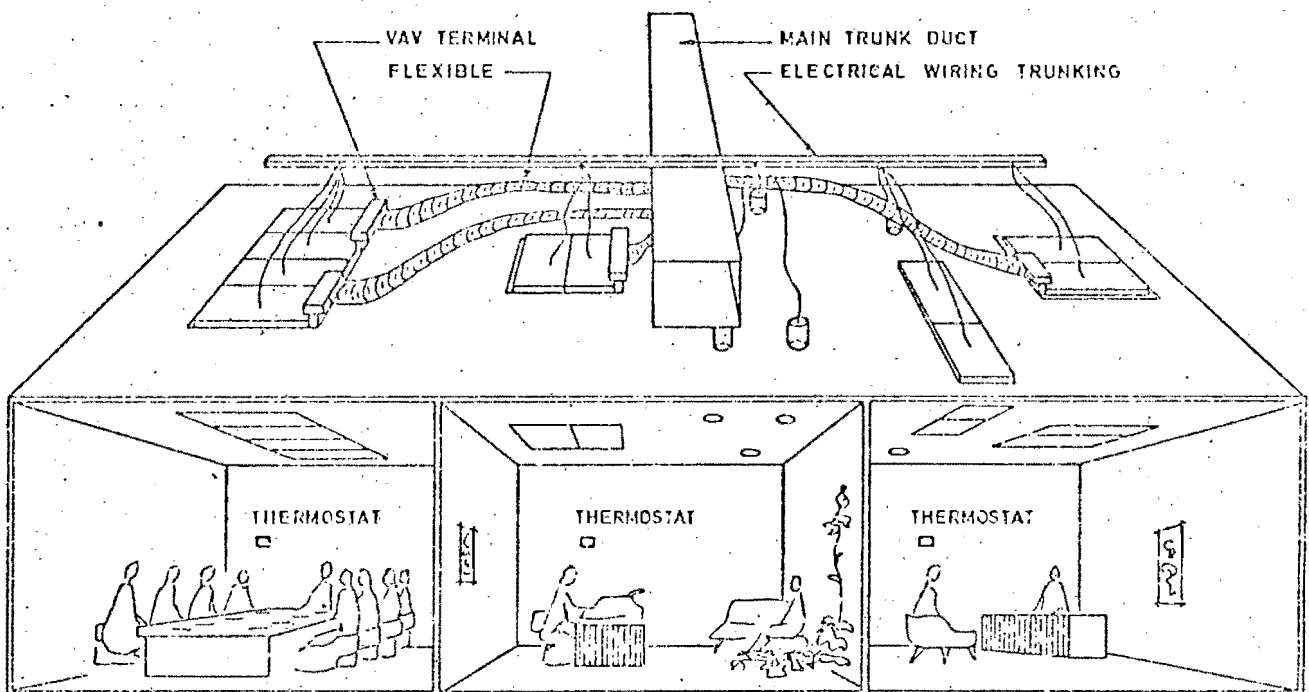


FIG. 4.1 : Ceiling mounted task lighting

The light fittings have flexible cables that are plugged into outlets on the electrical distribution system.

The ceiling tiles are interchangeable with the light fittings, and both are supported by the ceiling grid.

Thus the light fittings can be readily installed in any location and can be easily repositioned.

The electrical load and energy consumption of this non-uniform ceiling mounted lighting system is shown in Table 4.1 below, together with the reference building values :

Lighting System Energy Consumption	Ceiling-Mounted Task Lighting System (adaptable arrangement)	Reference Building: Uniform System (modular arrangement)
Connected Load	25 W/m ²	40 W/m ²
Annual Energy Consumption	75 kWh/m ² /annum	120 kWh/m ² /annum

TABLE 4.1 : Consumption - Ceiling mounted task lighting

4.1.2.2 : Furniture Mounted Task Lighting System

A recent development in non-uniform lighting systems has been that of the furniture mounted system.

The task light is positioned above, or to the side of, the working space. General background lighting, also called ambient lighting, is provided by one of two methods. It can either be provided by ceiling mounted light fittings that distribute the light over the whole area, or from light fittings mounted on the furniture that shine upwards, hence reflecting the light off the ceiling.

The ambient lighting level may be about 50% of the task level. Its main function is to provide general lighting to the non-task areas, such as circulation spaces.

The consumption data is given in Table 4.2 below:

Lighting System Energy Consumption	Furniture - Mounted Task Lighting System	Reference Building Modular Arrangement
Connected Load	20 W/m ²	40 W/m ²
Annual Energy Consumption	60 kWh/m ² /annum	120 kWh/m ² /annum

TABLE 4.2 : Consumption - Furniture mounted task lighting

A recent development in space systems design is the installation of a false floor to replace the suspended ceiling. The electrical and air conditioning systems then use the void below the floor for distribution, and the services terminate at the work station.

This is illustrated in Figure 4.2 below:

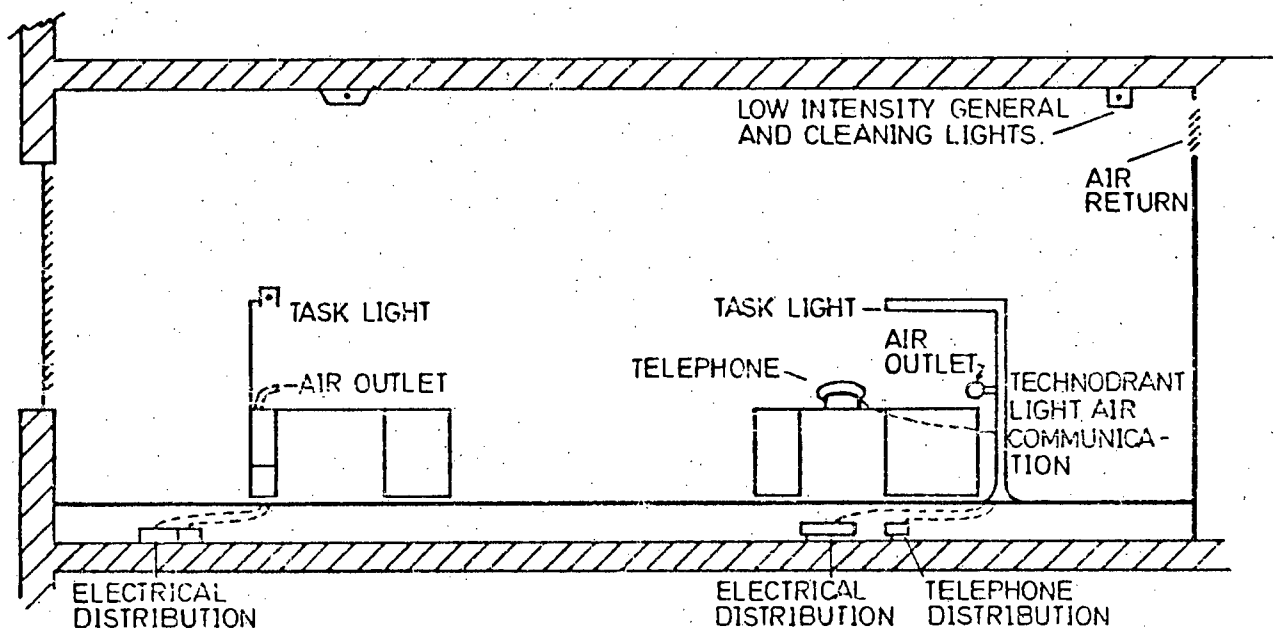


FIG. 4.2 : Raised floor distribution system

A cost comparison between the modular lighting system and the ceiling and furniture mounted task lighting system is shown in Table 4.3 below, taking into consideration:

- the capital cost of the installation
- the energy consumption
- the lamp replacement cost, and
- the space adjustment cost

(The space adjustment cost is a function of the Area of Change x Rate of Change x Cost of Change).

data? where from

Lighting System Costs	Uniform Lighting (Modular)	Task Lighting	
		Ceiling Mounted	Furniture Mounted
Capital Cost (R/m ²) <i>mid cost of floor vs. ceiling</i>	38	25	25
Energy Consumption (kWh/m ² /annum)	120	75	60
Lamp Replacement Cost (R/m ² /annum)	0,9	0,6	0,4
Space Adjustment Cost (R/m ² /annum)	1,5	1,5	1,2

TABLE 4.3 : Cost comparison - Modular and task lighting

From the above data it is apparent that the task lighting system, using furniture-mounted light fittings, will be more economical on a life-cycle costing basis.

4:1.3 Introduce Localised Light Switching

In most modern commercial buildings, the office lighting switching arrangement is decided upon at the design or construction stage. Tenant requirements are unknown at that stage, and it is thus impractical to plan a lighting switching system that will be inexpensive yet flexible enough to cater for the subsequent tenant requirements. It is usually the building owner who pays for this part of the installation and he is loathe to pay for additional flexibility that may not be required.

The solution most prevalent today is to sub-divide the floor into several lighting 'banks'. Each bank has a single switch, usually located against the core wall, near the entrance from the lift lobby.

This location is most suitable as it is usually kept free and accessible while the rest of the area may be altered. This 'bank' switching system is inflexible. The lights in individual offices cannot be controlled, and unoccupied areas such as store rooms and filing rooms must have lights burning continually.

There are many systems available that will allow switching and control of the lighting. Some are very sophisticated and incorporate dimming devices. This allows the amount of natural light entering the working area to be monitored and the artificial lighting is then dimmed so that the total amount of light is kept constant.

A brief summary of lighting control systems is given in Appendix C.

The installation of simple on-off switches to individual offices and particularly to unoccupied areas can usually be economically justified, as can the switching off of perimeter lights when there is sufficient daylight.

In many cases, these switches are installed after the initial bank switching system has been installed. The tenant is then expected to bear this cost. This procedure, unfortunately, often causes problems due to the following reasons:

- a) The workmanship is often of a lower quality and is done under less supervision than the initial installation.

- b) There is a disruption to adjacent areas through which wiring may have to pass
- c) Indiscriminate switching off of lights may cause the air conditioning system to reheat the space due to the loss of the heat from the light fittings
- d) Any subsequent alteration to that or any adjacent office may require major rewiring work to be done

It would thus be far better to install a switching system that will allow individual areas to be switched, and subsequent alterations to be relatively easily carried out.

Such systems are available, but are usually very expensive. As a compromise, the initial installation should be wired to provide a degree of flexibility for local switching, while at the same time without significantly increasing the capital costs. For example, more circuits than are actually required from the design or regulation aspects could be installed, as could extra wiring for switching controls.

An example of the capital cost and subsequent energy saving when individual switches were provided to part of an office floor is given in Appendix D.

4.1.4 Switch Off Lights at Lunch Times

The effect of switching off lights at lunch time has been widely debated.

On a practical level, this procedure may be unsuitable in many cases. There may be very little natural light in circulation areas, and the

switching system will have to be adjusted accordingly. If people want to work during lunch time, or want to spend this period in their offices the system will have to allow for this.

On a technical level, there are two fundamental potential problems. In cases where a flexible switching system is not provided, the same problems will arise with the wiring as with the installation of any switching system, as previously described. Secondly, the life of the lamps will be reduced due to the reduction of the continuous burning period.

Despite the above drawbacks, there are many situations where switching off lights during lunch times is a feasible energy saving procedure. Assuming that 80% of the lights can be switched off for 45 minutes on a normal working day, the energy saving per annum on the standard reference building will be as shown in Table 4.4 below :

	REFERENCE BUILDING DATA			
	kWh/Floor	kWh/m ²	R/m ²	Rands (based on 20,000 m ²)
	Annual Saving	5.100	6	R0.10

TABLE 4.4 : Switching Off Lights at Midday -
Annual Energy Saving

In a situation where the controls have to be added to the original installation the payback period will be approximately 20 months.

The calculations are included in Appendix E.

*

4.1.4.1 Effect on Lamp Life. Regular switching of fluorescent lamps causes the life of the lamp to be reduced from the nominal rating of approximately 9 000 hours. This reduction is generally not more than 10%.

If a planned re-lamping programme is used in which all lamps are replaced at 90% of the rated life, then the effect of the regular switching will not be significant. The savings in energy will be far greater than any re-lamping costs due to early lamp failure.

The effect of switching on lamp life is shown in Appendix F.

4.1.5 Introduce Central Master Over-riding Switching

Central switching systems are usually used to ensure that all lights are extinguished after normal working hours. In most office buildings there are often lights left burning at night and on weekends, although the building is unoccupied.

The central switching system may be controlled from a convenient location, such as the central Security office. Naturally, in a multi-tenant building an administrative system must be introduced to allow individual tenants to work after normal hours. Tenants may be required to pay for the additional lighting energy and may also be charged a levy for use of the air conditioning system.

Central switching systems usually control each floor individually, and may also be adapted to allow lights to be switched off at lunch times.

The technical details of some central systems are included in Appendix C.

4.1.6 Introduce Controlled "After and Before" Hours Cleaning Lighting Switching

Cleaning staff usually do their work at night. All the lights are either switched on, or left on by departing occupants. The cleaners then turn off the lights once they have finished their work.

To save this lighting energy, cleaning should ideally be done during normal working hours, lunch times or immediately after normal working time. This is, however, often unsuitable to tenants.

An alternative method is to introduce a special "cleaners switch" that would permit only a small percentage of lighting to be switched on. This arrangement would be most suitable for offices with large areas or complete open plan.

4.1.7 Introduce kWh Meters

In many commercial buildings the total amount of energy used for lighting is not monitored, nor the amount consumed by individual tenants.

On buildings where meters are installed, they usually meter a whole floor and the consumption is apportioned to occupants on a pro rata basis, according to the area. In other cases the energy consumed by the total lettable area is metered and apportioned similarly. Where sub-metering is not installed, energy is usually included in the rental.

In order to encourage tenants to consume less energy they should be informed of their actual consumption regularly and of the cost of this energy. The energy cost should be a separate charge to the basic rental, thus providing an incentive to tenants to conserve, *name*

To provide this consumption data comprehensive sub-metering must be installed. Individual tenants should be metered separately, even if this means that the wiring must be altered.

Other advantages of sub-metering are :

- a) By keeping accurate records of consumption it is easy to compare the actual consumption with the budgeted one. This will immediately allow wasteful areas to be identified and corrective action to be taken. The budget can be based on historical or seasonal data, can be estimated or can be obtained from similar buildings elsewhere.
- b) Large users of energy can easily be identified by comparing recorded consumption with check figures. This may induce the user to investigate ways of reducing consumption. In some cases, there may be a penalty imposed due to the extra load that the air conditioning plant has to cope with. Metering of tenants should monitor lighting and power together.

B - OPERATE ILLUMINATION SYSTEM EFFICIENTLY

4.1.8 Maintain and Clean Light Fittings on a Regular Routine Basis

Lighting design is based upon an "average through life" calculation. This takes into account the fact that the initial lumen output of the lamp will drop off as the hours of use increase. This is illustrated graphically in Figure 4.3 overleaf.

