THE MANAGEMENT OF ELECTRICITY COST WITHIN AN ACADEMIC INSTITUTION

by

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SUMMARY

With the rationalisation of government and sponsor funding, concern for the environment, increasing energy prices and possible government legislation, institutions have begun to pursue the management of resource cost and in particular the cost of electrical energy. Unfortunately an abundance of financial and human resources are not available within these institutions and as such these programmes are very seldom initiated or supported. The solution lies in the adoption of a systematic approach that ensures the sustainability and viability of an energy management programme.

The systematic approach to an energy management programme involves a clear definition of the link between an energy policy and energy strategy and the subsequent breakdown of the energy strategy into four areas-of-activity, namely Energy Diagnosis, Energy Load Management, Energy Maintenance Management and Energy Awareness and Education. This novel methodology ensures that the often forgotten areas of maintenance and awareness are brought into the energy management fray ensuring the completeness of the energy management programme. Each area-of-activity is covered in detail in a separate chapter. The conclusion of this dissertation focuses on evaluation methods with which to provide feedback and ensure that the energy strategy and policy remain focussed on the task of managing the electricity cost.

This dissertation includes all of the energy management and financial analysis tools that are required in order to plan and evaluate individual projects and where necessary, the models and methodologies in this dissertation have been explained through elements of the energy management programme at the University of Pretoria.

KEYWORDS

Academic Institution, Energy Management Programme, Energy Policy, Energy Strategy

Titel: Die Bestuur van Elektriesiteitskoste binne `n Akademiese Inrigting

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OPSOMMING

Met die rationalisering van die staats- en borgbefondsing, omgewingsbesorgdheid, toenemende energiepryse en moontlike regeringswetgewing, het inrigtings begin om hulpbronkostebestuur na te streef – in besonder die koste van elektriese energie. Ongelukkig is 'n oorvloed van finasiële en menslike hulbronne nie beskikbaar binne hierdie inrigtings nie, en daarom word sulke programme baie selde op die been gebring of ondersteun. Die oplossing lê in die aaname van 'n stelselmatige benadering, wat die instandhouding en uitvoerbaarheid van die energie program sal verseker.

Die sistematiese benedaring tot 'n energiebestuur program, behels 'n duidelike definisie van die skakel tussen 'n energiebeleid en –strategie en die gevolglike ontleding van die energiestrategie in vier aktiwiteitsareas, naamlik Energiediagnose, Energielasbeheer, Energieonderhoudbestuur en Energiebewustheid en -opvoeding. Hierdie unike metodiek veresker dat die gebiede van onderhoud en bewustheid wat dikwels vergeet word ook na die energiebestuuromgewing toegevoeg word. Dit verseker die volledigheid van die energiebestuursprogram. Die vier aktiwiteitsareas word elkeen in diepte in aparte hoofstukke behandel. Die gevolgtrekking van hierdie verhandeling fokus op evaluaeringsmetodes waardeur terugvoer voorsien kan word om te verseker dat die energiestrategie en –belied op die taak van bestuur van elektrisiteitskoste toegespits word.

Hierdie verhandeling sluit all energiebestuur- en finansiële ontledingsgereedskap wat benodig word om individuele projekte te evalueer en waar nodig, die modelle en metodiek in hierdie verhandeling word deur die elemente van die energiebestuursprogram van die Universiteit van Pretoria verduidelik.

SLEUTELWOORDE

Akademiese Inrigting, Energiebestuursprogram, Energiebeleid, Energiestrategie

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To Lindy

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CHAPTER 1: PROBLEM IDENTIFICATION AND BACKGROUND

"You cannot make luminous to other minds that which is dark in your own mind."

John H. Patterson

1.1 ENERGY MANAGEMENT BACKGROUND

The Oxford English Dictionary [1] defines "energy" as "fuel and other resources used for the operation of machinery etc." and the word "manage" is defined as "to have under effective control". Energy management therefore, in the pure definition of the word, is the effective control of fuel and other resources that are used for the operation of machinery.

Cratty *et al* [2] define energy management as the control of energy consuming devices for the purpose of minimising energy demand and consumption. This definition is rather broad and does not necessarily address the true drive of energy management, which is cost based. While it can be argued that the social benefits of reducing energy consumption hold great importance as a driving factor for energy management, the predominant driving factor is most certainly cost optimisation. Cost optimisation is not necessarily cost reduction but involves the reduction in the cost of energy per product. Based on this approach, it is possible to actually increase the energy costs with the adoption of an energy management programme whereby the increase in energy costs is incremental in relation to the increase in production or business operation. In other words, a business could, through the adoption of an energy management programme, increase energy costs for the purpose of increasing production so that the ratio of cost to production is actually decreased. Furthermore, it is important to understand the relationship between energy consumption (and demand) and the cost of that energy consumption (or demand). The relationship is defined through a tariff structure, which is applied to the consumption (and demand). Reducing the energy cost can be achieved by reducing the energy consumption from using energy more efficiently i.e. conservation. Alternatively, with the onset of various time differentiated tariff structures, using energy during different times of the day can also reduce the energy cost.

Sant [3] describes energy management as a collection of four principles. The first of these is to control the costs of the energy function or service provided and not the amount of energy consumption itself. In other words, attention should be directed to processes or end-users according to their cost contribution and not necessarily energy consumption. The second principle is to control energy functions as a product cost and not as part of manufacturing or general overhead. This requires the implementation of benchmarks attached to key processes whereby the energy cost of each product or business activity can be apportioned to it. The third principle is to control and meter only the main functions. This is a variation of Pareto's 80/20 principle [4] and ensures that scarce financial and human resources are used effectively. The final principle is to put the most effort of the energy management programme into installing controls and achieving results. It is common to find general knowledge about how large amounts of energy can be saved in a plant but this information is useless unless the discipline necessary to achieve these potential savings is present. The discipline that is required for an energy management programme must be received from the top management who must be dedicated and committed to the programme [5]. The necessary financial and human resources must be provided and the top management must believe that energy management is very important to the future health of their company.

Thumann and Mehta [6] define energy management as the judicious and effective use of energy to maximise profits (minimise costs) and to enhance competitive positions. According to Thumann and Mehta, a successful energy management programme is more than conservation, it is a total programme that involves every area of business and includes energy awareness, which is essential in motivating employees to save energy.

According to Basson [7], the management of energy represents a total comprehensive and all inclusive management function involving various disciplines within the organisation and stretches over a wide range of uses. Energy management in this definition includes saving energy, the cost-effective use of energy, the use of energy control and monitoring systems, reuse of waste energy, design guidelines and the training and education of employees.

From the definitions presented above, it can be said that a complete energy management programme must look at reducing cost within the context of environmental harmony in order to enhance competitiveness and maximise profits. This programme should contain a prescribed set of elements and these have been narrowed down to a set of four areas. The *diagnosis of the energy load* of processes and end-users through the activities of auditing, load metering and measurement is paramount towards determining the contributors towards energy usage. The cost of the energy consumption needs to be apportioned to a product, end-user or business function. Secondly, *energy awareness and education* must be generated amongst employees and students. The implementation of various *load management* projects aimed at reducing the energy cost per product or process is the third key area and includes items such as electronic retrofit programmes or direct load control. The implementation of an active *equipment maintenance* programme is the last area and is aimed at system efficiency and sustainability through proper maintenance of system components. Each of these areas will be individually handled in chapters 4 to 7.

1.2 ENERGY MANAGEMENT IN SOUTH AFRICA

South African industry, mining and commerce sectors rely heavily on electrical energy and account for approximately 60% of commercial energy consumption, at a cost in the region of R18 billion in 1995 [8]. In the past, the South African government devoted little attention to the promotion of energy efficiency in industry, mining and commerce despite widely acknowledged potential for improvement. While cheap energy is a comparative advantage for South Africa's major foreign exchange earners, the concern exists that the consumption of energy has harmful environmental and health effects, the costs of which are not included in the price of energy. Although researchers have identified significant opportunities for energy efficiency improvements in South Africa with typical conservative estimates of between 10% and 20% of current consumption [8], barriers towards the adoption of efficiency measures still exist and include:

- Inappropriate economic and pricing signals
- Lack of awareness, information and skills
- Lack of access to efficient technologies
- Demand for a high return on the investment of capital
- High cost of investment capital

To overcome these barriers, the South African government undertakes, through the national energy policy, the following actions for the management of energy:

- The creation of consciousness regarding energy efficiency
- The establishment of energy efficiency norms and standards for commercial buildings
- The facilitation of the performance of audits, demonstrations, information dissemination, sectoral analyses and training programmes
- The establishment of energy efficiency standards for industrial equipment

From the above policy actions, it is apparent that the extent of governmental involvement is aimed at creating an environment in which energy management can take place. The policy does not make provision for legislature aimed at forcing companies to adopt energy management programmes. For this reason, it will be up to each individual company to implement their own energy management programme using cost optimisation as a major internal driving factor. The external factor could be the need for a company or organisation to maintain a level of energy efficiency prescribed by government in order to ensure competitive edge and marketability. In other words, companies (and institutions) with a high degree of public visibility will be expected to implement energy management programmes.

Where does this leave an academic institution? The academic institution, as with any commercial company, has to implement their own energy management programme if they aim to optimise their energy costs. Furthermore, this programme needs to be launched using internal financial and human resources as no external resources can be expected from the government, other than programme support.

1.3 DEMAND-SIDE MANAGEMENT AND THE ROLE OF GOVERNMENT

In the United States of America, the government does not legislate at customer level but rather creates incentives for utilities to do their own Demand-Side Management (DSM) [9]. The concept of DSM originated in the U.S.A. in the 1970's when the energy prices started to rise sharply and this resulted in an increase of electricity prices as well. It prompted customers to reduce their energy consumption. The cost of building new power stations also rose sharply and utilities wanted to avoid the building of power stations. It then became a joint effort between the utility and the customer to use electricity wisely. DSM is defined by Gellings [10] as those activities that involve actions on the demand (i.e. customer) side of the electricity meter either directly caused or indirectly stimulated by the utility.

These activities that can be performed to change the shape of the system load shape are illustrated and described as follows [11]:

- *Peak clipping* is generally considered as the reduction of the system peak load by using direct load control over equipment that does not store energy
- *Valley filling* entails building load during off-peak periods

- *Load shifting* involves shifting load from on-peak to off-peak periods through the process of controlling equipment that does store energy
- *Strategic conservation* is the load shape change which results from utility programmes directed at reducing end-use consumption
- *Strategic load growth* is increasing sales, stimulated by utility, beyond the valley filling category mentioned above
- *Flexible reliability* is when customers are presented with options of variations in quality of supply and services. Thus, rather than providing the needed high reliability by increasing capacity, it can be obtained by selectively reducing reliability to customers who are willing to accept low reliability in exchange for financial incentives.

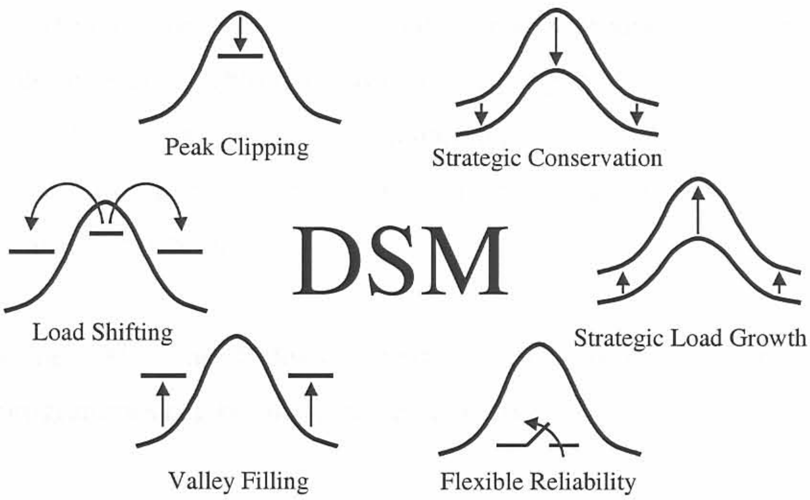

Figure 1.1: Demand-Side Management Activities

This approach adopted by the American government is successful in the competitive energy marketplace because it is in the best interests of the supplier to implement DSM and assist with project financing and all those other skills that are lacking (as mentioned previously). The emphasis here is not on coercion but orientated rather to the creation of support systems to help customers and national energy issues.

The terms "energy efficiency" and "energy conservation" must not be confused, although they have a very close relationship. Conservation is aimed at reducing energy consumption and involves the judicious application of energy through deciding whether the use of energy is really necessary. Efficiency involves the delivery of the same results with little or no energy wastage. For example, energy conservation is turning off an incandescent lamp when you are leaving a room and energy efficiency is replacing this incandescent lamp with a more efficient compact fluorescent lamp (CFL). Both activities reduce the amount of energy that is consumed and as such the DSM activity of strategic conservation in figure 1.1 includes energy efficiency.

1.4 PROGRAMME ACCEPTANCE AT ACADEMIC INSTITUTIONS

During March 1995, the Energy-University-Environment (EUE) Consortium was established in Bordeaux, France [12]. The consortium recognises that the management of natural resources at university campuses and research laboratories is based on a laissez-faire policy and this approach is undesirable for the following reasons:

- The financial cost of energy increases, as more electronic equipment is added to laboratories and offices
- The environmental degradation associated power production for the operation of heating, cooling and lighting to support teaching and research activities has also increased with a growth in energy consumption
- Students are not receiving the best training because of limited texts and poor examples in campus buildings

According to the EUE, the following barriers need to be removed before energy management programmes can be implemented at Universities:

- The lack of social concern for reducing energy use
- A lack of priority for energy and environmental matters
- Insufficient or inadequate capital funds
- Inappropriate financial mechanisms that are able to capture savings in accounts that can be used to finance additional conservation investments
- In countries in economic transition, other difficulties also appear:
    - fuzzy relations between sustainable development principles, economic restraints and energy or environmental policies
    - divergent economy policy goals such as rapid growth and dwindling resources
    - inadequate and ineffective privatisation of state property

The Association of Higher Education Facilities Officers, in the United States of America, published an energy management workbook in 1994 [13]. The purpose of the workbook is to meet the needs of those institutions wanting to eliminate energy wastage on campus and reduce unit costs but lack the resources to implement the energy conservation projects that would increase their efficiency or address unit costs. The workbook focuses on a broad base of energy resources and includes electricity, coal, steam and natural gas.

The workbook is based on five basic premises. The *first* of these is that there is no single planning or management approach that can be suggested that would fit any two campuses exactly the same way. Each campus is unique in terms of its facilities, location, resources, personnel and history or culture.

The *second premise* is that key administrators at any college or university must have a part in developing any plan if that plan is to be undertaken or implemented. This sentiment is echoed by Alberts *et al* [14] that the strategic objectives of the energy management programme have to be set out with the long-term vision and goal of the organisation in mind. The planning process that determines these strategic objectives must fit in with the corporate strategy of the organisation. Likewise, the corporate planning process should also take the energy management efforts into account.

The *third premise* is that no one understands or knows the campus better than the campus personnel. This includes the facilities personnel, the academic personnel and the students. The technical personnel own valuable information with respect to the design and support functions of the energy networks whereas the academic personnel and students have exposure to the end-use of energy.

The *fourth premise* is that energy management is a subset of facilities management and the two cannot be separated. Alexander [15] defines facilities management as the process by which an organisation delivers and sustains support services in a quality environment to meet strategic needs. In this instance, the supply of energy to all workers is a key service that is vital to the success of an organisation. Energy management is sometimes placed under the environmental management component of facilities management but this would depend on the urgency regarding the management of energy cost.

The *final premise* is that resources for the reduction of energy consumption are available through a combination of internal and external funding sources. Internally, energy costs can be apportioned to specific processes as a recurring liability that must be budgeted for and proper external financing will allow the capital investment necessary to release funds through a process of reduced energy costs. These released funds can be used to support the academic teaching process. These five premises are vital towards understanding the manner in which energy management should be approached on a campus.

Using these five premises, the workbook is organised into three basic sections namely, diagnosis, programme development and implementation as illustrated by the solid lines in figure 1.2.

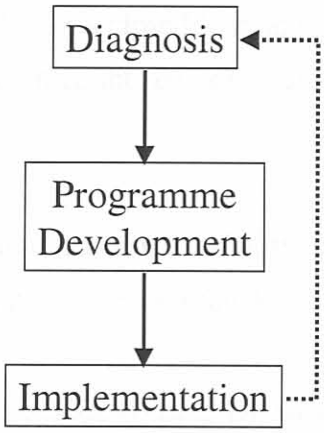

Figure 1.2: Structure of the Energy Management Workbook

The *first section* relating to diagnosis focuses on the collection of information regarding the people, facilities and financing on campus. Information provides the building blocks from which a facility and energy management programme is built because it is necessary to create consensus regarding the energy budgets and liabilities on campus.

The *second section* on programme development draws on the information and experience that has been obtained and processed during the diagnosis section. Developing an energy management plan relies on achieving consensus as to the priority by which resources should be assigned to problematic areas.

The *final section* on implementation is a method that is used to keep track of the various projects that constitute the energy management programme. During the course of the programme, a campus may decide to ammend or change the project priority plan dependent on a range of factors and contingencies that may come to the fore. According to the workbook, the highest priority projects should be those that have the greatest reduction potential for the resources expended.

This three-sectioned approach is very effective because it provides a set structure with which to approach the management of energy as illustrated by the solid lines in figure 1.2. By following a process of first identifying and gaining consensus regarding problem areas ensures that resources are optimally utilised. The problem with this three-section approach is that it fails to acknowledge that the energy management programme is not a process that can only be implemented once off. In other words, the workbook fails to create feedback whereby not only the progress of the programme is diagnosed, but the projects that have already been implemented and completed are revisited to ensure that they have performed as intended. This closed loop approach is illustrated with the dotted arrow in figure 1.2 and ensures that the energy planners are able to learn from past experiences.

Although seemingly well structured and very useful, the workbook itself is not a complete solution because it fails to adequately address a few key issues such as:

- A broad base of energy sources are considered, which may divert the focus from that resource which generates the highest cost and deserves the most attention
- Energy tariff structures are not explained or dealt with and this is usually the starting point of any cost driven campaign
- Very little attention is paid to establishing a relationship with the energy suppliers
- No emphasis is placed on feedback with which to create a closed-loop energy management programme
- Energy conservation (including efficiency) is considered as the only DSM activity that should be pursued by the institution themselves
- Consequently, it is felt that the utility should initiate the other DSM activities as only they can benefit from it
- Energy awareness is considered as a secondary activity to the other elements of the programme and no structured approach is attached towards this activity

In 1994 Basson [7] wrote a thesis aimed at a management strategy for the optimal use of energy in South African academic institutions. The thesis is structured in four parts namely, background literature study, technical aspects, financial management and energy management. The thesis is technically very strong in terms of the definitions and explanations of electrical values such as power factor, load factor and diversity factor. A strong link is made to electricity tariffs and the financial analysis of projects. One of the most valuable inclusions in this thesis is the life-cycle costing approach that has particular reference in academic institutions when it comes to the purchase and maintenance of equipment. Unfortunately this thesis falls short of its full potential for the following reasons:

- The closed-loop approach to an energy management programme is not emphasized
- The different types of electricity tariffs are not explained in such a manner that an institution will be able to customize the value of the thesis for themselves. Basing explanation solely on existing supplier tariffs allows for this material to become obsolete
- The thesis looks at a very broad range of energy issues and includes items such as the distribution of electricity in South Africa
- The energy policy enjoys minor importance and is considered as an activity secondary to the energy management projects that are undertaken
- No systematic approach is presented making the collection of information, all of which is relevant, very confusing to follow and implement

1.5 ENERGY MANAGEMENT PROGRAMMES AT INTERNATIONAL ACADEMIC INSTITUTIONS

Many international institutions have implemented energy management programmes. Not all of these programmes address all of the four elements that were concluded in section 1.1.