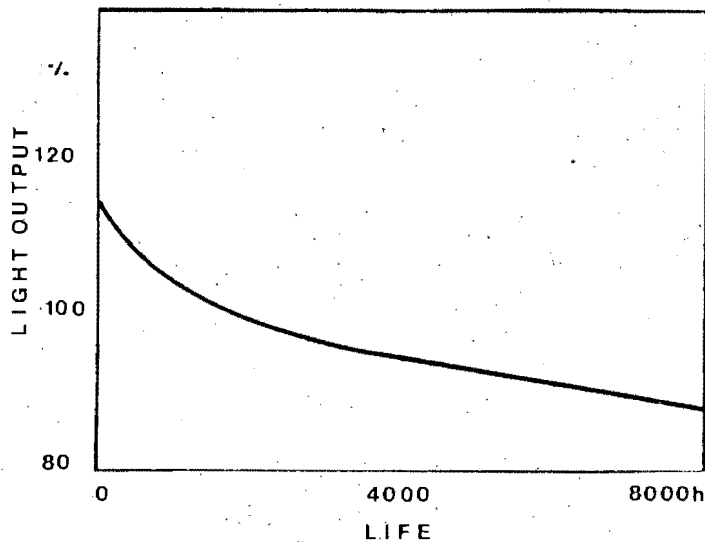


FIG 4.3 : Light Output

As low energy lighting schemes make full use of each lamp, this sharp reduction in lumen output will have a noticeable effect on task illumination. To avoid this, lamps should be replaced on a regular basis at about 90% of the rated life.

A second important factor in lighting design is the "maintenance factor". This takes into account that diffusers and lamps get dirty and covered in dust as the building gets older. This causes the illumination level to drop. To prevent this happening, light fittings and lamps should be cleaned regularly.

4.1.9 Remove Unnecessary Light Fittings

A brief scrutiny of most offices today will reveal that there are many light fittings burning that may be removed without affecting the user.

This situation arises from many causes. It may be due to a change in the use of the space, due to a re-arrangement of the office layout, due to there being adequate lighting from adjacent light fittings, or there may be sufficient natural light in the area. These causes are most readily identified by inspecting the occupied area. This should be done regularly and surplus light fittings should be removed or disconnected.

4.1.10 Remove Unnecessary Lamps

In most offices a standard light fitting is provided to the tenant by the building owner as part of the furnishings. This often leads to a situation where a multiple lamp light fitting complete with diffuser is installed in storerooms, record rooms, etc. In these areas a fitting without a diffuser and with less lamps will usually be adequate. When such a case arises tenants should be encouraged to remove lamps and diffusers from these fittings to reduce running costs. To provide this flexibility the fluorescent light fittings must be equipped with switch-start control gear so that individual lamps can be disconnected without affecting other lamps.

MODIFY AND IMPROVE THE HVAC SYSTEM

- A - ELIMINATE SIMULTANEOUS HEATING AND COOLING OF A ROOM OR ZONE
- B - ENSURE SYSTEM OPERATION AT OR NEAR OPTIMUM EFFICIENCY WITH REDUCED BUILDING LOADS
- C - COOL WITH OUTSIDE AIR WHEN POSSIBLE AND DON'T WASTE ENERGY ON UNNECESSARILY LARGE VOLUMES OF OUTSIDE AIR
- D - SELECT EQUIPMENT FOR EFFICIENT OPERATION INSTEAD OF ONLY FIRST COSTS
- E - INTRODUCE EQUIPMENT TO REDUCE USAGE OF 'NEW ENERGY'

The air conditioning system installed in a typical building can use approximately 40-50% of the total building energy, and generally amounts to 50-60% of the connected load.

The major energy consuming items are:

- a) The water chiller or main cooling plant - consisting of a centrifugal type machine with associated chilled and condenser water pumps, and, usually, a remote located mechanical draft cooling tower. It is generally found that this system is split into two equally sized plants.
- b) Air handling units - located in central plantrooms or distributed around the building. These units filter, cool or heat, humidify or dehumidify and distribute the air around the building by means of fans. An additional fan (the return-air or exhaust fan) is generally associated with the air handling unit.
- c) The heating plant - usually consisting of an oil fired or electrode type boiler with associated pumps, which distribute hot water to the air handling units or to terminal reheat units. A further variation is the electric convector heater or panel radiator located in the conditioned space, usually on the external window.

A - ELIMINATE SIMULTANEOUS HEATING AND
COOLING OF A ROOM OR ZONE

4.2.1 Convert Double-Duct, Multizone or Terminal Reheat
Systems to Variable Volume Constant Temperature Systems

The double or dual duct system consists of a hot and cold duct, from which it gets its name, which supplies hot and cold air to a terminal mixing unit. The hot and cold quantities are controlled by a thermostat located in the space.

Thus, for an unoccupied space, with no heat from the lights or solar gain, on a mild day there will not be any requirement for heating or cooling. As the cold air duct usually supplies air at 10°C and the hot air duct at 65°C, and as the terminal units are designed to operate at a constant volume, 3 parts cooling to 1 part of heating will be required to achieve a nil temperature change in the space.

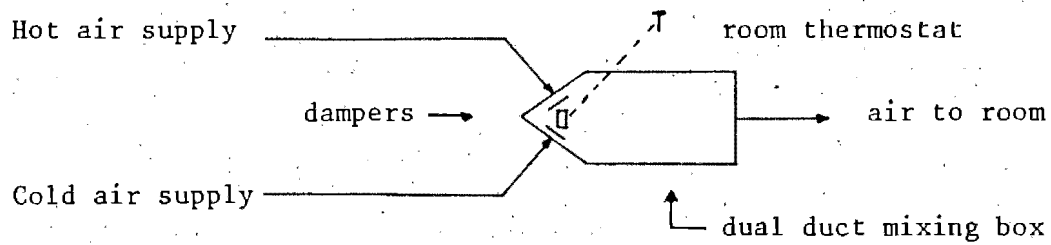
The multizone system operates on a similar design concept, with the mixing of hot and cold air streams at the central air handling plant. This system also operates on the constant volume principle, and the air mix temperature is controlled by a zone thermostat.

The terminal reheat system operates on the principle of cooling the total air quantity to the lowest temperature required by a particular room or zone. To achieve the required temperatures in rooms having less than the maximum cooling requirement, terminal reheaters are used.

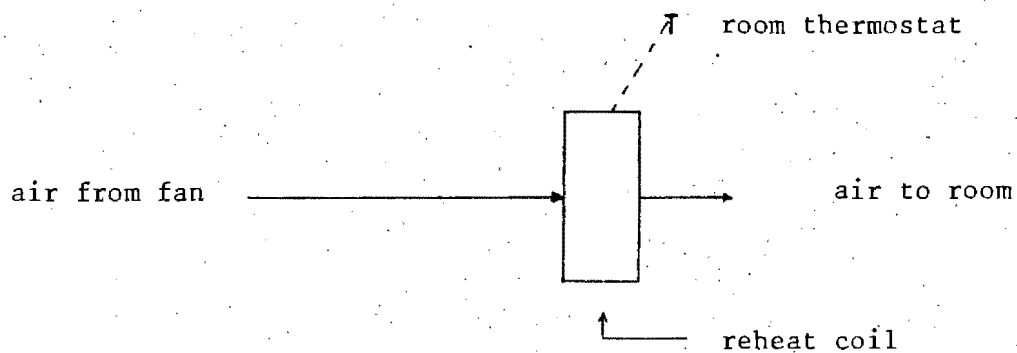
The above systems are energy wasteful as the large constant volumes of air are being treated and retreated.

Variable volume constant temperature systems (VAV) include a terminal unit that adjusts the air flow to the space to exactly match the required cooling requirement.

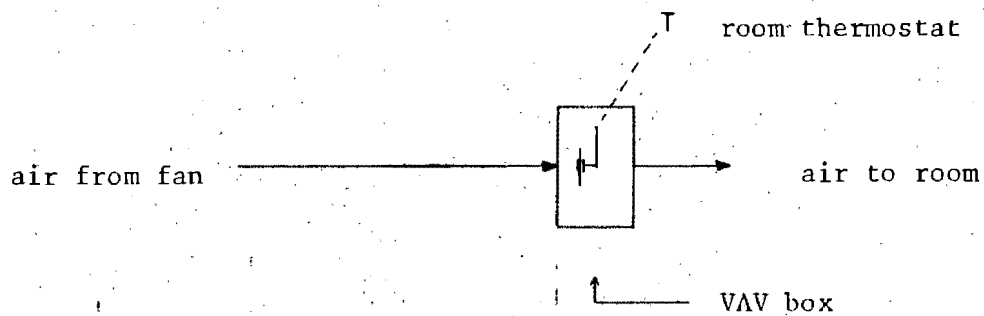
The above systems are illustrated in Figure 4.4 overleaf.



a) Dual duct system



b) Terminal reheat system



c) Variable volume system

FIG 4.4 : Air- conditioning systems

In most modern buildings the design allows significant savings to be made in first costs and energy costs, as not all areas require maximum cooling at any one time. A careful design using the VAV system will allow smaller main duct sizes and installed motor kW. Further energy savings can be made during the intermediate season and winter by fitting the fans with variable speed motors, variable pitch control on axial fans or variable pitch guide vanes on centrifugal fans to compensate for the lower cooling requirement.

A VAV system with a separate heating system has been shown to be one of the most energy efficient All-Air systems available. The heating system should not be a function of the VAV terminal as this will prevent increases in energy consumption due to malfunction of a thermostat, static pressure controller or branch line damper.

Building and system surveys have shown that the VAV system, with separate heating, requires approximately 30% less energy to operate than a constant volume double duct system, and approximately 50% less energy than a multi-zone or terminal reheat system.

4.2.2 Control Perimeter Heating by Outside Air Master Control

Perimeter heaters usually have an integral thermostat which is often accessible to the room occupant.

The heating system should be prevented from operating in sympathy with a malfunction on the cooling system, and the effect of unauthorised tampering or adjustments should be limited.

Thus, the system should be controlled in such a way that it can only operate when the outside temperature falls below a preset minimum.

4.2.3 Use Only Water Sprays for Humidification

Should ambient and room temperatures permit, a spray coil can be used to obtain "free" cooling. Thus, the required humidity level may be obtained without operating the pre-heater coils.

4.2.4 Eliminate Heating in Interior Zones

Interior zones usually have a steady cooling requirement due to the load from the lights and occupants.

It is thus important to ensure that the correct air volume at the correct temperature is supplied, to prevent heating being required.

B - ENSURE SYSTEM OPERATION AT OR NEAR OPTIMUM
EFFICIENCY WITH REDUCED BUILDING LOADS

4.2.5 Use Multiple Refrigeration Machine Systems with Auxiliaries
(Pumps and Cooling Tower) which Operate (and Shut Down) as
the Load decreases

Most centrifugal refrigeration machines will operate at 50% capacity with a reasonably linear reduction in energy consumption. However, the pumps and fans will still operate at full capacity, and there will be no further reduction in energy consumption. Thus, multiple systems should be used which can be switched off as the load decreases, or central cooling towers should have multiple fans or inlet dampers.

4.2.6 Cycle at Full Load and Stop and Start Manually

On a multiple refrigeration system the machines should be operated at their peak efficiency. This can be achieved by manually starting and stopping a complete system.

4.2.7 Use Speed Control on Pumps and Supply Fans
Whenever possible on Varying Demands

Speed control should be introduced on the chilled and condenser water pumps to match the reduced load when one machine is shut down. Ventilation systems such as on garages should also be controlled in this manner.

4.2.8 Monitor and if Necessary Relocate Sensing
Points of Capacity Control System

The sensing points of the system controls should not be affected by false outside influences that may lead to an unnecessary and wasteful use of energy.

4.2.9 Reset Supply Air Temperatures and Pressures under Part - Load Conditions

On a VAV system, the supply air temperature should be reset with an outdoor compensator to avoid over cooling of a space on minimum air requirements, which will require energy to correct.

Under part load conditions the supply air pressure should be reduced by speed control, thereby reducing the motor absorbed kW.

Figure 4.5 below illustrates the reduction in motor absorbed kW resulting from a reduction in air volume:

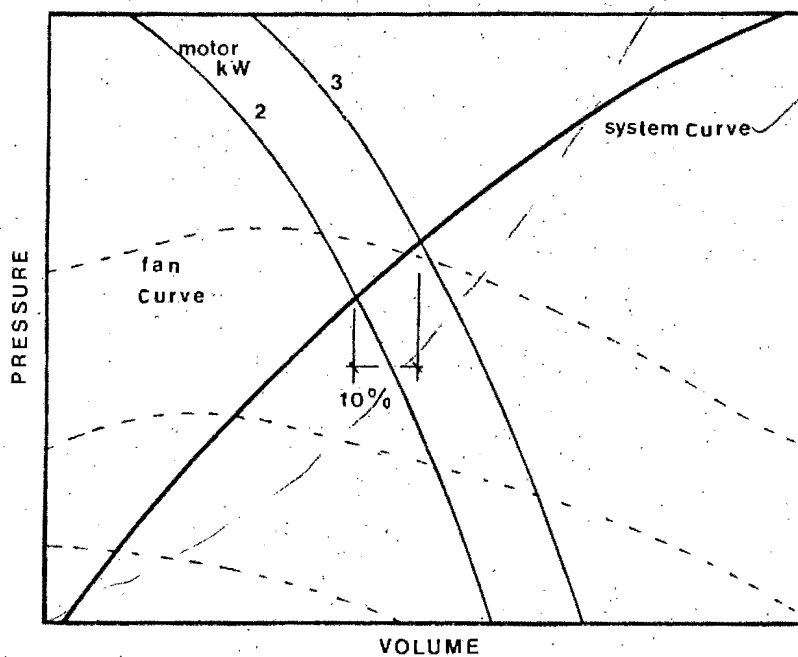


FIG 4.5 : Effect of reduced air volume on motor kW.

- C - COOL WITH OUTSIDE AIR WHEN POSSIBLE AND DON'T WASTE ENERGY ON UNNECESSARY LARGE VOLUMES OF OUTSIDE AIR

4.2.10 Use Outside Air, Return Air and Relief Damper (Economiser Cycle)

The Economiser cycle system allows 100% fresh air or 100% return air to be introduced to the air handling unit. It usually consists of a set of dampers on the fresh air intake, exhaust air outlet and recirculation duct. With this system it is possible to use outside air for cooling. The changeover point is measured by a wet bulb or enthalpy sensor located in the fresh air intake. Whenever the total heat of the fresh air is below that of the required room condition, outside air may be used to cool or assist in cooling the space.