Murdoch University [16] have incorporated their energy management programme into the office of facilities management and consider it as one of the services that they deliver. While their programme does address all four elements, the amount of attention to each element could be improved. The reason for this is that no formal programme structure has been adopted and seemingly unimportant components inadvertently fall by the wayside as a result. All programme successes have been achieved as a result of the lengthy history of energy management at the University (since the early 1980's) that has allowed ample learning opportunities and the gaining of valuable experience. The strong points of the programme at Murdoch University include a very well established link to the environment and improved operational service. The University of Houston [17] and the University of Vermont [18] also have fairly complete programmes in operation. At Houston, their energy management team, designated as the Utility Services unit, was amalgamated in 1992 from the previously fragmented groups focussed on energy management, utility production, distribution system maintenance and energy administration. The joining of these valuable resources enabled the University of Houston to adopt a very sound energy management programme. The University of Vermont has a dedicated energy management engineer as part of their physical plant department. This appointment ensures the success of their programme. Carleton University [19] have an energy management programme aimed towards reduced energy and water consumption. After defining clear goals, they are pursuing these goals through a programme using benchmarks, campus awareness, system maintenance and energy system optimisation.

Many international institutions focus their efforts on a programme that includes load metering, load management and education and awareness [20, 21, 22, 23, 24, 25, 26]. Their programmes do not include maintenance aspects of energy. Their programmes rely on a great deal of student participation and are highly successful in generating energy awareness. Maintenance is performed at these Universities as part of the functions of the facilities department but no direct official link is made between the energy equipment and the rest of the energy management programme. For example, conducting maintenance on the seating in a lecture hall is an important part of the campus maintenance but has nothing to do with the management of energy cost. On the other hand, regular maintenance of the filters on the HVAC (Heating, Ventilation and Air-Conditioning) systems can ensure the energy costs are minimised because the energy equipment is maintained at operational efficiency.

Some institutions have implemented energy management programmes but these programmes seem to be very informal because they do not consider load diagnosis or measurement as an element [27]. Diagnosis is a crucial component as was highlighted in section 1.4. Naturally expensive load measurement equipment is not always viable on a limited budget, but many alternatives are available which include conducting audits and loaning measurement equipment for a measurement audit. Determining the total energy cost is relatively easy because this can be ascertained from the energy accounts. The process of verifying and apportioning these costs to end-users relies on the diagnosis elements of the energy management programme.

In closing, it is important to realise that whatever the extent of the energy management programme that is being conducted at an institution, the fact that the institution has established a programme, assigned resources and placed energy on the agenda of the institution management, reflects very positively. The basic groundwork of their programmes has been completed and to improve their efforts through adopting a formal structure will put their energy programmes on a higher level.

1.6 ENERGY MANAGEMENT PROGRAMMES AT SOUTH AFRICAN ACADEMIC INSTITUTIONS

South African institutions predominantly make use of electricity for their energy needs because it is easily available, is comparatively cheap in relation to other energy sources and the supply infrastructure is installed. Mostly these institutions are supplied with electricity from their local Municipal authorities and not directly from electricity companies. Other forms of energy are also utilised and include liquid petroleum gas, diesel, steam and water. The total annual energy expenditure for tertiary institutions could account for as much as 3% to 5% of their total operational budgets [7].

At present, very few South African tertiary institutions have established energy management programmes and those institutions that do have programmes have created them for the purpose of cost management or academic research as illustrated in figure 1.3. With the rationalization of government and sponsor funding, concern for the environment, increasing energy prices and possible government legislation, institutions have begun to pursue the management of resource cost and in particular the cost of electrical energy.

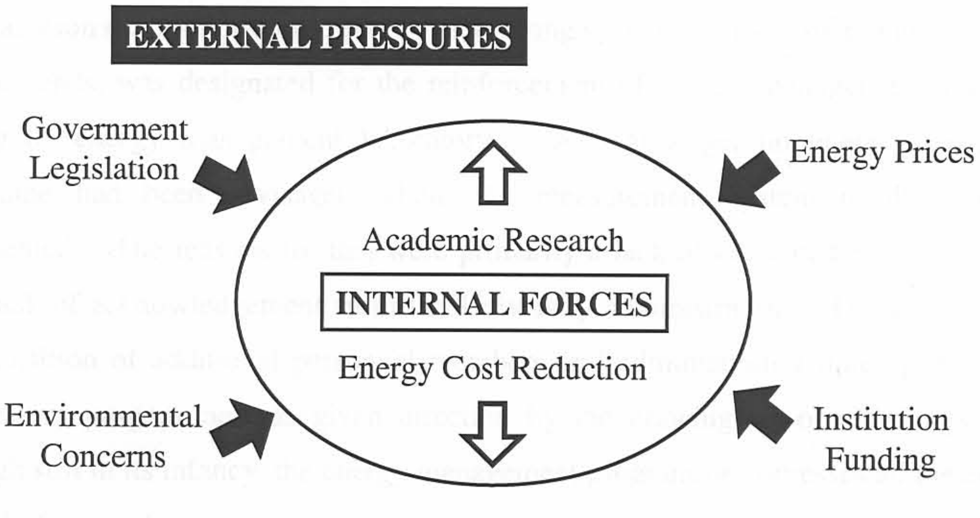

Figure 1.3: Energy Management Pressures and Forces acting on an Academic Institution

Reasons for South African institutions failing to implement an energy management programme include:

- Lack of additional financial capital for the investment into modern efficient equipment
- Lack of in-house expertise
- Lack of awareness of the benefits of an energy management programme
- Lack of portfolios dedicated towards energy
- Very few incentives for personnel to drive the programme
- No legislative pressures from Government

The institutions that do have established programmes have been able to marry the expertise and research capabilities of their engineering departments (traditionally electrical and mechanical engineering) with the facilities management department of their institutions. This union is brought about by the necessity of academics to experiment with their solutions and following this approach allows for the facilities of the institution to be used as a site-wide energy management laboratory.

The institutions with energy management programmes in South Africa fall into two categories: those that use energy management on campus to both reinforce their energy management teaching as well as reducing costs and those that pursue energy management purely as a management function aimed at cost management.

The University of Pretoria [28], initially started their energy management programme with the installation of a campus wide energy monitoring system. This system, purchased from research funds, was designated for the reinforcement of energy management training by creating an energy management laboratory. At that stage, no energy management programme had been envisaged where the measurement system results would be implemented. The reasons for this were primarily a lack of dedicated posts for the task and a lack of acknowledgement from the University administration. During 1998, after the acquisition of additional personnel members and administration funding, the energy management programme was given direction by the drawing up of an energy policy. Although still in its infancy, the energy management programme addresses all the elements required of a sound energy programme.

Two other institutions, namely the University of Natal and the Potchefstroom University for Christian Higher Education, have also started addressing energy management on campus, primarily in response to the academic pursuit of personnel members and students

[29, 30]. Their programmes are aimed primarily at the areas of load diagnosis followed by load management through the direct control of energy equipment.

Rhodes University [31], have formulated an energy management plan and have adopted an energy policy with which to give their programme direction. The motivation at this institution for their programme is on the management of energy cost only as the university offers no formal energy management training. A shortcoming of their programme is the inclusion of the students and staff. This should be considered as a shortcoming because the students and staff are the ones that use the energy in the first place and they are more likely to notice faults with the energy equipment that require some maintenance.

Once again, the programmes of these institutions should be praised from the fact that they have started the process of addressing the energy costs. Adopting a formal structure and developing an understanding on campus will ensure that their programmes will enjoy greater success.

Often there tends to be a lack of communication between the academics who are pursuing energy management on campus and the facilities management who recognise the importance of addressing energy cost but are unaware of the efforts of the academic personnel. Each group pursue energy management but could be more effective if they amalgamated resources and adopted a formal structure that ensures that their limited resources are optimally utilised.

1.7 DISSERTATION OBJECTIVES

The main objective of this book is to:

Present a systematic and structured approach for the management of electricity cost within an academic institution.

A structured approach will ensure that the energy management programme is implemented against a quantifiable plan and that it will be sustainable throughout its lifetime. This main objective will be achieved by addressing the following specific objectives:

- Present a model indicating the involvement of resources for the management of energy.

- Introduce an energy management policy.
- Introduce an energy management strategy.
- Explain key concepts required for the judicious management of electricity cost such as energy auditing, electricity tariffs, benchmarks, maintenance management, awareness marketing and end-user education.
- Present a method for project selection with which to select between different energy management projects and between alternatives for the same project.
- Present key projects as examples of the energy management programme.
- Present a method with which to evaluate the success of a project as part of the energy management programme and the success of the programme itself.

1.8 HOW THIS DISSERTATION IS STRUCTURED

This dissertation has been constructed in the knowledge that different institutions have different driving factors that are specific to the culture on their campuses and management councils.

Chapter 2 introduces the concept of an energy policy as a plan based on the management of people and equipment in order to address the energy costs. Included here is the relationship between an energy policy and an energy strategy. A model is presented that will enhance the systematic approach to an energy management programme at an academic institution.

Chapter 3 includes the technical and financial tools that are required by an energy manager for the management of electricity cost. The material in this chapter will be required in the subsequent chapters and has been collectively grouped in a single chapter in an attempt to make this dissertation more structured.

Chapters 4, 5, 6 and 7 each deals with one of the elements of a complete energy management programme or area-of-activity.

Chapter 8 focuses on evaluation methods by which the performance of each element of the energy management programme and the programme itself can be evaluated. This function is vital in order to ensure that the energy management programme has maintained its direction and goals.

CHAPTER 2: PRINCIPLES OF AN ENERGY MANAGEMENT PROGRAMME

"Man's mind stretched to a new idea never goes back to its original dimensions."

Oliver Wendell Holmes, Snr.

2.1 INTRODUCTION

From chapter 1, it can be said that a complete energy management programme must look at reducing energy cost within the context of environmental harmony in order to enhance competitiveness and maximise profits. This is the goal of an energy management programme. This goal can be achieved by addressing four areas, namely the diagnosis of the energy load, generating energy awareness and education, undertaking load management and conducting equipment maintenance.

From the case studies of energy management programmes presented in the previous chapter, it was noted that very few academic institutions have a structured energy management programme in place. Some of these institutions have highly successful programmes while others, although their effort is positive, have not adopted a structured approach towards their programme. It is not possible to merely conduct a series of retrofit projects and hope to achieve the eventual goal of the energy management programme. Naturally this approach will produce immediate results but the energy management programme, as a whole, will be a failure because other key areas such as maintenance and student and staff education will have been ignored. Very often the latter two areas are forgotten because the results that they deliver are very difficult to quantify and measure. However, attention must be paid to all four areas.

The problem facing many institutions is the limited human and financial resources available to tackle all programme areas simultaneously. Any funding procured will more often that not be used to generate the maximum amount of energy savings which invariably implies investment into new technologies and not programme awareness and end-user education. How is it possible to address all programme areas with these limited resources? The answer is the implementation or adoption of a systematic and structured approach to the energy management programme as will be presented in this chapter.

2.2 SCHEMATIC REPRESENTATION OF THE ENERGY MANAGEMENT PROGRAMME

If the purpose of an energy management programme is to reduce the energy cost per product, then the focus areas of this cost reduction must be the equipment that uses electrical energy and the people that use the equipment. This concept is illustrated in figure 2.1.

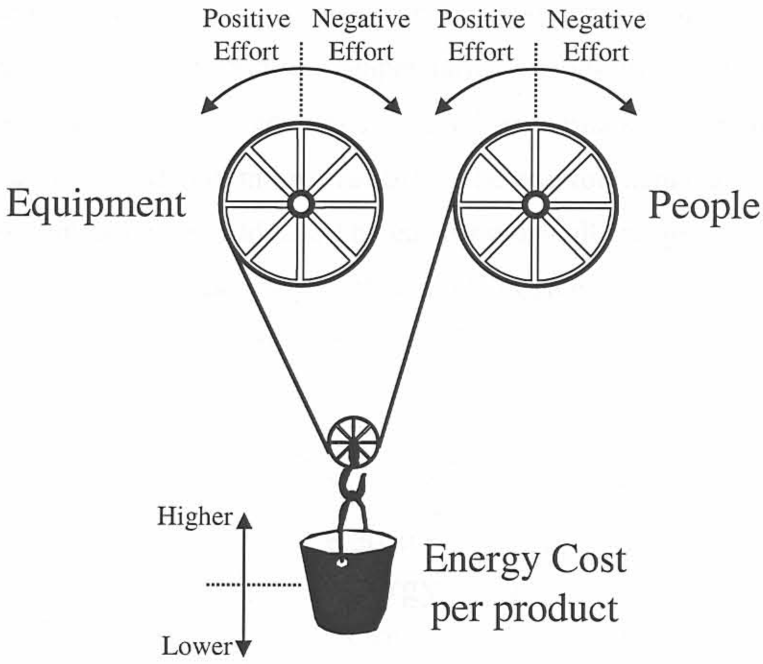

Figure 2.1: Schematic Representation of an Energy Management Programme

Without the full co-operation and support of each and every person on campus, the energy programme will fail to reduce the energy cost per product or process. In a similar vein, the energy management programme cannot only place attention on the people on campus without paying attention to the types of equipment that are being used. After all, it is this equipment which uses the energy in the first place. The human element may simply be contributing to the exorbitant energy consumption as a result of improper use through a lack of knowledge or skills.

However, according to the definition of an energy management programme in chapter 1, focusing on the equipment and people on campus must be brought into an environmental context if the energy management programme is to be complete. Environmental concerns are presently focussed on the reduction of non-renewable energy consumption. Non-renewable energy sources are those obtained from the burning of fossil fuels whereas renewable energy sources include, amongst others, solar, wind, wave and animal power.

The burning of fossil fuels contributes to the degradation of the environment and affects the climate through global warming. In other words, reducing energy consumption assists the environment. In chapter 1, the concept of reducing energy cost without necessarily reducing energy consumption was introduced. For example, using energy during different times of the day could reduce costs if you were billed on a time-differentiated tariff structure. Although it would seem as though an energy management programme orientated towards cost could counteract the environmental concerns, it should be remembered that using energy during cheaper tariff periods in order to reduce overall product cost does help because it ensures improved performance from an energy supply point-of-view (i.e. improved system load factor). The environmental aspect of the energy management programme can be addressed by ensuring that all energy reliant processes and sub-systems on campus are operating with a high degree of efficiency. Figure 2.2 illustrates the activities that form part of the energy management programme.

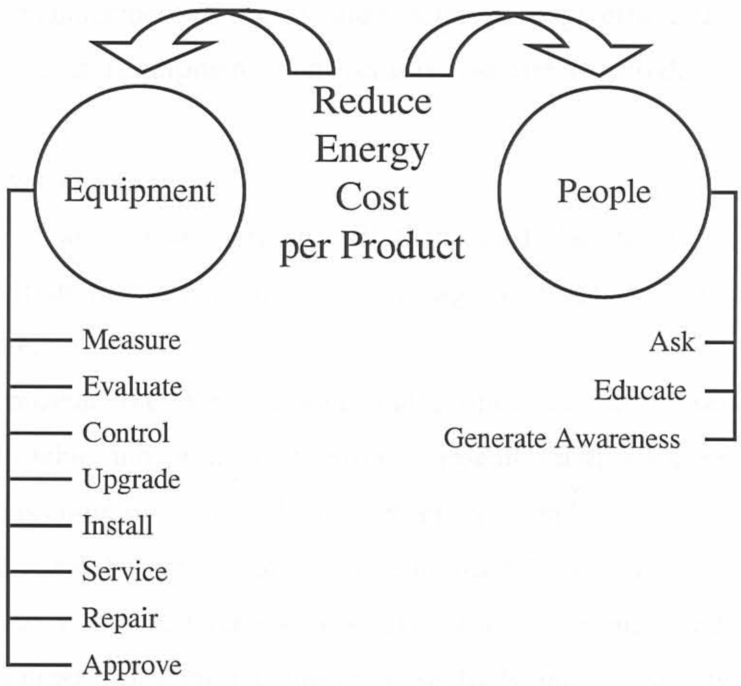

Figure 2.2: Activities of an Energy Management Programme

2.3 AN ENERGY POLICY

An energy policy is a formal statement that is made by a government, party or person through which the course that is being adopted with respect to energy is defined. The energy policy defines the direction of the energy management programme and is specific to each institution. Energy policies ensure the sustainability and transparency of the energy management programme and are statements of corporate commitment towards environmental harmony through the activity of reducing energy costs per product or business process. More simply put, an energy policy states what an institution intends doing about energy management and the goals they hope to achieve. An energy policy should not be confused with an energy strategy. The policy defines what the institution intends doing regarding energy whereas the strategy determines how it will be accomplished. An energy policy has three essential components and should not be longer than a single page in order to maintain programme focus:

- *Declaration of Commitment*

  The written support of top management sets the tone for the energy policy. As the name implies, it is a declaration that ensures that the management of energy will be sustained and supported as one of the many vital activities within the institution. For example:

  "As part of its environmental strategy, the University of Warwick is committed to the responsible management of energy and practices energy efficiency throughout all its premises, plant and equipment wherever it is cost-effective to do so."[21]

- *Mission Statement*

  The mission statement is more specific than the declaration of commitment in the sense that it defines the focus of the energy management programme. Some examples are:

  - "To provide the most reliable and economical utility services for a safe, comfortable and productive learning, research and work environment for the campus community at the University of Houston."[17]
  - "To control the energy consumption in order to avoid unnecessary expenditure, improve cost-effectiveness, productivity and working conditions, protect the environment, prolong the life of fossil fuels and investigate and promote the use of renewable fuels."[25]
  - "To guard in a responsible manner over energy usage on campus as a scarce, necessary and expensive resource and to provide maximal benefit to the users in return for the minimum energy consumption and cost."[31]

- *Programme Goals*

  The goals of the energy management programme determine the specific objectives of the institution in order to achieve the mission statement. The goals will eventually determine whether the energy management programme has been successful or not. For example [25]:

- To ensure that commitment is obtained from staff at all levels within the University on aspects of energy efficiency
- To purchase fuels and energy sources at the most economic costs
- To reduce the amount of pollution caused by energy usage, particularly emissions which are the main contributor to global warming
- To annually invest 50% of the previous energy saving costs in order to further reduce energy usage across the University
- In order to ensure its effectiveness, this policy will be reviewed and amended annually.

Occasionally a quantifiable target may also be included in the goals. Once a set target has been reached, a new target can be set either along the same line or towards another objective of the energy management programme. For example:

- To achieve a 2% energy saving each year for the next 3 years by good housekeeping supplemented by a capital spend not exceeding £50,000 per year. [21]
- Reduce energy consumption by 20% in the next fiscal year. [19]

The interaction of these three components is illustrated in figure 2.3. If all the goals have been achieved, the mission statement will have been satisfied.