4.2.11 Use Spray Coils or Air Washers for Evaporative Cooling

Under conditions of low ambient humidity, evaporative cooling can be used in conjunction with the economiser cycle.

4.2.12 Reduce Quantity of Outside Air to Zero or Minimum during "before and after" hour Periods, and when on Cooling or Heating Cycle

When the building is unoccupied, the fresh air should be reduced to zero.

4.2.13 Use Outside Air for Precooling Building at Night whenever possible to reduce Maximum Demand

Precooling the building at night will reduce the peak maximum demand cooling load.

- D - SELECT EQUIPMENT FOR EFFICIENT OPERATION
INSTEAD OF ONLY FIRST COSTS

The following self explanatory measures should be considered when selecting equipment:

- a) Use life cycle costing - capital, energy and maintenance costs - in selecting equipment.

- b) Modify ducting system for lowest practical static pressure to reduce fan kW.
- c) Select piping, auxiliaries and heat exchangers for lowest practical pressure loss to reduce pump kW.
- d) Select heat exchange surfaces (condensers, evaporators and cooling coils) for lowest kW.

E - INTRODUCE EQUIPMENT TO REDUCE USAGE OF 'NEW' ENERGY

The following recommendations, if applied, will reduce energy consumption:

- a) Use air purifying systems instead of outside air. *Contradictory*
- b) Use heat reclaim devices (double circuit condensers^x) on air water systems.
- c) Use air heat recovery systems.
- d) Use 2-stage evaporative cooling systems in dry climates instead of refrigeration.
- e) Use 'heat' and 'cold' storage - (water, rocks, etc.) on daily or seasonal cycle whenever practical.

4.3 MODIFY AND IMPROVE HOT WATER SYSTEM

- A - USE MORE EFFICIENT SYSTEM
- B - OPERATE SYSTEM EFFICIENTLY

A - USE MORE EFFICIENT SYSTEM

4.3.1 Reduce Heat Losses - Improve Insulation

A poorly designed system may require the hot water tap to be open for several minutes before hot water runs. One may thus draw off 4 litres of "cold" hot water to get 1 litre of hot, which all requires to be heated from cold.

Thus a pumped circulation or gravity fed system must be correctly designed or modified to ensure that hot water is available at the tap.

4.3.2 Use Efficient Heat Exchanger

The heat exchangers should be selected for lowest absorbed kW, i.e. for low pressure drop. The surface of the heat exchanger should also be increased, if possible, as this will allow the "approach" temperature to be reduced.

4.3.3 Run at Lowest Possible Temperature

In commercial buildings, the hot water is used mainly in toilets and tea kitchens. It is often too hot for people to use, and is subsequently mixed with cold water.

Storing water at high temperatures is usually energy wasteful due to an increase in the heat loss through the insulation caused by the increased temperature differential. Thus, the water should not normally be stored above 50 - 60°C.

4.3.4 Use Cheapest Possible Fuel

Many buildings with central hot water systems either have boiler plants or electrically operated systems. In the case of electrical systems, a peak load can be added to the building's total maximum demand, thereby causing the owner to incur additional costs unnecessarily.

The design of the hot water system should include an evaluation as to whether oil, coal, gas or electrically operated appliances should be used.

4.3.5 Reduce Heating Losses During Periods of "Low" and "No" Demand

Whenever the temperature of the hot water falls below the pre-set level, the heating elements will be switched on. This will occur at night and on weekends, unless controls are installed.

To avoid this unnecessary use of energy, there are two solutions.

The storage tanks should be well insulated to reduce the heat loss, and for night time and weekends, controls should be installed to prevent heating taking place.

B - OPERATE EFFICIENTLY

4.3.6 Monitor Controls and Operate at Lowest Possible Temperatures

The efficient operation of the hot water system will only be ensured if the controls are regularly monitored.

Faulty controls may lead to energy waste.

Controls should be set correctly to ensure :

- a) Operation at recommended temperature.
If the temperature can be lowered without causing complaints from tenants, this should be done.
- b) Operation at correct periods.
- c) That the operation of electrical hot water systems does not cause the building maximum demand to be increased.

4.3.7 Reduce Consumption Through Leaking Taps

Leaking taps cause a draw off of water and hence the fresh water entering the cylinder will have to be heated.

4.4 ENSURE EFFICIENT OPERATION AND MAINTENANCE OF SERVICE SYSTEMS

- A - ENFORCE ENERGY CONSERVATION
- B - ENSURE EFFECTIVE BUILDING SERVICES OPERATION AND MAINTENANCE
- C - UPDATE OPERATING AND MAINTENANCE DOCUMENTATION

A - ENFORCE ENERGY CONSERVATION

4.4.1 Prepare Energy Consumption Budget

An energy budget is the most important item of any energy management programme.

The budget breaks down the amount of energy consumed by the various sub-systems of the building. It allows large and wasteful areas to be identified by comparing the actual consumption to the estimate.

There are two budgets that are useful aids:

The "correct operation" budget allocates the energy consumption between the sub-systems based on the assumption that the building is being operated correctly. In many cases the standard of operation of buildings is very poor, and features of the design intended to ensure efficient operation are ignored.

There are many reasons for this, but very often it is due to inadequate training of the building operator. The operator is often not fully briefed about the systems or the way in which they have been designed to operate, and he is left to his own devices to establish operating routines.

The operator is often also provided with inadequate and incomplete operating instructions and documentation. This will usually result in a waste of energy as controls will not be properly set and monitored, and seasonal adjustments may not be correctly made.

The second budget is the "energy efficient" budget. This budget reflects a saving over and above the "correct operation" budget. It is based on the implementation of specific energy saving measures such as those proposed in the checklist.

The potential savings will naturally depend upon the type of building, the air conditioning, lighting and other systems, and the capital cost of the modifications.

The amount of detail to which the budget is broken down must be reasonable in relation to the area of the building and the number of sub-systems.

STEP BY STEP PREPARATION OF ENERGY CONSUMPTION BUDGET

4.4.1.1 Connected Load of Individual Equipment

The building must be sub-divided into the various areas and energy consuming sub-systems. The connected load of each sub-system in each area is added to the schedule, and this gives the total load for each sub-system throughout the building.

A sample filled-in schedule is shown in Figure 4.6 below:

	System Area	Area (m ²)	Lights	Small Power	Lifts	Air Conditioning			Vent. Fans	Hot Water	Misc.	Total	W/h?
						Fans	Cooling	Heating					
Office	Offices	20750	830	100 *	257	115	608	1139	27	86	-	3162	152
	Service Areas	4165	102	12	-	-	-	-	16	-	-	132	31
	Computer	-	-	-	-	17	60	62	-	-	135	274	-
Retail	Offices	2591	86	13 *	9	25	131	205	-	-	-	469	181
	Shopping	1770	57	9 *	-	71	123	183	-	-	-	393	222
	Service Areas	120	4	1 *	-	-	-	-	6	-	-	11	91
Garage	Parking	7723	12	2 *	14	-	-	-	103	-	-	131	17
	Service Areas	57	6	1 *	-	-	-	-	-	-	-	7	122
	Central Plant	2140	15	7 *	-	-	-	-	-	-	6	28	13
	Total	39316	1112	145	280	178	922	1589	154	86	141	4607	117

* Average Connected Load to small power distribution system

FIG 4.6 : Equipment connected load

4.4.1.2 Maximum Demand Work Sheets

The maximum demand of the building reflects the sum of the maximum demands of the various sub-systems in the metering period. If part of this load can be spread over other periods, a lower maximum demand will result.

It is thus important to identify the time of the day when the highest maximum demand is likely to occur. This must naturally be done on a seasonal basis.

A maximum demand work sheet for summer is shown in Figure 4.7 below:

	Light	Small Power	Lifts	A.C.			Vent. Fans	Hot Water	Misc.	Total
				Fans	Cooling	Heating				
Connected Load	1110	145	280	178	922	1589	154	86	141	4667
Time										
0200	120	0	0	20	80	0	60	20	30	330
0400	120	0	0	20	80	0	60	20	30	330
0600	120	0	100	160	80	60	65	20	30	635
0800	1110	50	250	170	430	30	150	40	100	2350
1000	1110	135	250	170	580	30	120	36	140	2621
1200	1110	145	250	170	720	30	150	70	140	2785
1400	1110	145	250	175	800	30	120	70	140	2840
1600	1110	145	250	175	900	30	150	50	140	2790
1800	1110	50	250	175	900	30	65	40	140	2760
2000	400	25	100	50	0	0	60	20	100	350
2200	120	10	0	20	0	0	60	20	80	190
2400	120	0	0	20	0	0	60	20	30	130

FIG. 4.7 : Maximum demand work sheet

For a 24 hour period, the connected load for each sub-system (derived from the connected load work sheet) is estimated.

The hourly total maximum demand for the whole building is thus obtained, as shown on the sample work sheet.

4.4.1.3 Hourly Maximum Demand Curves

The hourly maximum demand for the whole building for each season can be plotted as shown in Figure 4.8 below:

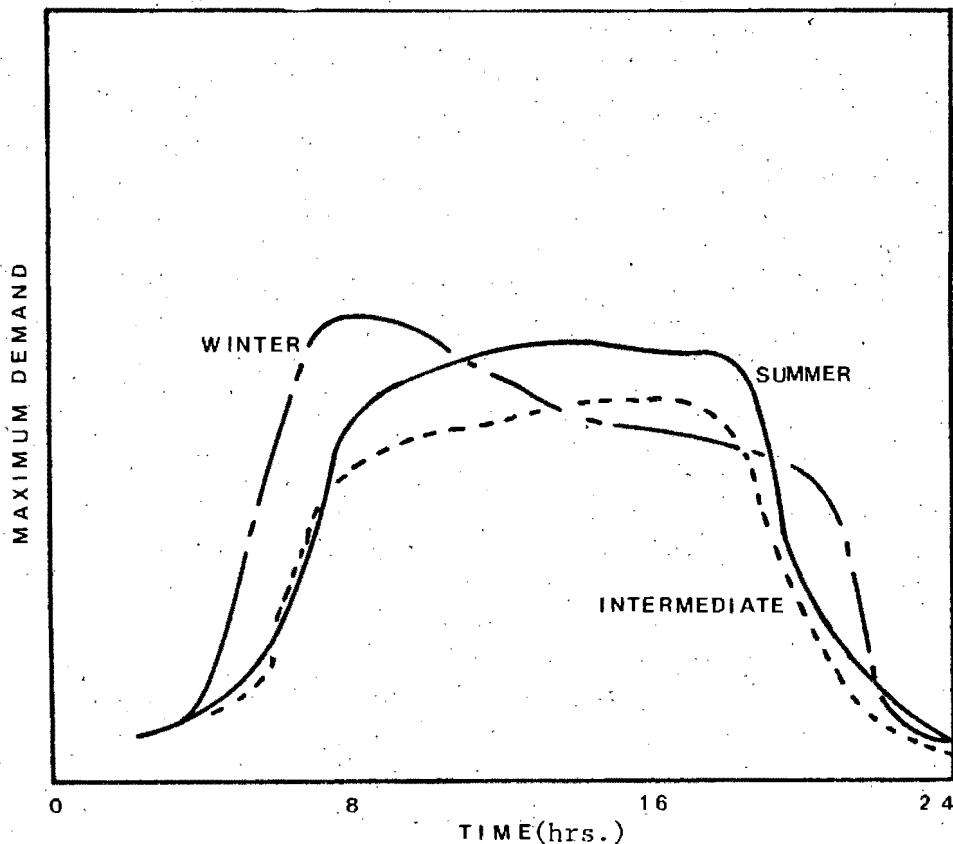


FIG. 4.8 : Maximum demand curves

The curves readily show up the peaks in the maximum demand profile of the building. Ways must then be found to reduce or redistribute this load over the rest of the day, if possible.

From the maximum demand work sheets the actual components of the peak maximum demand can be established, e.g. lighting, heating, etc.

4.4.1.4 Energy Consumption Work Sheet

In order to estimate the magnitude and allocation between sub-systems of the energy consumption, all the loads must be put on an equitable basis. This is done by analysing the number of hours per annum the sub-system is likely to operate, and at what percentage of its full load.

Thus the "equivalent full load operating hours" for each sub-system for each part of the building is derived.

Figure 4.9 below illustrates a sample energy consumption work sheet :

Area	Service	Operating Mode	Annual Operating Hours	Load Factor	Equivalent Full Load Operating Hours
Tower Offices	Lights	0700-1800 Workdays	3200	1,0	3200
	Small Power	0700-1800 Workdays	3200	1,0	3200
	Lifts	0700-1800 Workdays	3200	0,2	
		1800-0700 Workdays	3700	0,05	
		Other Times	1800	0,03	
		Total			830
	Hot Water	Work Days	1300	0,4	
		Other Times	5460	0,15	
		Total			2412

FIG. 4.9 : Full load operating hours

4.4.1.5 Allocation of Energy Consumption

By multiplying the connected load of the individual equipment by the equivalent full load operating hours, the annual energy consumption (kWh) is obtained for each sub-system for each part of the building.

An example is shown in Figure 4.10 below :

	System Area	Area (m ²)	Lights	Small Power	Lifts	Air Conditioning			Vent Fans	Hot Water	Misc.	Total	kWh per m ²	
						Fans	Cooling	Heating						
OFFICE BUILDING	Offices	20750	7656	320	226	345	678	1010	23	207	-	5465	263	75%
	Service Areas	5405	893	38	-	-	-	-	118	-	-	1049	194	
	Computer	-	-	-	-	145	368	54	-	-	887	1458	-	
SHOPPING CENTRE	Offices	2591	299	41	28	75	300	59	-	-	-	802	310	15%
	Shopping	1770	214	29	-	65	282	50	-	-	-	640	362	
	Service Areas	120	33	3	-	-	-	-	52	-	-	90	750	
GARAGES	Parking	7723	56	7	11	-	-	-	466	-	-	540	70	6%
	Service Areas	51	52	3	-	-	-	-	-	-	-	55	965	
	Central Plant	2140	49	23	-	-	-	-	-	-	6	78	36	1%
	Total	40556	4254	464	265	634	1628	1173	659	207	893	10177	251	
			42%	4 1/2%	2 1/2%	6%	16%	11 1/2%	6 1/2%	2%	9%			
			42%	4 1/2%	2 1/2%	33 1/2%			6 1/2%	2%	9%			

$$\text{Average Monthly Consumption} = \frac{10177 \times 10^3}{12} = 848 \times 10^3 \text{ kWh}$$

FIG. 4.10 : Energy Consumption Allocation

The information in this table allows a full energy analysis of the building to be carried out.

Annual consumption figures for any sub-system for any part of the building can be calculated, as well as the average monthly consumption for the entire building.

With appropriate sub-metering of the subsystems, the actual consumption can be compared to the budget estimate.