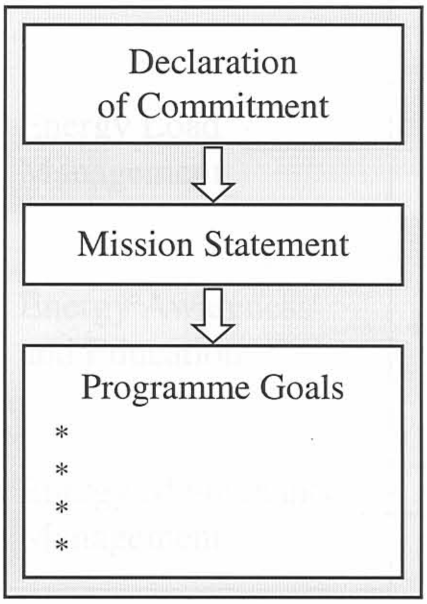

Figure 2.3: Components of an Energy Policy

2.4 AN ENERGY STRATEGY AND AREAS-OF-ACTIVITY

If the energy policy determines the destination of the energy management programme, then the energy strategy determines the route. The energy strategy is the working plan that is put in place in order to achieve the programme goals and eventually the mission statement. At this point it is evident that the goal of the energy management programme is to reduce the energy cost per product or process and that this can be achieved by addressing both the equipment and people on campus as illustrated in figures 2.1 and 2.2. However, the problem lies in ensuring that all the programme activities listed in figure 2.2 are addressed in a systematic manner in order to optimise resources.

The answer lies in the four areas that were first introduced in chapter 1 and these are now included and defined as areas-of-activity as follows:

- Energy Diagnosis
- Energy Awareness and Education
- Energy Load Management
- Energy Maintenance Management

These areas-of-activity are the links between the goals of the energy management programme and the activities that are undertaken as part of the programme as shown in figure 2.4.

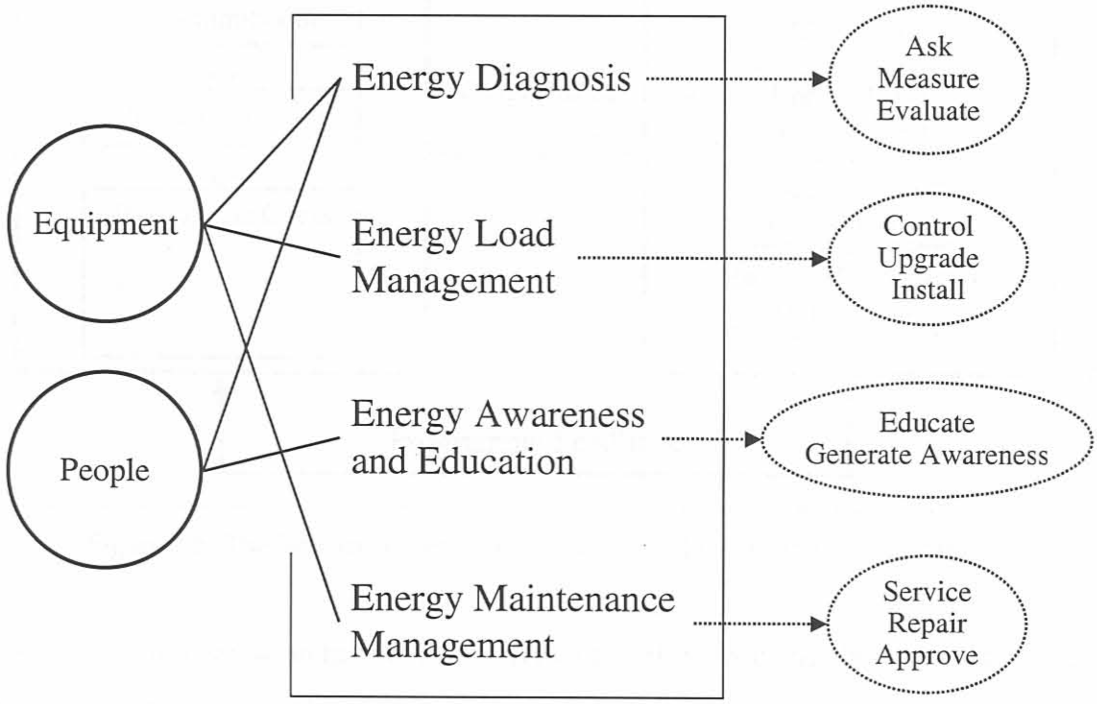

Figure 2.4: The Areas-of-Activity as part of the Energy Strategy

Each area-of-activity is not a stand-alone component of the energy management programme and relies on a high level of interaction with the other areas. The energy strategy could therefore be defined as a series of tasks vital towards achieving the goals of the energy management programme, grouped under different areas-of-activity. Examples of these tasks could include the installation of a campus-wide energy management system under the energy diagnosis area-of-activity or re-scheduling lecture timetables in order to optimise the occupancy as part of the energy load management area-of-activity. The flow of communication between the areas-of-activity will be dealt with later on in this chapter.

2.5 ENERGY POLICY AND STRATEGY INTERACTION

The energy policy and strategy are the primary planning elements of the energy management programme. They determine the goals of the institution with regards to energy and the structured plan to achieve those goals. As mentioned in chapter 1, an energy management programme is not a process that can only be implemented once off. In other words, without feedback creating a communication closed-loop, the energy planners are unable to learn from past experiences on their campus. This closed-loop approach is illustrated in figure 2.5.

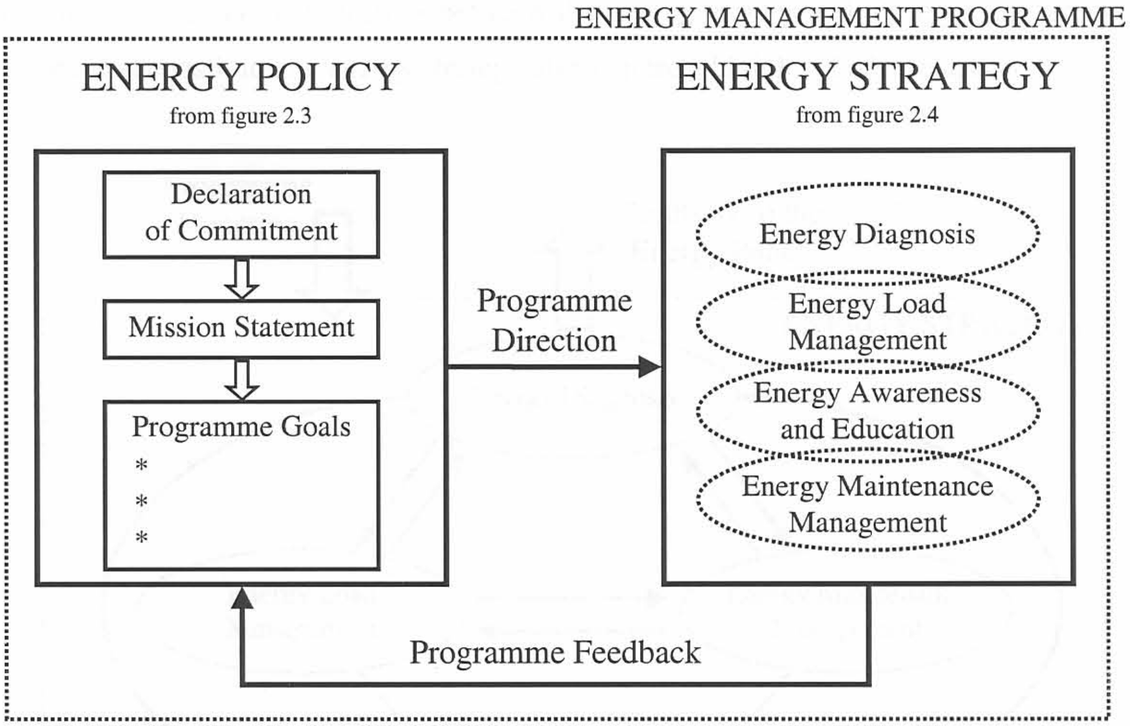

Figure 2.5: The Interaction between the Energy Policy and the Energy Strategy

For example, an institution has set themselves a target of reducing their consumption, by a percentage within a couple of years, as one of their programme goals in their energy policy. This goal, along with all the others, provides the direction of the energy management programme but does not determine how this set target will be achieved. In the energy strategy, it is determined that achieving this specific target can be accomplished through the installation of power factor correction equipment at all the infeed points and a few other smaller projects. Having reached this target, the energy policy needs to be updated and ammended to firstly remove the existing target and possibly replace it with a new one if desired. The energy policy could also be ammended to reflect changes in the declaration of commitment or the mission statement in line with other policy decisions of the institution management.

The frequency of feedback will be determined from the successes of the energy programme. It is never wise to continuously rewrite the policy. As a guideline, the energy policy should at least be revisited annually to reflect the ammendments as a result of programme successes and the growth in knowledge of the personnel responsible for the management of energy.

2.6 AREA-OF-ACTIVITY INTERACTION IN THE ENERGY STRATEGY

As with external communication between the energy policy and strategy, the areas-of-activity that constitute the energy strategy also require a high level of interaction.

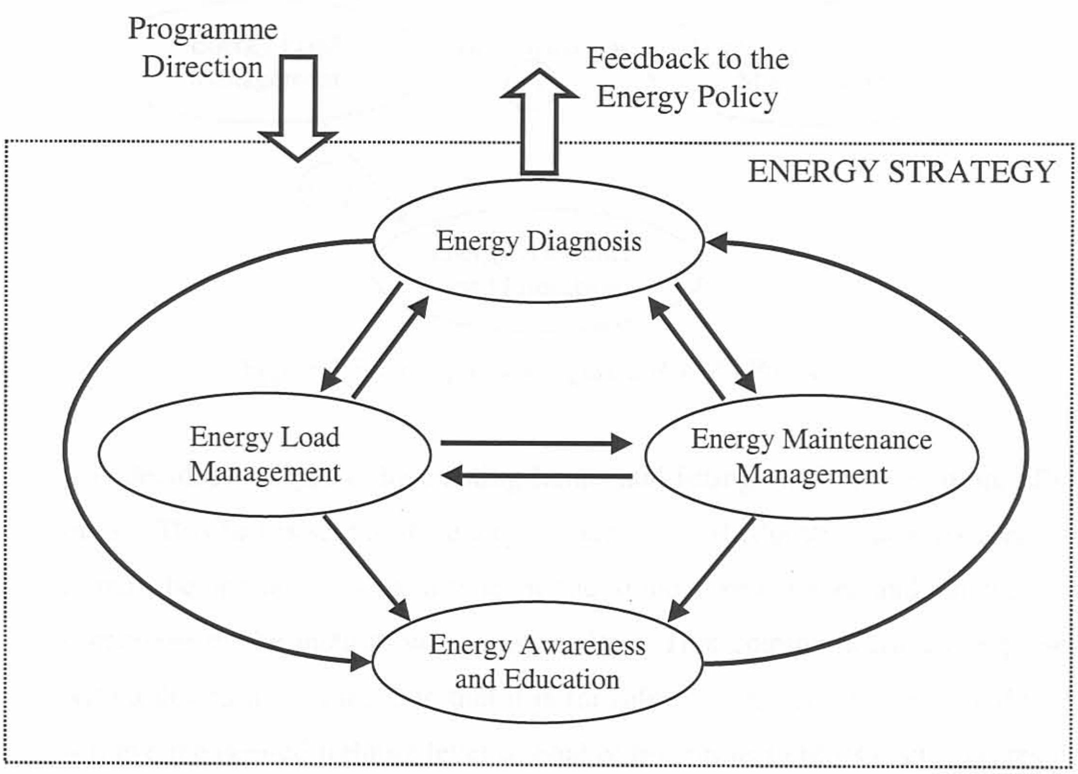

Figure 2.6: The Interaction between the Areas-of-Activity

Strong emphasis was placed on the closed-loop approach to energy management and this principle is illustrated in figure 2.6. The communication between the areas-of-activity in this diagram can best be explained with some examples.

2.6.1 Example of a Lighting Retrofit Project

In this example, the interaction between the areas-of-activity will be explained for the case where poor energy benchmarks are corrected through a lighting retrofit project.

Step 1: Energy inefficient lamps in terms of lumen/W are identified as one of the culprits of a poor energy benchmark in a building.

Step 2: It is decided to pass this problem onto the energy load management activity area, as it is a fault caused primary from poor equipment and neither as a result of human occupancy or poor maintenance (see arrow A). This communication is presented with a solid line to indicate that it is a primary activity vital towards the success of the project.

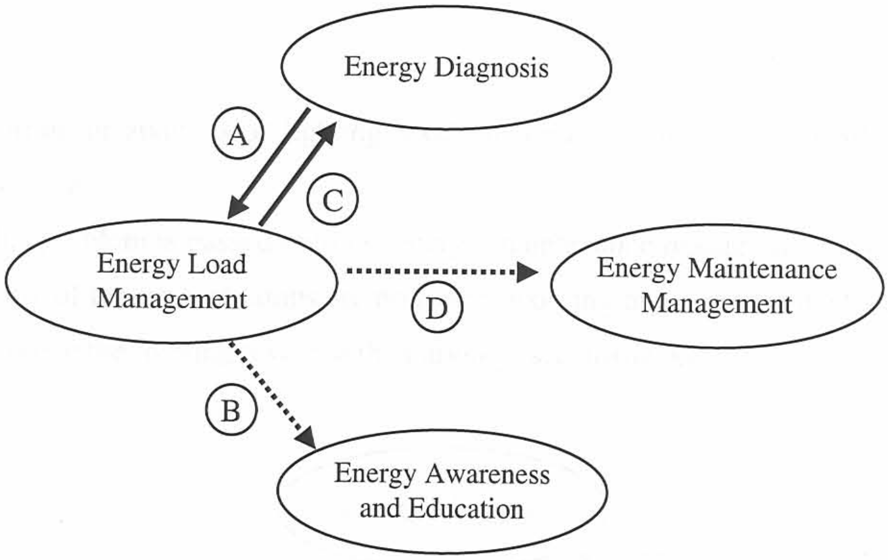

Figure 2.7: Example of a Lighting Retrofit Project

Step 3: It is decided to replace the existing lamps and fittings with newer, more efficient ones. This fact is sent to the energy awareness and education activity area so that it may be included as an article in the student newspaper and on the energy homepage of the institution (see arrow B). This communication is represented with a dotted line to indicate that it is for information purposes only and will not achieve the desired lighting level or goal of this project but its exclusion results in an incomplete programme.

Step 4: After installation of the new lights, the new level of energy performance needs to be determined (see arrow C).

Step 5: If the benchmark is reached or partially improved, the project was successful and no other interaction is necessary. In this instance, the final part of the project involves transferring all technical specifications regarding the lamps and their supply to the energy maintenance management activity area so that they may be included in the inventory of energy equipment and that the necessary spares may be stocked (see arrow D).

In reality, performing one single project may not achieve the energy benchmarks for a building. It will take many projects but each one of these projects interacts in the same way as this one.

2.6.2 Example of a Lighting Maintenance Project

In this example, the interaction between the areas-of-activity will be explained for the case where inefficient lighting levels are corrected through a maintenance programme. Figure 2.8 refers.

Step 1: During an audit, poor lighting levels in terms of lumen/m^2 are identified in a building.

Step 2: This problem is passed onto the energy maintenance management activity area as many of the present lamps are no longer working and correct maintenance would improve the lighting levels in the building (see arrow A).

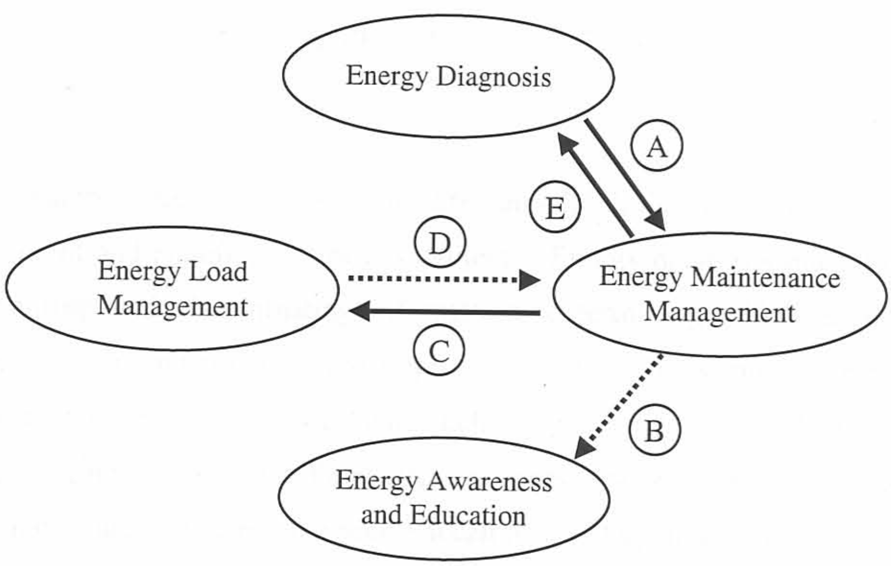

Figure 2.8: Example of a Lighting Maintenance Project

Step 3: It is decided to replace the faulty lamps. However, the existing lamps are no longer manufactured. In this instance, a plan is devised to salvage half of the existing lamps as replacements for the other half and to acquire new lamps and fittings for the stripped half. This plan allows for the gradual replacement of fittings, which ensures sustainability of existing lighting equipment and economic efficiency when purchasing new equipment. This plan is once again distributed to the energy awareness and education area to be used as marketing information (see arrow B).

Step 4: The energy load management area is tasked with the upgrade of the new lamps (see arrow C) and when completed, all equipment information is passed back to the energy maintenance area for stock and maintenance scheduling (see arrow D). Once again the difference between arrows C and D can be ascribed to their importance in achieving the goal of the project. Here arrow D is not vital but its inclusion ensures the sustainability and completeness of the project.

Step 5: Ensuring that the correct lighting levels have been reached again concludes the project (see arrow E).

In this example, the same route would have been followed if it was decided to replace all of the lamps at once on the basis that the existing ones were not only in partial working order but were inefficient too. These decisions are determined by the availability of funds.

2.6.3 Summary

Needless to say, achieving the desired level of energy efficiency or energy benchmark in a building is usually only possible with a multitude of projects that will require tasks in all three areas of energy load management, energy maintenance management and energy awareness and education.

In both the examples presented in sections 2.6.1 and 2.6.2, the area of energy diagnosis is the starting point and ending point of any project. Energy diagnosis plays the important role of acquiring and disseminating information, determining which area would best address the problem and finally evaluating the outcome. This function ensures that in extreme cases where solving a problem such as poor lighting levels through proper maintenance creates a new problem such as poor energy benchmarks because the maintained lamps are inefficient, the problem can be acted upon immediately.

It is very important to remember that each activity area is not a standalone function. In other words, each activity area is not a separate department that operates independently of the others. This model requires a high level of communication and each activity area must be capable of determining when a problem can be best addressed by another area.

2.7 STAFFING REQUIREMENTS OF THE ENERGY MANAGEMENT PROGRAMME

An energy management programme that has been completely represented through an energy policy and strategy is only as good as the people who manage it. To this end, three areas have been identified as follows:

- *Energy Co-ordination Committee*

  The energy co-ordination committee is made up of a representative sample of the institution community and undertakes the following tasks:

  - Ensure the energy management programme remains focussed through acting as the custodian of the energy policy
  - Review the policy annually or on the recommendation of the energy manager
  - Provide an environment in which the energy manager and his or her team can perform their function
  - Represent all components of the institution community
  - Advise the top management of the institution on energy related issues on campus

  The committee should meet regularly (i.e. monthly) during which the energy manager has an opportunity to pinpoint problem areas that need to be solved by the committee. For this reason, the membership of the committee will depend on the various facets of activities on campus. As an example, consider the composition of an energy co-ordination committee taken from James Madison University [32] where the director of facilities management chairs the committee. The committee includes representatives from the facilities management, procurement, dining services, faculty of psychology, faculty of biology, faculty of health sciences, retail services, recycling, campus life and students.