4.4.1.6 Total Energy Budget

The average maximum demand and average monthly consumption reflects the total energy status (electrical) of the whole building.

Application of the relevant charges and tariffs enables the actual total energy budget to be calculated.

Figure 4.11 illustrates the derivation of a typical monthly account estimate.

If other sources of energy, such as oil, are used, the monthly costs may be added to the electricity costs, and the building's monthly energy costs obtained.

A) Demand kVA (Average max demand)		2 748
B) Units kWh (Average monthly consumption)		848 000
C) Number of Days		<u>30,4</u>
D) Service Charge	R	10
E) Demand Charge		
$= \frac{A \times R4,40}{\text{Power Factor}} = \frac{2748 \times 4,40}{0,88} \quad (\text{PF Correction})$		
	R	<u>13 740</u>
F) Unit Charge @ 1,60c/ kWh	R	<u>13 570</u>
G) Total	R	27 320
H) 7% Discount for H.V. Bulk	R	<u>1 912</u>
I) Monthly Account	R	25 408

FIG. 4.11 : Derivation of monthly account

4.4.2 INSTALL kWh AND HOUR METERS

4.4.2.1 Sub-Systems

In order to monitor the consumption of the various sub-systems, the building owner must meter each of these systems individually. The meters should be installed in each plantroom, on all major items of plant and equipment.

The meters will enable the following functions to be carried out :

- a) Comparison between actual consumption and estimated consumption
- b) Comparison between actual consumption and previously recorded consumption
- c) Accurate monitoring of the effectiveness of the energy conservation measures
- d) Quick and easy spotting of items that may have excessive consumption due to faulty controls or incorrect operation
- e) Spot checks to ensure that sub-systems do not operate wastefully (e.g. heating in warm weather).

4.4.2.2 Tenants

Large buildings are usually master-metered by the Supply Authority. This means that one central meter is installed by the Authorities. This meter is usually read monthly and an account for the total monthly consumption is rendered.

Consumers within the building are often not sub-metered and the owner provides the electricity "free" as part of the overall rental. Tenants thus also benefit from the bulk discount as the owner passes on this saving to make the rent more competitive.

(In residential areas, when individual consumers do not have monthly feedback and an economic incentive for conservation of electricity usage, their consumption usually increases).

The economic incentive to reduce consumption will be strongest if tenants are charged for their electricity separately to their overall rental and if they are metered individually.

In some offices, factors such as the lighting level, occupancy, thermostat settings and hours of operation are often determined by company policy and not by electricity consumption. Tenants should be encouraged to reduce their consumption even if this means a review of company policy.

Figure 4.12 illustrates the inter-relationship of the above elements :

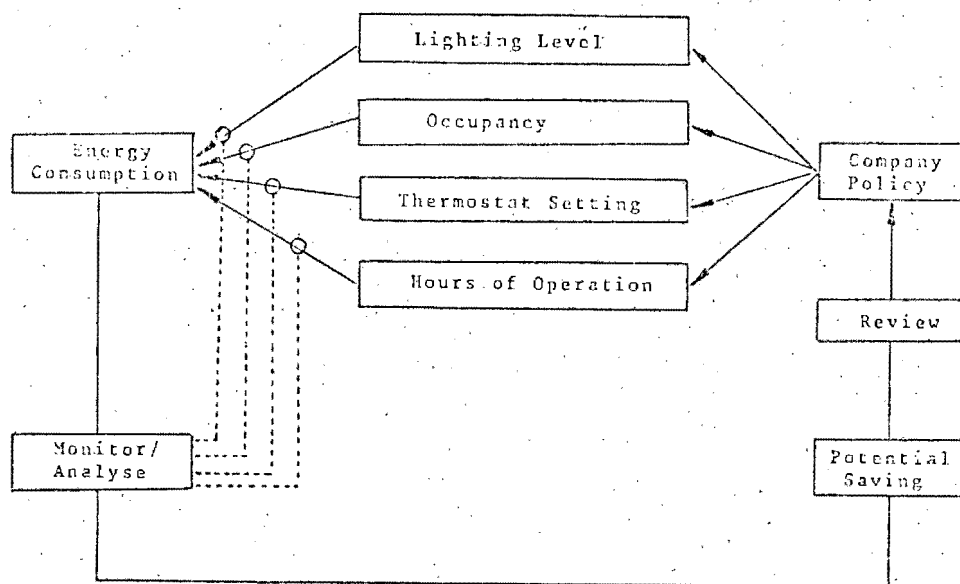


FIG.4.12 : Relationship between energy consumption and company policy

4.4.3 Reconcile Electricity Accounts with Budget

Comparison of electricity accounts with the budget estimate should be done on a regular basis.

Discrepancies between them should immediately be resolved. These may be simply explained, but can also identify areas where in-depth investigation is required.

If the actual account is above or below the budget, the reasons should be identified. Below-budget consumption can have serious consequences as this may be due to incorrect operation of equipment.

An air conditioning plant that is switched off too early to reduce energy consumption will lead to complaints from tenants and will adversely affect the "marketability" of the building.

Comparing the account with the budget will also enable the following aspects to be monitored :

- a) Wasteful use of energy
- b) Incorrect operation
- c) Selection of most suitable tariff
- d) Checking on tariff at which tenants are charged
- e) Faulty meters

B - ENSURE EFFECTIVE BUILDING SERVICES OPERATION AND MAINTENANCE

4.4.4 Appoint Manager of Engineering Services

A large building, complete with its services, but without suitable people to operate them, can be compared to a ship without a rudder as far as the operation and maintenance aspects are concerned.

These dynamic systems are vital to the smooth functioning of the building as a whole.

The replacement value of the equipment is very high, and they consume large amounts of energy.

Building owners in South Africa generally do not safeguard their large investments in building services. This is evident by the fact that many buildings have a single handyman who acts as plant operator, maintenance mechanic and general repair man.

To ensure effective operation and maintenance of all plant and equipment an Engineering Services Manager should be appointed on all large buildings. (For smaller buildings one person can look after several buildings).

This person must be responsible for ensuring that the building is correctly staffed, that energy consumption is minimised, and that the overall operation and maintenance is effectively carried out.

4.4.5 Appoint Building Technicians, Operators and Servicemen

The Engineering Services Manager must have adequate staff to ensure that the building services are kept in prime condition. Complaints must be dealt with promptly, while routine maintenance must be carried out according to schedule.

4.4.6 Provide Job Aids and Training Programme

In South Africa today post contract service from Contractors is generally poor. Upon completion of the project the services are handed over to the building owner or operator. The training he receives is minimal, and the operating and maintenance documentation is usually extracted from suppliers' catalogues and is often difficult to relate to the specific installation.

Thus, a thorough training programme should be implemented for the building operators, who must be taught to understand the building systems, generally, and must be trained to operate and maintain the particular installation.

Job-aids geared to the capability of the operator must be compiled. These job aids could also be used in the training process.

4.4.7 Record and Log Equipment and System Performance Daily

To ensure that malfunctioning and faulty items are detected as early as possible, the operator must record and log the plant daily. Faulty operation can result in expensive repairs and wastage of energy.

4.4.8 Analyse Logged Data and Correct Deviations

The data that the plant operator records must be regularly analysed by a responsible person such as the Engineering Services Manager. This will ensure that the plant is operated in accordance with the correct settings. Consumption figures must also be compared against the budget estimate. The reasons for any deviations must be established as soon as possible so that corrective action will have an immediate effect.

4.4.9 Implement Preventive Maintenance Programme

Maintenance embraces all work done to prevent, repair, or compensate for deterioration caused by use, by aging, and by accident. It also includes modification work done to enable plant to carry out its present task more reliably.

Most plant equipment maintenance is done on a failure basis - when the unit fails, repair work is then done to get it working again.

The maintenance staff become involved in urgent repair tasks, and there is little time left over to overhaul equipment or to correct minor, non-critical problems.

Preventive maintenance is not based on the failure approach. Rather than wait for a unit to fail, a preventive maintenance programme attempts to uncover problems and their causes while they are still minor, and before the equipment breaks down.

Although the maintenance staff workload and the maintenance costs may increase initially, in the long term this approach will be more beneficial. It will be possible to schedule the staff workload, and spares requirements will be easier to plan. The life of the plant will be increased, operating costs will be contained, and premature equipment failure due to frequent breakdown will be avoided.

Disruptions of building operations with possible loss of profits, lost rental income or penalty clauses within the lease will be reduced.

4.4.10 Employ Specialist Equipment Service and Maintenance Contractor

To ensure that each sub-system in the building is maintained by people with the necessary expertise, outside specialist contractors should be appointed.

A new approach to building air conditioning system maintenance has recently been introduced in South Africa. The entire maintenance of the plant is put into the hands of a specialist maintenance contractor who has to guarantee that the plant will not break down due to usage. In the event of a breakdown for reasons beyond his control, parts must be replaced within a specified time limit.

All repair and maintenance costs are borne by the contractor.

Although the building owner may face a relatively higher annual maintenance bill, there are major advantages that will offset this. The plant will be well-maintained and will operate efficiently, and this correct maintenance will increase the life of the plant, as well as optimise energy consumption. Further, the owner will not be presented with large repair bills when plant does break down, and he will be able to budget more accurately for annual maintenance.

4.4.11 Implement Reporting System for System Malfunctioning and Corrective Repairs

In large buildings with several operators and maintenance staff, a system must be implemented to ensure that the Engineering Services Manager is aware of all problems encountered with the services. Remedial repair work carried out must also be monitored by him.

A comprehensive reporting system will be a useful aid in ensuring that the reasons for malfunctioning equipment are identified and analysed. The appropriate action can then be taken, depending on whether the malfunction was caused by faulty equipment or maloperation.

C - UPDATE OPERATING AND MAINTENANCE DOCUMENTATION

An important job aid for the building operation and maintenance staff is comprehensive documentation. The existing documentation for the building sub-system should be reviewed and improved upon in accordance with the following guidelines. These guidelines should also be used when specifying the documentation to be submitted by the contractor

for new buildings :

- a) Provide technical schematics and systems geography in the building
- b) Update systems and equipment stopping, starting and emergency operating instructions
- c) Provide equipment logging and inspection instructions and reporting system
- d) Provide system malfunctioning diagnosis sheets
- e) Provide system description and trouble shooting guide

The efficient operation and maintenance of the service systems is described in block diagram in Figure 4.13 overleaf.

Efficient Operation and Maintenance of Systems

Reduce operating hours of equipment to minimum

Reset air temperatures and pressures under part load conditions

Ensure output is achieved with lowest possible process energy consumption

Maintain operating efficiency and reliability of equipment

Supervised skilled Operators, Inspectors, Technicians

- Documentation
1. System description
 2. Operating instructions
 3. Trouble shooting instructions

- Budgets
1. Monthly maximum demand
 2. Monthly unit consumption
 3. Monthly equipment operating hours
 4. Monthly costs/number consumables

- Operation & Inspection Aids
1. Instrument & meters
 2. Integrated control panel
 3. Remote position indicators
 4. Illuminated observation provisions

- Reporting System
1. Sub system log books
 2. Sub system inspection report forms
 3. Summary report forms
 4. Diary - narrative reports

FIG. 4.13 - Efficient operation and maintenance of building systems.

4.5 MODIFY AND IMPROVE THE BUILDING

A - REDUCE COOLING AND HEATING LOSSES THROUGH
THE FACADE OF THE BUILDING

B - IMPROVE BUILDING HOUSEKEEPING

A - REDUCE COOLING AND HEATING LOSSES THROUGH THE FACADE OF
THE BUILDING

4.5.1 Reduce Glass Area

Energy is supplied to the HVAC system to offset heat losses and gains in order to maintain the comfort conditions within the building.

The heat gain and heat loss vary with each day of the year and with every hour of the day. It varies with the orientation of the building, the geographic location, exposure to winds and usage, and will even be influenced by surrounding buildings.

A large amount of glass in the facade will lead to increased heat loss in winter and heat gain in summer, with a corresponding increase in energy consumption.

Figure 4.14 illustrates the heat gain variation due to a change in the percentage of glass in the facade in a typical building.

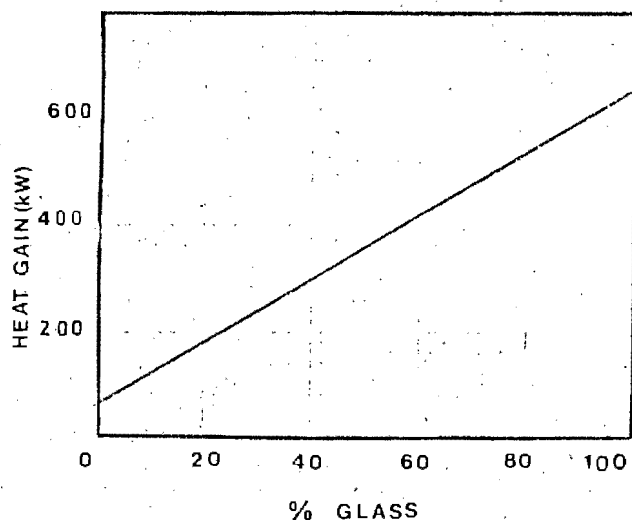


FIG. 4.14 : Solar heat gain.

The glass area of the facade should thus be kept to a minimum and should not exceed 25%. There is often an aesthetic problem in trying to reduce this glass area, but energy consumption considerations are now having greater influence on this subject.

4.5.2 Install Double Glazing, Improve Shading and Insulate Facade

The reduction of solar heat gains presents an important opportunity to reduce energy consumption in the entire building.

The sun's influence, starting in the east when tenants arrive, and moving to the west in the evening is high in the sky in summer and low in winter. Mechanical systems have difficulty in coping with this changing situation, and often supply air based on the maximum load.

To reduce the associated large energy consumption, the solar influence must be reduced as far as possible. This can be done by double glazing, by improving the shading devices on the building, and by insulating the facade.

Table 4.5 below illustrates the solar heat gain through glass for various types of glazing and shading devices. For example, a light colour venetian blind will reduce the solar heat gain through ordinary glass to 56%.

Type of Glass	Glass Factor No Shade	Inside Venetian Blind			Outside Shading Screen	
		Light Col.	Med. Col.	Dark Col.	Medium Colour	Dark Colour
ORDINARY GLASS	1,00	0,56	0,65	0,75	0,22	0,15
HEAT ABSORBING GLASS (48-56%)	0,73	0,53	0,59	0,62	0,16	0,11
DOUBLE PANE Ordinary Glass	0,90	0,54	0,61	0,67	0,20	0,14

TABLE 4.5 : Solar heat gain through glass

4.5.3 Make Facade Air Tight

If there are leaks in the facade of the building, the warm air in winter and cool air in summer will not maintain its temperature. Thus additional energy will be required to maintain the temperature requirements of the office space.