  Typically, the energy co-ordination committee would contain representatives of facilities management, energy researchers, academic staff, students, retailers on campus, residences and hostels. The committee reports directly to the top management of the institution through the chairperson.

- *Energy Manager*

  The energy manager is responsible for achieving the goals and ultimately the mission statement of the energy management programme. For this task he or she receives assistance from an energy action team and the energy co-ordination committee. The energy manager is responsible for the design and implementation of the energy strategy. The post of energy manager should ideally be filled in a full-time capacity although occasionally it will need to be included in an existing manager's portfolio due to resource limitations. The energy manager reports to the energy co-ordination committee on the working status of the energy management programme and their function is to assist and not police his or her actions.

- *Energy Action Team*

  It is impossible for a single person to achieve all the tasks in the energy management programme. To this end, the energy manager appoints an energy action team of people who undertake the projects and tasks in the energy strategy. Typical membership includes energy researchers, academic staff, facilities technicians and students. The members of the energy action team are not dedicated positions but assist the energy manager as and when their help is required.

2.8 CONCLUSION

This chapter has explained the planning aspects of the energy management programme at an academic institution. The link between an energy policy and strategy is very often unclear and these two buzzwords are used inappropriately.

The chapter has highlighted the purpose of an energy management programme and that this programme is given direction through an energy policy. The policy is realised through an energy strategy that relies on four areas-of-activity.

In conclusion, the chapter has addressed the staffing requirements of the energy management programme through an energy manager and an energy action team. The energy co-ordination committee was also introduced as the custodians of the energy policy and the energy management programme as a whole.

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The models presented in this chapter are structured in a systematic manner in order to provide clarity in their relationships. Some academic institutions already have energy management programmes in action with a similar structure to the one presented here. On the other hand, there are many institutions that have started energy management on campus at project level without procuring vital management support or acknowledging the importance of maintenance or awareness. This in no way implies that these programmes are incorrect or that their managers are wrong. On the contrary, these institutions should be praised for efforts to date. However, for these programmes to become truly effective and balanced, a structured approach such as the one in this chapter should be adopted. It will be relatively simple for an institution presently conducting energy management projects to review their goals and mission and bring their present efforts in line with the structured programme in order to ensure the optimal use of human and financial resources.

The next chapter includes the technical and financial tools required for the subsequent four chapters that each address one of the areas-of-activity in detail to highlight their specific function and interaction with the other areas.

CHAPTER 3: THE ENERGY MANAGER'S TOOLBOX

"Tools of the trade are those vital instruments without which completion of the tasks required for the job would be very difficult."

Terry L. Fox

3.1 INTRODUCTION

A basic understanding of common energy management terms and quantities is essential to an energy manager in order to address the four areas-of-activity that were introduced in chapter 2. This chapter is divided into three sections, namely electricity load analysis, electricity tariffs and financial analysis:- electricity load analysis will provide the necessary tools with which to analyse the electrical performance of end-user groups or business units, electricity tariffs will address the tools required with which to determine the cost of electricity consumption and financial analysis will include the necessary information with which to calculate the financial viability of energy management projects.

3.2 ELECTRICITY LOAD ANALYSIS

When analysing the electrical performance of a building, end-user group or entire campus, it is important to extract only relevant information that will assist in the identification of problem areas. In other words, the energy manager must avoid an overload of information in order to eliminate confusion. This section will cover the basic information items that are used in this type of analysis.

3.2.1 Load Profiles

A load profile is a graphical plot of the power consumption for a specified time period (typically a day, week or month) [14]. Two essential elements can be obtained from a load profile. The maximum amount of power consumed (termed *Maximum Demand*) is the point of the greatest power consumption for the period under consideration and the sum of the area under the profile is the amount of energy that is consumed. Load profiles also provide an indication of the times that specific loads are being used as shown in figure 3.1.

Plotting separate loads on top of each other produces a disaggregated load profile. The function of the disaggregated load profile is to gain insight into the load distribution and to display the total load profile [14].

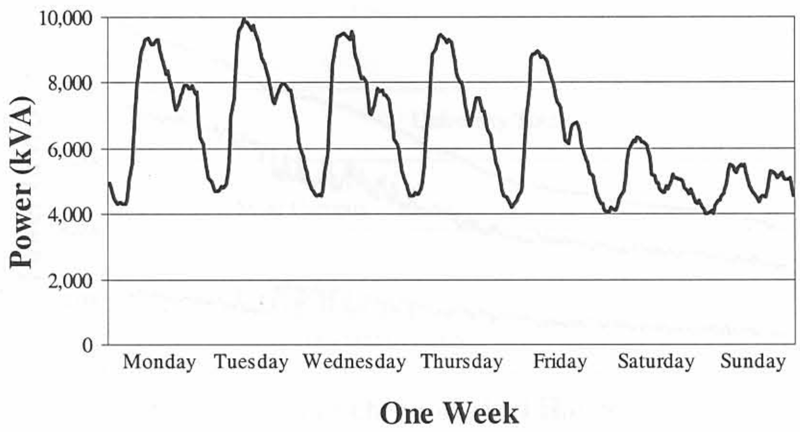

Figure 3.1: Sample weekly Load Profile from the University of Pretoria of the total load

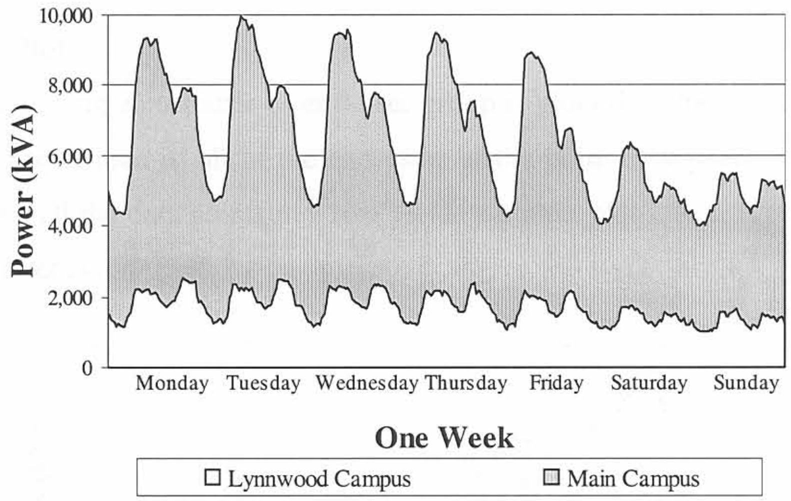

Figure 3.2: Disaggregated Load Profile of figure 3.1

3.2.2 Load Duration Plots

The load duration plot is constructed by sorting the load data from the highest value to the lowest value and then plotting this data against the duration interval. This plot is used to show the load distribution for each total demand value. An almost horizontal curve indicates a constant demand for electricity whereas a more negative curve indicates a time dependent process [14]. Figure 3.3 illustrates the load duration plot of the total University load as presented in figure 3.1. This load duration plot has been disaggregated into its two components, namely Main Campus and Lynnwood Campus (as presented in figure 3.2), which when added together provide the total University load. Figure 3.3 illustrates the interaction between the Main Campus and Lynnwood Campus and the effect that each has on the total University load. The varying gradients imply that that the Main Campus load predominates the total University load and that at the time of the peak of the total load, the Lynnwood Campus has not reached a maximum whereas the Main Campus has.

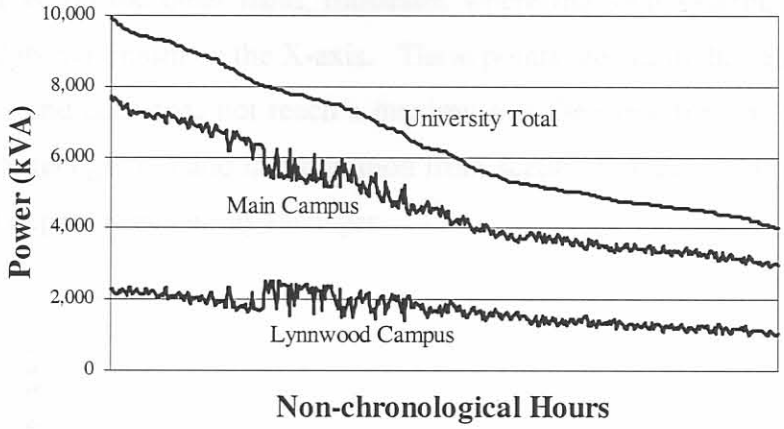

Figure 3.3: Load Duration Plot of the data presented in Figures 3.1 and 3.2

3.2.3 Scatter Plots

The load data of a single customer or end-user group is plotted on the Y-axis and the total load (that is the total load of all of the end-users at the point of supply) is plotted on the X-axis. Plotting all the data points in a row yields a scatter plot. A scatter plot is used to study consumer behaviour [14].

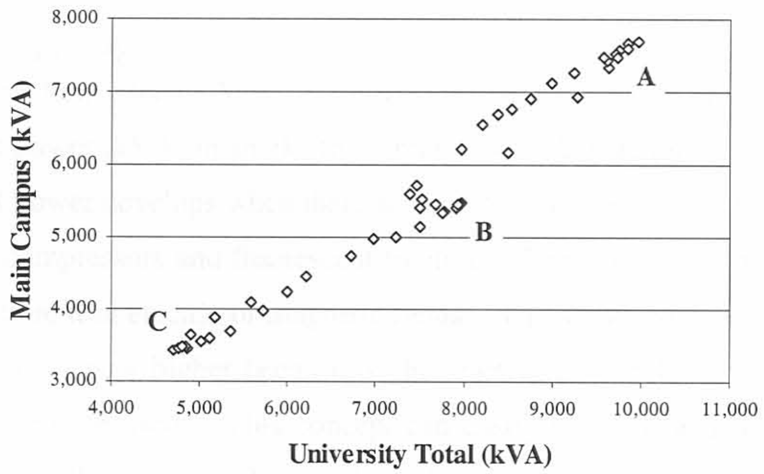

Figure 3.4: Scatter Plot of the Main Campus demand vs. Total University demand

If the dots on a scatter diagram tend to cluster in more than one place, the consumer has more than one regular mode of behavior as illustrated by the points A, B and C in figure 3.4. If the dots are scattered over a wide vertical range, the consumer has a very random behaviour. If the regression line through the dots has a positive slope, the consumer's load reaches a maximum at the same time as the point of supply. A negative slope in the regression line indicates that the consumer does not contribute as much to the overall system demand as the other end-users. For example, point A in figure 3.5 illustrates where this specific customer (Lynnwood Campus) reached its maximum against the

Y-axis. Point B, on the other hand, illustrates where the total system, at the point of supply, reached its maximum on the X-axis. These points are not in the same place, which implies that this end-user does not reach a maximum at the same time as that of the total system. Pattern recognition and interpretation from scatter diagrams is a powerful tool in the hands of an experienced energy manager.