B - IMPROVE BUILDING HOUSEKEEPING

Efficient operation and maintenance of the building to ensure energy conservation is an ongoing process. The operator should inspect the entire area regularly, in accordance with the following guidelines. Where necessary, other building personnel should be instructed accordingly.

- a) Close curtains and blinds every night when cleaning building
- b) Instruct tenants in proper usage of shading devices and monitor their use
- c) Close doors (or install self-closing devices)
- d) Close windows
- e) Repair air leaks
- f) Reduce amount of lighting used by cleaners
- g) Switch off unnecessary lights
- h) Tour "used area" of building on a regular schedule and adjust wrong temperature settings

CHAPTER FIVE

APPLICATION OF AN ENERGY MANAGEMENT PROGRAMME

In order to investigate the merits of introducing an energy management programme on existing buildings, several buildings were surveyed and analysed, and the results are described in this chapter.

5.1 ENERGY SURVEY

Two approaches were considered and are discussed below.

5.1.1 Method A - Detailed Survey of Sub-Systems and Measurement of the Energy Consumption

This method requires an in-depth survey of the building to be carried out initially, to establish where the "load centres" are located.

Measurements and recordings are then taken of the actual consumption over a period of several days for each of the sub-systems, and for the building as a whole. Reconciling this data with the monthly energy consumption account rendered by the Authorities enables a complete and accurate energy profile of the building to be established.

The consumption can then be compared to the standard reference values for similar buildings, after making due allowance for any special non-standard operating characteristics of the particular building, such as after-hour operation.

If the resulting actual consumption figures are not in line with the reference values, an energy and/or operation investigation should be implemented.

This method of surveying a building will provide very accurate data. However, this is a costly process, as it involves skilled people for several days, and expensive recording equipment must be utilized.

5.1.2 Method B - Detailed Survey of Sub-Systems and Preparation of an Energy Audit

As with Method A, a detailed survey of the building sub-systems is carried out. The operation of these sub-systems and usage of the building as a whole are also investigated.

Using this information, an energy budget is then prepared. This budget is an estimate of what the energy consumption ought to be, provided that the building is being correctly operated and maintained.

Comparing this estimate to the actual consumption will establish whether there is scope for energy to be saved and whether the building is being correctly operated.

5.2 DATA COLLECTION

To assist in carrying out an energy survey, a comprehensive questionnaire was compiled. It had to be detailed enough to identify the important loads, but it also had to be sufficiently general to avoid collecting detailed time-consuming information on sub-systems, analysis of which would not significantly alter the energy profile of the building.

The scope of the questionnaire covers the building area, the electrical consumption, operation of the building, as well as the building structure and equipment load details.

A sample filled-in questionnaire is included in Appendix G.

Several buildings were surveyed on the basis of this questionnaire. The results of other buildings that were surveyed were made available and these results were also analysed on the basis of the questionnaire.

5.3 SELECTION OF BUILDINGS

The buildings that were surveyed are located in Cape Town, Johannesburg and Durban. They include commercial office buildings and shopping centres.

The buildings varied in age from 3-10 years and in total area from 20 000 m² to 50 000 m².

These buildings were selected as typical examples of the different categories of modern commercial buildings most common in South Africa today. Although nearly all the buildings were more than 80% let, the owners were very conscious of the amount of energy being consumed, and were interested in investigating methods of saving energy.

The offices had a high lighting level of between 500-700 lux (30-40 W/m²) over most of the nett usable space, and were served by a central air conditioning plant.

5.4 OPERATING AND MAINTENANCE DOCUMENTATION

Before an on-site inspection is carried out, it is always useful to study any documentation that may be available. This includes plans of the building, schematics of the sub-systems and operating and maintenance manuals.

This enables a comprehensive picture of the building and its sub-systems to be obtained, provided that reasonable documentation is available.

5.5 SITE INVESTIGATION

Several interesting problems arose when on-site investigations were carried out.

The building staff were often suspicious of the personnel undertaking the survey, in fear of criticism of the present method of operation and maintenance of the building. The surveying engineer requires the co-operation of the building staff and must be very tactful in his approach.

Very often the actual installation on site was found to be different to the information shown in the documentation. This was due to changes in the usage of the area, or caused by modifications implemented by the operating staff.

The observations described below were made when buildings were surveyed. They do not all apply to all the buildings, but are representative of the problems encountered.

5.5.1 Documentation

On buildings that were more than about three years old the operating and maintenance documentation was sub-standard. In some cases the original documentation was inadequate and in others it had not been updated in line with alterations to the premises.

5.5.2 Staff

On many buildings the number and qualification of the people responsible for operating and maintaining the sub-systems was well below what could reasonably be expected and justified.

Any breakdown or maintenance problems were usually attended to by outside contractors, and the owner had very little control over costs.

The building staff were not fully conversant with all the features of the sub-systems. They had not been properly trained and did not understand, for example, how some control systems were designed to operate.

5.5.3 Maintenance of Plant

On most buildings the plant and equipment showed signs of a lack of involved maintenance.

Detailed inspections of the installation as a whole, and of the equipment and its components, had often not been carried out since the plant was installed.

Thus defects such as

- corrosion on cooling towers
- worn bearings on pumps
- poorly fitting and dirty filters
- corrosion on coils and sumps
- slack belts and poorly aligned drives
- leaks

were not being revealed and repaired as soon as they occurred.

On newer buildings this would not have an adverse effect in the short term. However, if these defects are not attended to, expensive repair bills will result in the future.

5.6 CLASSIFICATION OF BUILDINGS

Each building surveyed had particular features that initially made the building seem a "special case". These features ranged from the physical location and construction of the building to the condition and type of the systems and equipment.

In order to group buildings into categories, a chart was compiled taking the general features encountered into consideration. This chart relates mainly to the thermal qualities of the building and to the type and energy efficiency operation of the air conditioning system.

This chart is illustrated in Figure 5.1 below:

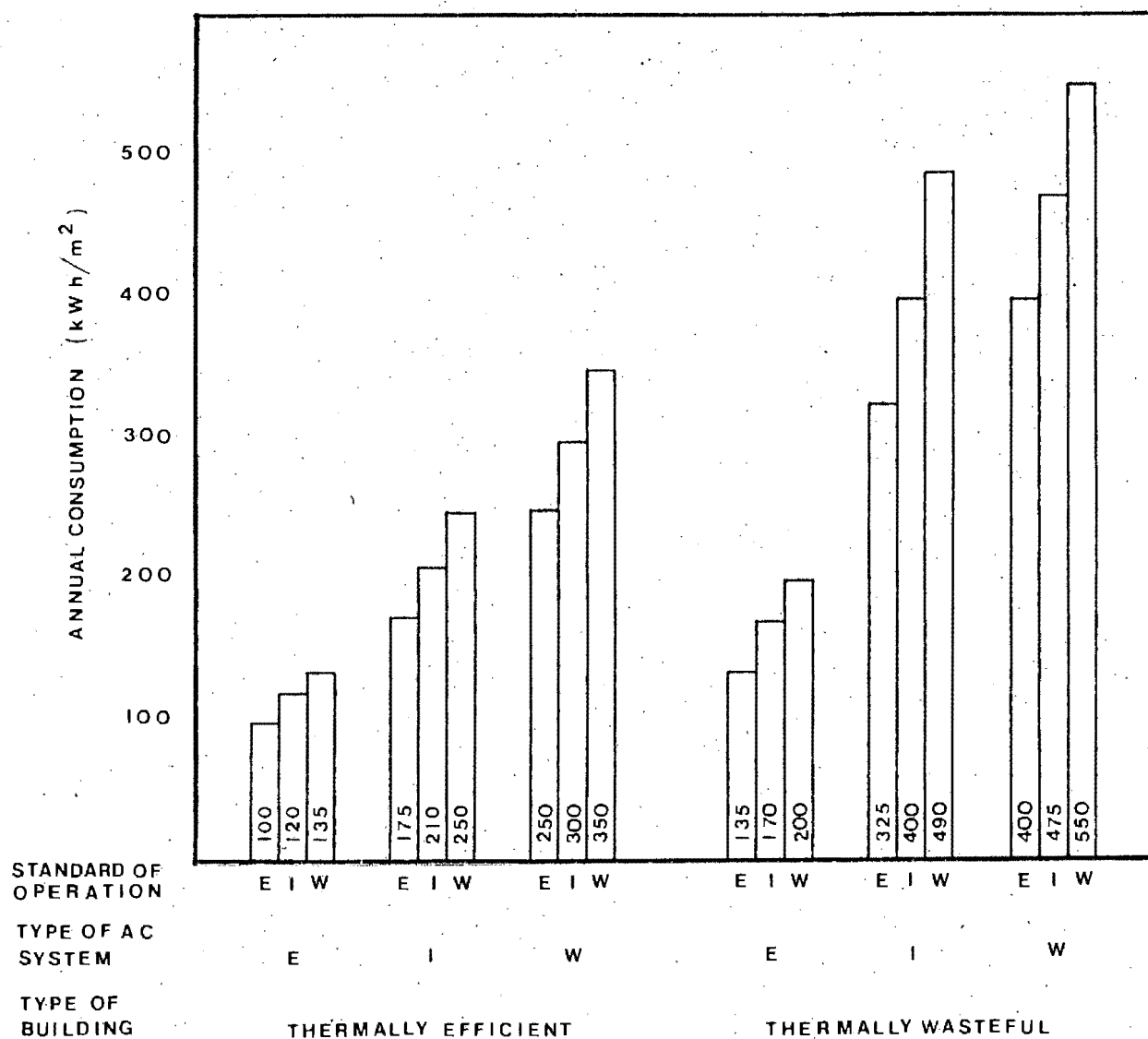


FIG 5.1 : Building classification and energy consumption
(E = energy efficient; I = energy inefficient;
W = energy wasteful)

The classification of the buildings surveyed into one of the above categories enables the actual consumption to be assessed on a realistic basis.

Thus a thermally efficient building with an energy efficient HVAC system and operated efficiently should have an energy consumption of approximately 100 kWh/m²/ annum.

The classification consumption figures have been derived from theoretical studies and published survey results and have been used as a guide only. In many buildings surveyed the difference between efficient, inefficient and wasteful systems and method of operation was difficult to distinguish.

5.7 IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

On all the buildings surveyed there were possibilities of conserving energy. In certain cases simple adjustments to control settings resulted in savings, while in others major modifications were required.

5.7.1 Preparation of Energy Budget

Having established the potential for energy savings, an energy budget was prepared for each building.

Preparation of the budget was based on the procedure outlined in Chapter 4, and included the maximum demand and unit consumption.

The completed budgets for several buildings are included in Appendix

These budgets are based upon the current way in which the building is being used, but assuming that the sub-systems are being operated correctly as designed. Thus, any weekend or after-hour operation, and other non-standard features, are allowed for.

Using the budget as the energy consumption target, an energy analysis was undertaken of each building. This analysis was assisted by using the energy conservation checklist as a guide (Appendix A).

Each potential energy saving modification was investigated in relation to the building. The cost of implementing each energy saving step varied between sub-systems and between buildings, as did the estimated savings.

5.7.2 Classification of Conservation Measures

To put these steps of the energy management programme into perspective, a classification system was introduced. This system categorises the steps into short, medium and long term items (Category 1, 2 and 3), and is based upon the simple payback formula of

$$\frac{\text{Estimated Capital Cost of Modification}}{\text{Estimated Annual Energy Saving}} = \text{Payback Period}$$

To bring the buildings into line with the "correct operation" energy budget, the modifications usually fell into Category 1, although on some buildings the cost of the modifications put the energy saving step into Category 2. Implementation of some Category 2 steps and most Category 3 steps would usually result in an improvement over the budget. A new budget would then be prepared, called an "energy efficient" budget. An example is included in Appendix H, together with the "correct operation" budget.

5.7.3 Energy Management Programme Sample Recommendations

Some sample steps from an energy management programme recommended on several buildings surveyed are described below. Further examples are included in Appendix.

5.7.3.1 Energy Management Programme Recommendation - Example A

Modify and Improve the Illumination System - Use More Efficient System

Introduce Task Lighting and Introduce Light on Work Surfaces.

In one building analysed it was recommended that instead of installing a uniform pattern of lighting, a task lighting installation would be more advantageous.

It was further recommended that luminaires incorporating highly polished aluminium parabolic reflectors be used. These Low Brightness Reflector luminaires are approximately 30% more efficient than the conventional luminaires with prismatic diffusers. (Luminaires with bare tubes are not usually permitted in offices because they create too much glare).

A waiver to the local regulations had to be obtained for the task lighting system. The regulations require that a uniform lighting level of 500 lux be provided over the whole of the interior office area. With a task lighting installation, 500 lux would only be provided over the desk area, and about 250-300 lux in the rest of the space. The waiver was readily granted and the installation is currently proceeding.

The use of task lighting is expected to save 15 W/m^2 of energy. Over the entire block this will result in a saving in energy costs of approximately R12 000,00 per annum.

The use of the Low Brightness Reflector luminaires has increased the capital cost of the installation. However, due to the resultant energy savings, this is expected to have a payback period of 2,25 years. The calculations are shown in Table 5.1 below.

Alt. Light Fittings	Standard 200 Watt (Prismatic Diffuser)	Low Brightness 100 Watt Al. Single Parabolic Reflector
Efficiency C.U. (for 70, 50, 10 Room Index 1.5) x Maintenance Factor	0,37	0,49
Number of fittings required for 16.500 m ² Nettable Area	1700	2500
Lighting Connected Load	340 kW	250 kW
Capital Costs Light Fittings	R85 000	R112 500
Running Costs M.D.+Unit Consumption (including Air Conditioning) Illumination Cons. x 1.3 Based on 3000 hrs/p.a. R4,50/kVA + 1,66 cents/kWh	R46 300	R 34 000
Pay back period at above electricity costs	0	$\frac{R27\ 500}{R12\ 300} = 2.25$ years

TABLE 5.1 : Payback Period to Install L B R Light Fittings

5.7.3.2 Energy Management Programme Recommendation - Example B

Modify and Improve HVAC System.

Ensure system operation at or near optimum efficiency with reduced building loads.

After-hours - Part System Operation.

Extended Operation of Supermarket.

The cost to provide air conditioning to a supermarket up to 20h00 on weekdays was investigated as part of the overall energy management analysis.

The results are summarised in Table 5.2 below.

MODE OF OPERATION	CAPITAL COST	TOTAL ANNUAL ELECTRICAL ENERGY COST
a) Fit positive shut-off dampers in branch duct to allow supply air to Supermarket only. b) Operate: Supply air fan Condenser water pump Chilled water pump One cooling tower fan One refrigeration compressor unit	R500,00	R37.444,00
As above, but provide smaller condenser and chilled water pumps to match load together with alterations to pipe work.	R5.000,00	R36.016,00
Provide complete self-contained plant to serve Supermarket.	R40.000,00	R35.302,00

TABLE 5.2 : Extended Operation of Supermarket

From Table 5.2 it is clear that the main plant ductwork should be modified to close off the supply air ducts serving the rest of the building. One supply air fan should be operated with one compressor of the standby water chilling set (Scheme 1).

5.7.3.3 Energy Management Programme Recommendation - Example C

Ensure Efficient Operation and Maintenance of Service Systems by Improving Operating Documentation.

As mentioned previously, on most buildings surveyed the operating documentation consisted of manufacturer's catalogue extracts and were unsuited to the operating staff.

It was recommended that the information from the "standard" maintenance manual be extracted, re-arranged and modified specifically for the plant operator, to enable him to run the plant at the lowest possible energy costs, while limiting tenant complaints.

It was recommended that this documentation be adapted to the skill and understanding of the operator, and that it should be used as a means of instruction and training. To be most effective, it was recommended that this documentation should incorporate the following information :

- 1) Description of the Building and its HVAC System
 - a) HVAC systems connected load matrix
 - b) Air conditioning - Technical Schematics :
 - Power Distribution
 - Chiller and Condenser Water Distribution
 - Air Distribution

Geography of Sub-Systems in the Building

- c) Ventilation
- d) Heating

2) HVAC Systems Operating Instructions

- a) Air conditioning -
Selection of equipment to be operated
Starting instructions - air handling units
and chillers
Emergency operating instructions
- b) Ventilation
- c) Heating

3) Systems Logging and Observation Procedures

- a) Air conditioning
- b) Ventilation
- c) Heating

4) System Malfunctioning Diagnosis Sheets

- a) Air conditioning
- b) Ventilation
- c) Heating

5) Diagrammatic Sub-System Description

- a) Air conditioning
- b) Ventilation
- c) Heating

5.7.3.4 Energy Management Programme Recommendation - Example D

Modify and Improve Building by Improving Shading.

The building surveyed had a building structure that was designed to provide shading of the glass areas during summer.

However, not all the glass areas were completely protected against direct solar heat gains. Thus the installation of a reflective film was evaluated. The financial implications were :

Approximate cost of reflective film	:	R15/m ² of glass area
Estimated Energy Saving	:	R1,60/m ² per annum

The modification would thus pay for itself within $\frac{15}{1,6} = 9,37$ years

At present day costs this modification was not worth considering.

5.7.3.5 Energy Management Programme Recommendation - Example E

Modify and Improve the Illumination System - Use More Efficient System.

Introduce Localised Light Switching.

An investigation was carried out into the possibility of installing a lighting control system that would monitor the average sum of the natural and artificial lighting. As the daylight increased, the system would reduce the amount of artificial lighting to the space.

The costs are summarized below :

1)	Lamps per floor	364
2)	Actual load (per floor)	17,29 kW
3)	Annual electrical consumption	38902 kWh x 18 floors
	based on 2250 hrs use per year	= 700245 kWh

4)	Design illuminance	500 lux
5)	Assumed daylight factor	3,6
6)	Reduction in use of electric lighting achieved by control	80%
7)	Dimmer rating	40 kVa per floor
8)	Control system cost (single zone system)	R4 176 per floor
9)	Additional cost of heater transformers	
	364 lamps @ R4,30	R1 565,20 per floor
10)	Total cost of fluorescent lighting control system	R5 741 per floor = R103 338,- for 18 floors
11)	Cost of installation per kW	R332
12)	Annual electricity consumption of installation at 20% of initial consumption	140049 kWh
13)	Electricity consumption by cathode heaters	
	5 x 2250 hrs x 364 lamps kWh	73710 kWh
	This is the maximum quantity of electricity consumed by the lamp heaters assuming they are on for 2250 hrs/year. In practice the figure will be lower because heaters will be switched off at times.	
14)	Total annual electrical consumption	213759 kWh
15)	Annual saving (line 3 minus line 14)	486486 kWh
16)	Effective reduction in electricity consumption	69%
17)	Annual reduction in running costs at 3,7 c per kWh	R17 999,98
18)	Period to recover costs (Line 10 ÷ Line 17)	5,74 years

In this particular case, the capital cost of the modification was relatively high and it was decided to reassess the situation when electricity tariffs are raised again.

5.7.3.6 Energy Management Programme Recommendation - Example F

Modify and Improve the HVAC System - Cool with Outside Air and Do Not Waste Energy on Unnecessary Large Volumes of Outside Air.

Use outside air, return air and relief damper (Economiser Cycle).

An air conditioning plant on a building was investigated. This plant operated continuously at 100% air and had been equipped with 132 kW of heating and a spray pump which appeared to run continuously. By converting to an Economiser Cycle, the heaters became redundant.

The following recommendations were made :

1. Install motorised fresh air, recirculation and exhaust dampers.
2. Install economiser control system.
3. Stop pump and remove eliminators to save pump and fan power and reduce maintenance (corrosion).

Estimated Cost	:	R2.500,00
Estimated Saving	:	R1.000,00 - R1.200,00 p.a.

CHAPTER SIX

POTENTIAL FOR ENERGY CONSERVATION

6.1 EXTENT OF ENERGY MANAGEMENT MEASURES

The results of the energy consumption analyses carried out on the buildings surveyed clearly indicate that the implementation of energy management programmes would lead to a definite conservation of energy.

In South Africa at present many building owners are choosing short-term solutions to their energy problems. Thus, quick payback items such as Power Factor Correction equipment is often installed as a solution. This equipment does not require any maintenance, and the savings are usually immediately apparent, with the overall payback period being between 12-24 months. Although in-depth and costly modifications are implemented less frequently, this situation is expected to change as energy costs increase.

6.2 SURVEY QUESTIONNAIRE

In undertaking energy consumption surveys, the comprehensive survey questionnaire proved to be an extremely useful aid, especially on the older (5 years and over) and larger buildings. On the older buildings it was difficult to obtain any operating and maintenance documentation, and that which was available was often out of date.

As the surveying engineer usually had a limited time in which to complete his work, the questionnaire enabled the important areas to be identified immediately and only the most relevant information was gathered.

The questionnaire and the subsequent transformation of the information into the energy budget enabled the entire building to be broken down into sub-systems that could readily be analysed.

6.3 EFFECTIVENESS OF ENERGY CONSERVATION GUIDELINES FOR NEW AND EXISTING BUILDINGS

The application of the recommendations of the energy conservation checklist could often not be easily implemented. Many existing installations could only be converted or modified at great expense, which would have resulted in a long payback period.

Thus many of the energy conservation guidelines are more suitable for inclusion in the design of new buildings than for the retrofitting of existing ones. This applies particularly to items that do not immediately show any energy savings, or that do not have any apparent savings, such as the installation of sub-meters, effective operation and maintenance and optimum equipment selection.

The above notwithstanding, many of the energy conservation measures recommended could be applied to all the buildings surveyed.

An example of the effect on energy consumption of the implementation of an energy management programme is shown in Figure 6.1 below.

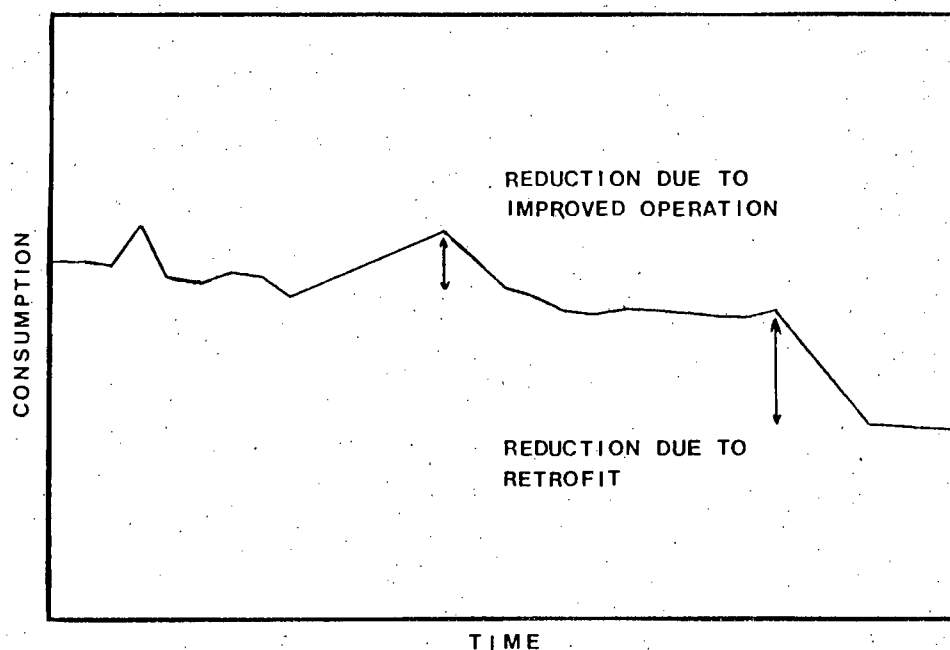


FIG. 6.1 : Consumption reduction due to energy management

Immediate energy savings were achieved by readjusting the controls and improving the operation of the sub-systems, particularly the air conditioning system. Subsequent larger savings were made possible after an in-depth analysis of the building and its sub-systems, and the implementation of the energy management programme recommended.

It was generally found that energy savings in the order of 10% to 20% could be achieved by implementing short-term and medium-term recommendations. Long term recommendations (10 years and over payback) would result in a further saving of approximately 10%.

The calculated results of the implementation of the conservation recommendations generally agreed with the savings predicted in the theoretical analysis on the model building.

6.4 FACTORS INFLUENCING PRESENT ENERGY USAGE

It was interesting to observe the many possibilities that exist in most buildings in South Africa today for energy conservation.

Although many building owners and operators interviewed were fully aware of the possibilities of saving energy and of the rapidly increasing costs of energy, very few had actually implemented any significant modifications and improvements to their buildings.

While undertaking the energy surveys an attempt was made to identify the reasons for this apparent inaction and the following observations were made and conclusions drawn :

6.4.1 Cost of Energy

Energy had always been cheap and its use uncontrolled and unmonitored. There appeared to be little awareness of the amount and proportion consumed by the building sub-systems. With the recent sharp price

increases, a new understanding and appreciation had to evolve, and this has taken time to overcome the inertia of the previous operating methods and procedures.

6.4.2 Post Contract Professional Advice

On most buildings the normal procedure at the end of the contract has been for the building and its sub-systems to be tested, commissioned and handed over to the owner. The Consulting Engineer's involvement was virtually terminated, and it was left to the building operator and the maintenance contractor to operate and maintain the plant and equipment.

The operator's priority was to ensure that the plant operated satisfactorily so that tenants did not complain. This was done regardless of the amount of energy consumed and regardless of whether the plant was actually operated correctly, as designed. Thus any energy conserving features of the design that were not fully understood by the operator were simply ignored and the benefits lost.

6.4.3 Design

In designing a complete building that will only be occupied in the future by as yet unknown tenants, the designer requires considerable skill to accurately estimate the total anticipated load of the building sub-systems.

For example, in sizing air conditioning equipment, the engineer must allow for average as well as peak conditions. Naturally, the lower the estimated load, the smaller the capacity of the equipment required, and hence less energy will be consumed.

Building owners rely fully on the engineer for correct sizing of the plant, and the consequences of undersizing a plant appear to have influenced many designers to specify plants that cater more for peak rather than average conditions.

During many months of the year these plants do not operate near their full load which results in their inefficient running and, thereby, in an energy wasteful situation.

6.4.4 Owner and Operator

In many property development organizations there appears to be a very definite dividing line between the development department and the operating and maintenance staff. The personnel staffing these departments often come from very different backgrounds and there is a noticeable lack of co-operation and integration between them.

Some organizations have attempted to overcome this problem by involving the maintenance staff in the design process of the building. Thus, any energy saving proposals and criticism of equipment manufacture or layout can be considered by the design team prior to the construction stage.

It also has the advantage of allowing the operating staff to fully understand the design philosophy of the installation, especially as regards energy saving techniques.

6.4.5 Authorities

Unlike their counterparts in many countries abroad, South African authorities (local and national) do not appear to have the same concern over their own specific energy costs and over those of the commercial sector generally.

In considering new designs, energy consumption as well as operating and maintenance costs do not appear to have a major influence and serious attempts are not made on existing buildings to regulate these costs.

In addition, designers have to contend with building by-laws that are outdated and unrealistic. For example, the minimum requirements are prescribed specifically with regard to the illumination and air conditioning systems and there is no scope for a "performance specification" approach.

As these by-laws are restrictive, they can lead to inefficient usage of space and wastage of energy.

It is encouraging to note however, that in recent months a reappraisal of these building by-laws has taken place and waivers have been readily granted when properly motivated.

6.5 REVIEW OF RESULTS IN RELATION TO PUBLISHED LITERATURE

The results of the calculations carried out on the buildings surveyed agree generally with the main observation made by others on this subject, that the principal savings potential in energy consumption in large buildings can be made on the air conditioning system.

In the literature surveyed, detailed examples of energy conservation measures applied to commercial buildings were difficult to find. The data published was usually for a sector of the economy as a whole, and was not concerned with the sub-systems of a particular segment.

Where case studies were available, they generally dealt with several buildings and showed the overall savings achieved. The reports do not deal with specific steps implemented on each building and the associated energy savings.

Many reports describe in great technical detail modifications to components and circuitry of a specific item of equipment that resulted in less use of energy. There is an abundance of this type of report available, mainly in overseas technical journals. Total energy management programmes, using a systems engineering approach and describing in detail the steps implemented and the resulting savings, along the lines of this thesis, were not generally available.

6.6 GENERAL PARAMETERS FOR ENERGY ECONOMY

The subject of energy management in buildings is very vast, and can be dealt with on many levels, ranging from the broad conceptual approach regarding the use and location of the space, to a detailed engineering examination of individual items of equipment.

This project is mainly concerned with the application of energy management programmes to existing buildings, and with the application of the guidelines to new building design, while maintaining in all cases a systems engineering approach.

The following items should be considered when investigations are carried out into energy economy :

6.6.1 Building Sub-Systems

The energy management programme described is concerned mainly with the lighting, air conditioning and hot water systems. Other energy consuming items such as pumps and lifts offer very little scope for energy economy.

Lifts may, for example, be prevented from operating during quiet periods, but the energy consumption will not change significantly as the remaining lifts will run more frequently.

6.6.2 Tenant Management

Building tenants should not be allowed uncontrolled use of building energy. This is particularly relevant for after-hour operation. In addition to the cost of lighting energy, tenants should be charged for the use of air conditioning plant. This latter charge should comprise an operating and maintenance part, as well as a cost incurred by the owner to replace the plant with a shortened life due to the extra hours of operation.

6.6.3 Annual Energy Consumption

Fig. 6.2 below illustrates the range of energy consumption of typical thermal efficient and inefficient office buildings.

In America and Europe an energy consumption target of $175 \text{ kWh/m}^2/\text{annum}$ has been promoted.

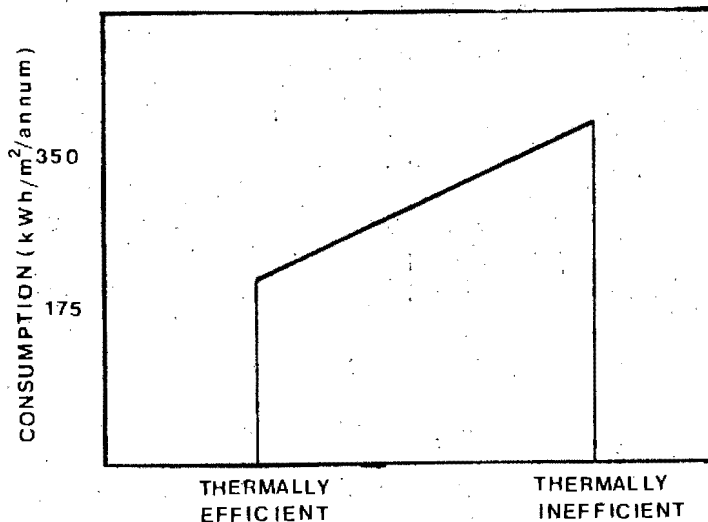


FIG. 6.2 - Range of consumption for typical buildings.

6.6.4 Award Price Formula

In America, the General Services Administration make use of an Award Price Formula in evaluating building tenders,

This formula takes into consideration the following costs :

- a) capital
- b) maintenance
- c) space adjustment
- d) energy
- e) luminaire relamping

In South Africa more emphasis should be place on a similar approach to building design evaluation.

6.6.5 Automatic Energy Management Controllers

Automatic control units are being used with increasing frequency for building energy management. These units monitor the consumption and automatically shed non-essential loads if a predetermined limit is about to be reached. Further savings are achieved by load cycling and pre-programmed switching control. Whereas the cost of these microprocessor based units may be justifiable in terms of the savings achieved, in many cases these savings are due to energy cost reductions and not due to more efficient use of energy.

6.6.6 Solar Energy

Solar energy has not had a great impact on commercial buildings. The main area where this could be readily applied is on the hot water system. The payback period for solar assisted systems is in the order

of 3-6 years, and as energy costs increase and as the reliability of the solar systems improve, one can expect to see a wider application of these systems.

CHAPTER SEVEN

CONCLUSION

The world has experienced rapid increases in the cost of energy over the past 6 years, together with many warnings of likely depletion of traditional energy sources if the current rate of consumption continues.

The cost of energy has become a significant factor in the total owning and operating costs borne by building owners, and this has led to an increased awareness of the potential for energy conservation.

Investigations carried out on South African Buildings with the broad aim of energy conservation have revealed that many buildings are operated inefficiently, resulting in an uncontrolled and wasteful use of energy and a rapid deterioration in the condition of the plant.

Further analysis has resulted in the identification of three major areas where efficiency can be improved, namely:

- a) Reduction in energy consumption
- b) Improvement of operation and maintenance methods
- c) Reduction in energy costs

The complex interaction between building sub systems, and between the components of individual sub-systems, required that a systems engineering approach be followed in analysing these buildings.

A total energy management programme was formulated, and a comprehensive set of energy management measures and guidelines was compiled.

Application of these measures to a hypothetical model building indicated that short to medium term energy reductions of 10% - 20% would not be difficult to achieve. The model building was chosen as being representative of typical modern commercial office buildings in South Africa.

The energy management programme was applied to several existing buildings, and the results achieved generally agreed with the predicted outcome.

On some buildings only a limited application of the programme could be implemented, due to restrictions imposed by the existing building and services design.

The maximum benefit would naturally be achieved if the guidelines are followed during the design process for new buildings.

Principles of energy conservation should play a more important role in the management and administration of new and existing buildings. The following specific recommendations should be investigated further:

- a) Building Code - A set of building guidelines should be developed setting energy consumption limits for various types of buildings. To encourage the modification of existing buildings to bring them in line with these guidelines, tax concessions should be made available.
- b) Consumption Data - Building owners and users should be made aware of the importance of minimising energy usage. This can be done by disseminating information on actual energy consumption and on possible reductions that can be achieved.
- c) Operation and maintenance - More attention should be given to training suitable people to operate and maintain buildings. Owners should be made aware that this is one of the best investments they can make, and that ultimately they will be contributing to a reduction in the country's energy demand.
- d) Capital expenditure - Building developers should be encouraged to consider designs in terms of life cycle costing, including energy consumption, rather than in terms of first costs only.

- e) Leases - Lease clauses dealing with energy consumption should be carefully compiled. Energy should be charged for separately for each individual tenant. Although competitive conditions in the letting market today may make it advantageous to include energy costs in rentals, many leases signed on this basis will still be valid when the surplus of accommodation ends, and opportunities to encourage energy conservation will have been lost.

The current approach to building design and operation in South Africa should be reappraised in accordance with the above recommendations, with the objective of minimising energy consumption.

APPENDIX A

CHECKLIST OF ENERGY CONSERVATION MEASURES

1. MODIFY AND IMPROVE THE ILLUMINATION SYSTEM

A - USE MORE EFFICIENT SYSTEM

- 1.1 Select efficient light fittings.
- 1.2 Introduce Task Lighting and concentrate the light on work surfaces.
- 1.3 Introduce localised light switching.
- 1.4 Switch off lights at lunch times.
- 1.5 Introduce central master over-riding switching.
- 1.6 Introduce controlled 'after and before' hours cleaning lighting switching.
- 1.7 Introduce kWh meters

B - OPERATE ILLUMINATION SYSTEM EFFICIENTLY

- 1.8 Maintain and clean light fittings on a regular routine basis.
- 1.9 Remove unnecessary light fittings.
- 1.10 Remove unnecessary lamps.

2. MODIFY AND IMPROVE THE HVAC SYSTEM

A - ELIMINATE SIMULTANEOUS HEATING AND COOLING OF A ROOM OR ZONE

- 2.1 Convert double duct, multizone or terminal reheat systems to variable volume constant temperature systems.
- 2.2 Control perimeter heating by outside air master control
- 2.3 Use only water sprays for humidification
- 2.4 Eliminate heating in interior zones.

B - ENSURE SYSTEM OPERATION AT OR NEAR OPTIMUM
EFFICIENCY WITH REDUCED BUILDING LOADS

- 2.5 Use multiple refrigeration machine systems with auxiliaries (pumps and cooling tower) which operate (and shut down) as the load decreases.
- 2.6 Cycle at full load and stop and start manually.
- 2.7 Use speed control on pumps and supply fans whenever possible on varying demands.
- 2.8 Monitor and if necessary relocate sensing points of capacity control system.
- 2.9 Reset supply air temperatures under part load conditions.

C - COOL WITH OUTSIDE AIR WHEN POSSIBLE AND DON'T WASTE ENERGY
ON UNNECESSARY LARGE VOLUMES OF OUTSIDE AIR

- 2.10 Use outside air, return air and relief damper (Economiser Cycle).
- 2.11 Use spray coils or air washers for evaporative cooling.
- 2.12 Reduce quantity of outside air to zero or minimum during 'before and after' hour periods, and when on cooling or heating cycle.
- 2.13 Use outside air for pre-cooling building at night whenever possible to reduce maximum demand.

D - SELECT EQUIPMENT FOR EFFICIENT OPERATION INSTEAD
OF ONLY FIRST COSTS

- 2.14 Use life cycle costing - capital, energy and maintenance costs in selecting equipment.
- 2.15 Modify ducting system for lowest practical static pressure to reduce fan kW.
- 2.16 Select piping, auxiliaries and heat exchangers for lowest practical pressure loss to reduce pump kW.
- 2.17 Select heat exchange surfaces (condensers, evaporators, cooling coils) for lowest kW.

E - INTRODUCE EQUIPMENT TO REDUCE USAGE OF 'NEW ENERGY'

- 2.18 Use air purifying systems instead of outside air.
- 2.19 Use heat reclaim devices (double circuit condensers) on air water systems.
- 2.20 Use air heat recovery systems.
- 2.21 Use 2 stage evaporative cooling systems in dry climate instead of refrigeration.
- 2.22 Use 'Heat' and 'Cold' storage - (water, rocks) on daily or seasonal cycle whenever practical.

3. MODIFY AND IMPROVE HOT WATER SYSTEM

A - USE MORE EFFICIENT SYSTEM

- 3.1 Reduce heat losses - improve insulation.
- 3.2 Use efficient heat exchanger.
- 3.3 Run at lowest possible temperature.
- 3.4 Use cheapest possible fuel.
- 3.5 Reduce heating losses during periods of 'low' or 'no' demand.

B - OPERATE EFFICIENTLY

- 3.6 Monitor controls and operate at lowest possible temperatures.
- 3.7 Reduce consumption through leaking taps.

4. ENSURE EFFICIENT OPERATION AND MAINTENANCE OF SERVICE SYSTEMS

A - ENFORCE ENERGY CONSERVATION

- 4.1 Prepare Energy Consumption budget.
- 4.2 Install kWh and Hour Meters.
- 4.3 Reconcile Electricity accounts with budget.

B - ENSURE EFFECTIVE BUILDING SERVICES
OPERATION AND MAINTENANCE

- 4.4 Appoint Manager of Engineering Services.
- 4.5 Appoint Building Technicians, Operators and Servicemen.
- 4.6 Provide Job Aids and Training Programme.
- 4.7 Record and Log Equipment and System Performance daily.
- 4.8 Analyse logged data and correct deviations.
- 4.9 Implement preventive maintenance programme.
- 4.10 Employ Specialist Equipment Service and Maintenance Contractor.
- 4.11 Implement reporting system for system malfunctioning and corrective repairs.

C - UPDATE OPERATING AND MAINTENANCE DOCUMENTATION

- 4.12 Provide Technical Schematics and Systems Geography in the building.
- 4.13 Update Systems and Equipment stopping, starting and Emergency Operating Instructions.
- 4.14 Provide Equipment Logging and Inspection Instructions and reporting system.
- 4.15 Provide System Malfunctioning Diagnosis Sheets.
- 4.16 Provide System Description and Trouble Shooting Guides.

5. MODIFY AND IMPROVE THE BUILDING

A - REDUCE COOLING AND HEATING LOSSES THROUGH
THE FACADE OF BUILDING

- 5.1 Reduce Glass area.
- 5.2 Install Double Glazing, Improve shading and Insulate facade.
- 5.3 Make facade air tight.

B - IMPROVE BUILDING HOUSE KEEPING

- 5.4 Close curtains and blinds every night when cleaning building.
- 5.5 Instruct tenants in proper usage of shading devices and monitor their use.
- 5.6 Close doors (or install self-closing devices)
- 5.7 Close windows.
- 5.8 Repair air leaks.
- 5.9 Reduce amount of lighting used by cleaners.
- 5.10 Switch off unnecessary lights.
- 5.11 Tour 'used area' of building on a regular schedule and adjust wrong temperature settings.

APPENDIX B

COMPARISON IN EFFICIENCY BETWEEN FLUORESCENT LUMINAIRES WITH:

A) PRISMATIC DIFFUSER, AND

B) LOW BRIGHTNESS SINGLE PARABOLIC ALUMINIUM DIFFUSER

	Prismatic Diffuser	Low Brightness Reflector
(1) Coefficient of Utilisation (Room Index : 1,5 Reflectances : Ceiling- 70% Walls - 50% Floor - 10%)	0,44	0,52
(2) Maintenance Factor	0,84	0,94
(3) Overall Efficiency (= (1) x (2))	0,37	0,49
Increased efficiency		32%

APPENDIX C

LIGHTING CONTROL SYSTEMS

SYSTEM 1 - LOCAL AND GENERAL CONTROL USING RELAYS

This system is suitable for both cellular and open plan offices. It can be readily adapted as the space is rearranged, and can be easily altered as partitions are moved and switching requirements changed.

The office floor is divided into a number of modules of approximately 2-3 square metres in area. Two relays are installed in each module, as usually each module can accept a light fitting. One relay is for control of the light fitting and the other will be controlled by the local switch.

All the relays are interconnected via a grid of switching control wires, which in turn pass through two "on-off" switches per module.

Once the switching arrangement has been selected, the two "on-off" switches of each module are set, and the relay controlling the local switch to be used is "primed" by insertion of a coil across the terminals. The local switch designated will thus control the number of modules comprising the area to be switched.

To change the switching arrangement the "on-off" switches are simply re-set and the local switch relays adjusted accordingly.

This type of system is generally expensive to install. A wiring network has to be installed throughout the space and the relays and switches have to be added.

SYSTEM 2 - PROGRAMME CONTROL

The programme control system is used mainly to reduce energy consumption by reducing the lighting level through the use of automatic dimmers.

Each floor is divided into several zones, each zone being controlled by a dimmer. At predetermined times the artificial lighting is changed to suit the usage of the space. Thus, at, say, lunchtime, the lighting level would be reduced to 40%.

Overriding facilities have to be provided in case the natural lighting is insufficient. This type of system is usually expensive to install and cannot be easily adapted to changes in the use of the space.

SYSTEM 3 - PHOTOELECTRIC CONTROL

The area is divided up into individual zones. Each zone has a sensor mounted on the ceiling which measures the combined reflected artificial light and natural light. This lighting level is compared to a preset level by a controller unit, which then causes the level of the artificial lighting to be adjusted via a dimmer.

This is shown diagrammatically in Figure C.1 overleaf.

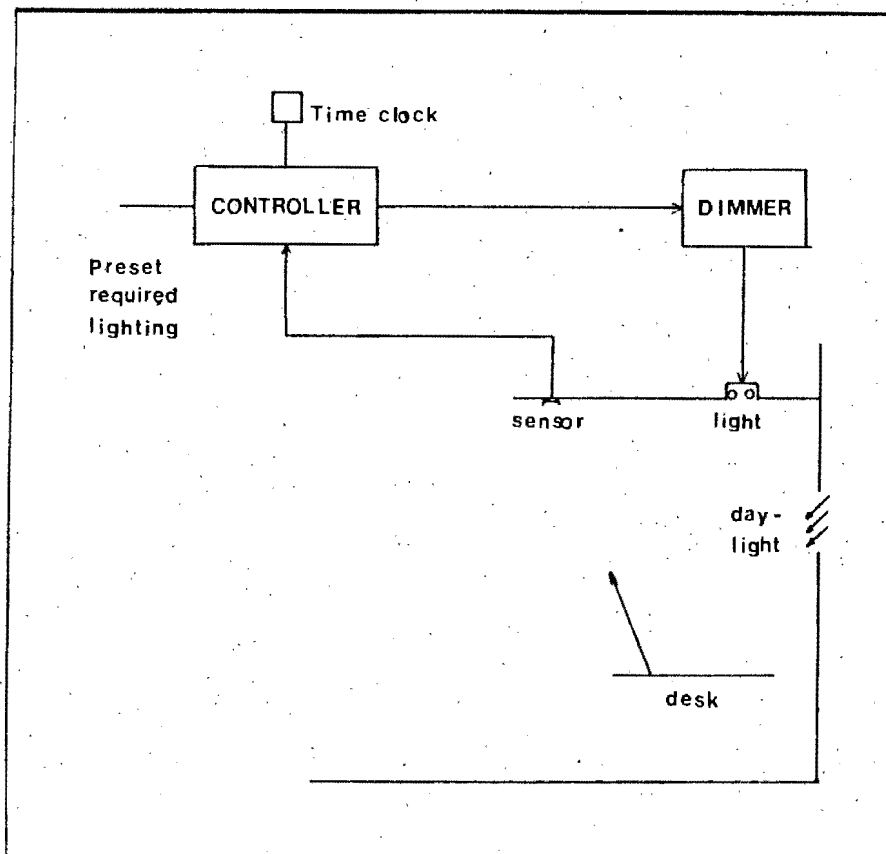


FIG C.1 : Photoelectric Lighting Control

This system is particularly useful in areas where a large quantity of daylight exists.

It can also be combined with a central programmer which will operate the system automatically along, for example, the following lines:

- 08h30 - switch on system (working days only)
- 17h30 - fade system to $\pm 20\%$ output
- 17h45 - switch off all lights
- allow corridor lights to be 2-way locally switched

Should staff wish to work late, they can override the system and this can also be monitored by the security staff.

SYSTEM 4 - ELECTRONIC GROUP CONTROL

This system comprises a number of electronic "slave" modules that each control the lights in particular sections of the buildings. The size of these sections depends upon the complexity of the control required. The system can be built up to provide any lighting control facility, such as dimming, master control and automatic switching, by selection of the appropriate modules.

This system is best suited to large single tenancy offices or buildings, where the initial installation and its control can be planned around the user's requirements. The advantage of this system is that energy consumption will be kept to a minimum. However, alterations to the lighting system may require adjustments to be made to the slave modules and changes to the mains wiring.

APPENDIX D

COST EFFECTIVENESS OF INSTALLING LOCAL SWITCHES TO INTERMITTENTLY OCCUPIED AREAS

In the reference building the estimated pay back period of installing local switches was approximately 22 months, based upon the following calculation :

Area of floor to be locally switched :	210m ²	(25%)
No. of local switches required	: 6	(1 per 35m ²)
Estimated cost of installation	: R 300,00	(R1,40/m ²)
Estimated reduction in energy consumption	: 40%	(48 kWh/m ² /per annum)
Payback period (@ 1,6c/kWh)	: $\frac{R1,40}{48 \times R0,016} = 22 \text{ months}$	

In addition to the above direct saving in lighting energy, there may also be a reduction in air conditioning power and in the maximum demand.

APPENDIX E

COST EFFECTIVENESS OF SWITCHING OFF LIGHTS AT MIDDAY ANNUAL SAVING ON MODEL BUILDING

- a) Percentage of lights switched off : 80%
- b) Duration : 45 mins.
- c) Days per annum : 260 days
- d) Floor area : 830 m²
- e) Lighting load : 40 W/m²

Energy saving = a) x b) x c) x d) x e) = 5100 kWh/floor/annum

@ R0,0166/kWh = R85/floor/annum

Cost of modification:

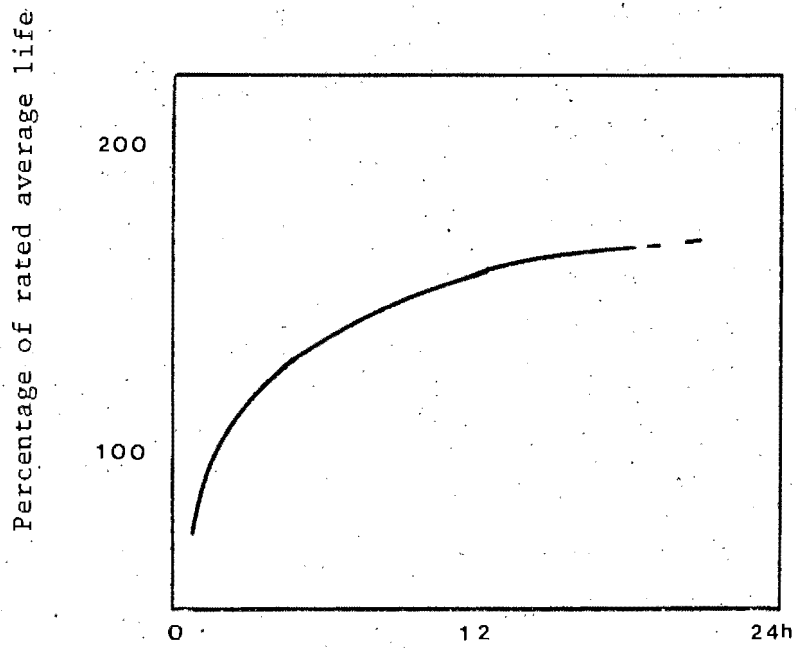
Time clock	R60
Alterations	50
Labour	<u>32</u>
	R142

$$\text{Pay back period} = \frac{R142}{85} = 20 \text{ months}$$

APPENDIX F

EFFECT OF SWITCHING ON LAMP LIFE FOR

FLUORESCENT LAMPS



The effect of switching on lamp life

APPENDIX G

SAMPLE FILLED-IN ENERGY SURVEY QUESTIONNAIRE

UNIVERSITY OF CAPE TOWN

ENERGY RESEARCH INSTITUTE

Date: Sept. 1977

ENERGY CONSERVATION IN LARGE BUILDINGS -- STEPHEN CARLIN

ENERGY SURVEY QUESTIONNAIRE.

For any further information please telephone Stephen Carlin : 43 7281

PART A - AREA AND ELECTRICAL LOAD.

1. AREA

	No. of Floors	Gross Area per floor (m ²)	Gross Area (m ²)	Lettable Area per Floor(m ²)
1.1 Tower - lettable area	28	1173	32844	972
1.2 Podium -Offices				
1.3 Podium -Shops			1664	1317 (Tot)
1.4 Podium-Other Use (Please specify)				
1.5 Basement - parking	3		11640	11000(Tot)
1.6 Basement - Other use (Please specify)				
1.7 Machine Rooms	2		1944	
1.8 Other(Please specify)				
		TOTAL AREA	48.092	

2. ELECTRICAL LOAD

2.1 Installed Transformers : 5000.... kVA

- 2.2 Tariff : ☐ Large User Rate (Rate No. 4)
☐ H.V. Large User Rate (Rate No. 5)
☐ General Rate (Rate No. 2)
☒ Other (Please Specify) H.V General (Rate No. 9)

2.3 Consumption :	Units x 1000	kVA	
June		...	
July		...	
August		...	
September		...	
October	594..	...	
November	606..	...	
December	597..	...	
January	657..	...	1975/76
February	645..	...	
March	642..	...	
April	666..	...	
May	564..	...	
June	543..	...	
July	618..	...	
August	588..	...	
September	576..	...	

Winter Max Demand: 2.8 MVA

Building Being Converted to Rate No. 5

ENERGY SURVEY QUESTIONNAIRE.

PART B - BUILDING DETAILS.

This form should be completed for each of the areas listed in items 1.1 to 1.8. in Part A, where relevant.

1. DESIGNATION OF AREA

Tower.....
.....

2. OPERATING HOURS FOR AIR CONDITIONING PLANTS

Weekdays : Start .7.a.m. Stop .6.p.m.
Saturday : Start 7 a.m. Stop 12.30 p.m.
Sunday : Start Stop

3. OPENING WINDOWS / NON-OPENING WINDOWS

...Non-opening.....
.....

4. TYPE OF SHADING DEVICE

(Venetian blind, Vertical Shades etc.)

...40° External Corner Overhang.....
.....

5. SWITCHING OF LIGHTS

(Bank, Individual)

...Bank - 4 Zones - 4 Banks/Zone (16 Switches)...
.....

6. FORM OF HEATING

(Electric, Oil, Gas, etc.)

...Diesel...(R3223,00/annum).....
.....

ENERGY SURVEY QUESTIONNAIRE

PART C - BUILDING DETAILS AND EQUIPMENT LOADS.

This form should be completed for each of the areas listed in items 1.1 to 1.8 in Part A, where relevant.

1. DESIGNATION OF AREA : Tower
2. IS ROOF INSULATED ? : Concrete Air Gap
3. FACADE AREA : (GROSS EXTERNAL) : 16260 m²
4. %AGE GLASS AREA IN FACADE : 47%
5. TYPE OF GLASS : Clear Laminated
6. ORIENTATION OF FACADE : 25 %N 25 %E 25 %W 25 %S
7. FRESH AIR SUPPLY QUANTITY TO LETTABLE AREA : 60.000 CFM 36.000 m³/hr
8. TYPE OF A.C. SYSTEM : Induction Ext Zone V.V. Internal
9. ECONOMISER CYCLE : ✓ YES NO

10. HUMIDIFICATION : ✓ YES ----- NO
11. TYPE OF HUMIDIFICATION : Spray Coil
12. TOTAL INSTALLED LETTABLE AREA
ELECTRIC LIGHTING LOAD : 787 kW
13. ILLUMINATION LEVELS FOR LIGHT
COLOURED FINISHES : 500 Lux 13 Upper Floors 750 Lux
1 - 15: 2
14. NO. OF LAMPS PER FITTING (LETTABLE AREA) : 16 - 28: 3
15. NO. OF FITTINGS (TOTAL) (LETTABLE AREA) : 228 x 28 = 6384
16. WATTS PER LAMP : 40 W U-Tube
17. ESTIMATED BURNING HOURS PER WEEK : 60
18. TOTAL ESTIMATED LETTABLE AREA
SMALL POWER AND EQUIPMENT ELECTRICAL LOAD : 2W/m²
19. TOTAL ESTIMATED HOT WATER CYLINDER
ELECTRICAL LOAD : 60 kW
20. TOTAL A.C. SUPPLY AND RETURN AIR FAN kW
SERVING LETTABLE AREA : 300 kW
21. TOTAL A.C. CHILLER kW SERVING LETTABLE AREA : 2 x 500 kW
22. TOTAL A.C. SPRAY PUMPS kW SERVING
LETTABLE AREA : 6 x 3½ kW

23. TOTAL A.C. CHILLED WATER PUMPS kW
SERVING LETTABLE AREA : 2 x 50 kW
24. TOTAL A.C. CONDENSER WATER PUMPS kW
SERVING LETTABLE AREA : 2 x 75 kW
25. TOTAL A.C. / HEATING CAPACITY LETTABLE AREA : 1200 kW
26. TOTAL ELECTRIC LOAD - SERVICE / PASSAGE / TOILET
AREAS : 5.6 kW
27. TOTAL VENTILATION FANS kW : 25 kW
28. TOTAL LIFT kW : 680
29. TOTAL AUXILIARY PUMPS kW : Fire 125 kW
Water 100 kW
30. PEOPLE DENSITY : 1473
31. TEMPERATURE - SUMMER OUTSIDE : _____
SUMMER INSIDE : 22°C
WINTER OUTSIDE : _____
WINTER INSIDE : 20°C

APPENDIX H

SAMPLE "CORRECT OPERATION" AND "ENERGY CONSERVATION OPERATION" BUDGETS

A - Correct Operation Budget

	AREA (m ²)	AIR CONDITIONING				LIGHTS (kW)	LIFTS (kW)	VENT (kW)	MISC (kW)	ELEC TOTAL (kW)	BOILER		
		FANS (kW)	REFRIG (kW)	PUMPS* COOL TOWER (kW)	ELEC HEAT (kW)						A/C (kW)	HOT WATER (kW)	TOTAL (kW)
OFFICES	7904	130	310	94	75	300	160	15	10	1094	280	75	355
SHOPS	652	25			68	21				114			
COMPUTERS	1062	12	100	25	100	40			140	417			
PARKING	3195	-	-	-	-	3		20		23			
SERVICE	2912	-	-	-	-	20				20			
PLANTROOMS	608	-	-	-	-	12		5		17			
CONNECTED LOAD (kW) (A)	16333m ²	167	410	119	243	396	160	40	150	1685			
Z OF TOTAL		10	24	7	14	24	10	2	9	100			
EQUIVALENT FULL LOAD OPERATING HOURS (B)		2200	1200	1600	700	3000	800	2300	5000	-	700	300	
ANNUAL CONSUMPTION (kWh) (A) (B)		367400	492000	190400	170100	1183000	123000	92000	750000	3377900	196000	22500	218500
ANNUAL MAX DEMAND (kVA)		1400	3000	1140	900	4000	1200	360	1000	13000			

COST ANALYSIS

MAXIMUM DEMAND	R 55 400
UNIT CONSUMPTION	52 200
FUEL OIL	5 400
TOTAL	R 113 000

B - Energy Conservation Operation Budget

	AREA (m ²)	AIR CONDITIONING					LIGHTS (kW)	LIFTS (kW)	VENT (kW)	MISC (kW)	ELEC TOTAL (kW)	BOILER	
		FANS (kW)	REFRIG (kW)	PUMPS+ COOL TOWER (kW)	ELEC HEAT (kW)	A/C (kW)						HOT WATER (kW)	TOTAL (kW)
OFFICES	7904	130	310	94	75	300	160	15	10	1094	280	75	355
SHOPS	652	25			68	21				114			
COMPUTERS	1062	12	100	25	100	40			140	417			
PARKING	3195	-	-	-	-	3		20		23			
SERVICE	2912	-	-	-	-	20				20			
PLANTROOMS	608	-	-	-	-	12		5		17			
CONNECTED LOAD (kW) (A)	16333m ²	167	410	119	243	396	160	40	150	1685			
% OF TOTAL		10	24	7	14	24	10	2	9	100			
EQUIVALENT FULL LOAD OPERATING HOURS (B)		2000	800	1300	200	2400	800	2000	5000	-	550	150	
ANNUAL CONSUMPTION (kWh) (A)(B)		334000	328000	154700	48600	950400	128000	80000	750000	2773700	154000	11300	165300
ANNUAL MAX DEMAND (kVA)		1400	2550	1026	360	3600	1200	324	1000	11460	-	-	-

COST ANALYSIS.

MAXIMUM DEMAND	R48 800
UNIT CONSUMPTION	R42 800
FUEL OIL	R 4 100
TOTAL	R95 700

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