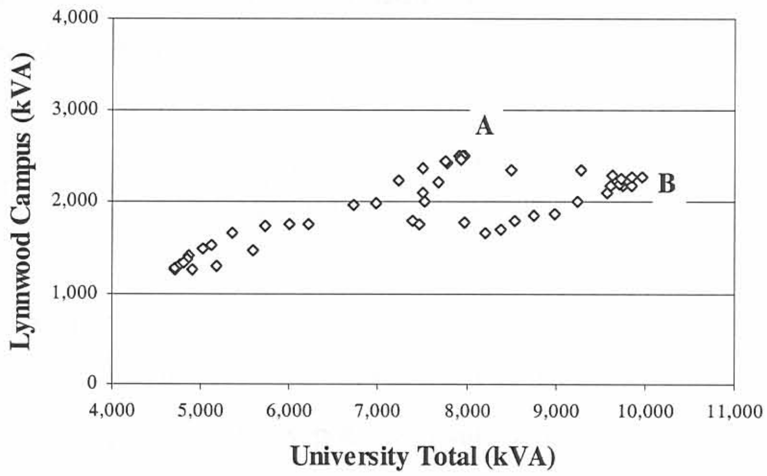

Figure 3.5: Scatter Plot of the Lynnwood Campus demand vs. Total University demand

3.2.4 Power Factor (PF)

Power factor is the term used to describe the ratio between the active or useful power (kW) and the apparent power (kVA) in an electric circuit [14]. A difference in the active power and the apparent power develops when there are inductive or capacitive loads in the circuit such as motors, compressors and fluorescent lighting. These loads do not only consume energy but also store it in electric or magnetic fields. The active power is not affected but the apparent power is now higher because of the reactive power that is developed in this circuit, which cannot be used. This concept can easily be explained on a management level (for tariff and billing purposes) using the following figure:

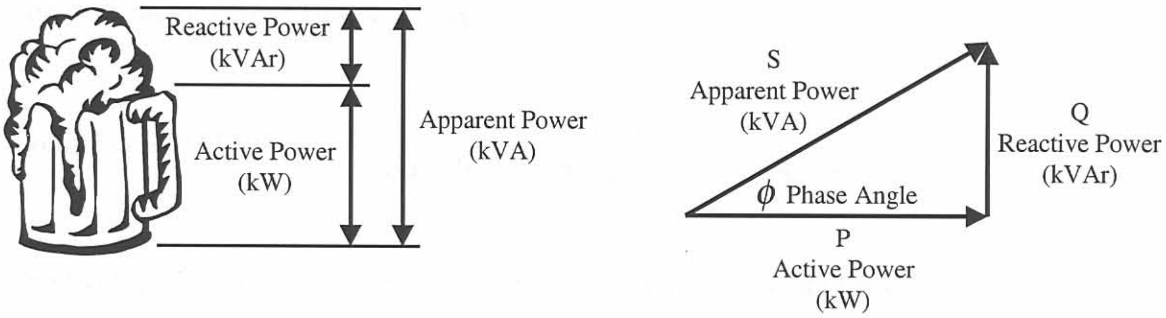

Figure 3.6: Power Factor Explained and the Power Triangle

Suppose the total beer is the apparent power. The tasteful part (or the liquid) represents the active power (P) and the foam that you drink, but does not taste like beer, is the reactive power (Q). One is fooled by the appearance of the beer but you actually get less useful beer. The power is represented by equation 3.1 with reference to the power triangle in figure 3.6 [33]. The power factor has an impact on the amount of power that is dissipated in electric circuits and there are many technical examples in text [33]. The power factor cannot be greater than 1.

$$Power\ Factor\,(PF) = \cos\phi = \frac{P}{S} = \frac{Active\ Power\,(kW)}{Apparent\ Power\,(kVA)} \qquad [3.1]$$

3.2.5 Load Factor (LF)

The load factor is a utilisation factor and is expressed as the ratio of the average demand to the maximum demand [34]. Simply put, the load factor is a ratio between the actual energy consumed during a period and the energy that could have been consumed had the demand remained at the maximum demand for that same period. The value for the load factor cannot be greater than 1.

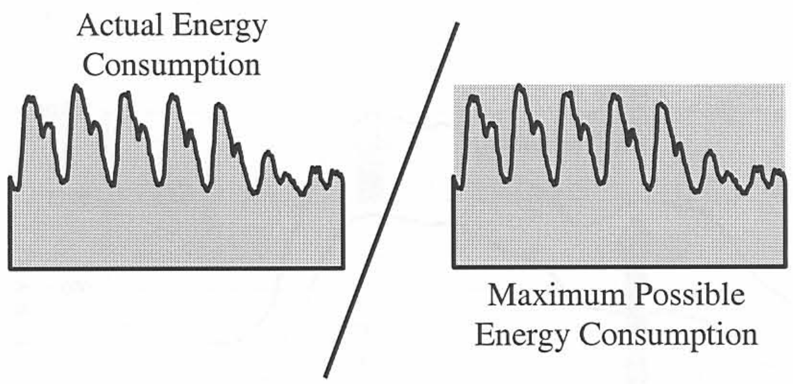

Figure 3.7: Load Factor Explained

The load factor can be calculated using equation 3.2 [35].

$$Load\ Factor\,(LF)_{\ for\ period} = \frac{kWh\ Consumed_{\ in\ period}}{Maximum\ Demand_{\ in\ period} \times Number\ of\ Hours_{\ in\ period}} \qquad [3.2]$$

The load factor for the load profile presented in figure 3.1 is calculated as follows:

$$LF_{\ week} = \frac{1{,}083{,}620\ kWh}{9{,}970\ kW \times 7\ days \times 24\ hours} = 64.70\% \qquad [3.3]$$

Note that active power (in kW) was used for the maximum demand in equation 3.3 in order to arrive at the same units of measurement. In this instance the maximum demand was available in active power but occasionally only the apparent power value (in kVA) is available. This typically occurs when information is being obtained from the electricity account and not from measured load data. In this case using the apparent power value that is available can approximate the load factor. Alternatively, the active power component can be calculated if an average value for the power factor is known.

3.2.6 Coincident Maximum Demand and Diversity Factor

The contribution that individual customers or end-users make towards the maximum demand of the system will vary. The result of this is that the real costs of the system are not necessarily caused by all of the customers connected to that system. For example, the Total University load presented in figure 3.9 is made up of two separate customers, namely Main campus and Lynnwood Campus. The total system peak occurs at point A. The Lynnwood Campus peak (point B) does not contribute to system peak whereas the peak of the Main Campus (point C) is a major contributor. In other words, the maximum demands of the Main Campus and the total system load coincide. This is termed coincident maximum demand.

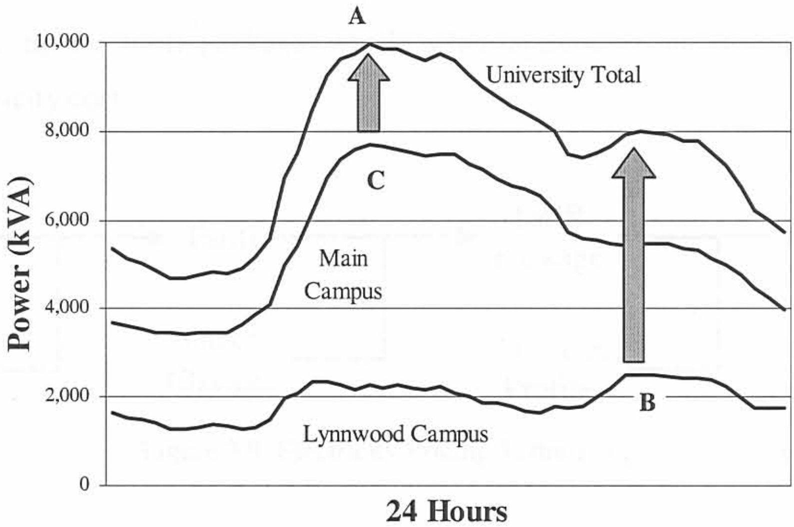

Figure 3.8: Coincident Maximum Demand Explained

The diversity factor of a number of customers, when considered from a single point of supply is defined as the ratio of their separate maximum demands to their combined maximum demand. It is a measure of the real maximum demand on a system at a mutual point of supply and is given by equation 3.4 [34]. The diversity factor is always greater than 1.

$$Diversity\ Factor\ (DF) = \frac{\sum_{i=1}^{n} Maximum\ Demand}{Combined\ Maximum\ Demand} \qquad [3.4]$$

The diversity factor between the separate loads and the total load presented in figure 3.8 is calculated as follows:

$$DF_{\,University\,Total} = \frac{MD_{\,Main\,Campus} + MD_{\,Lynnwood\,Campus}}{MD_{\,Total\,University}} = \frac{7{,}694 + 2{,}503}{9{,}970} = 1.023 \qquad [3.5]$$

3.3 ELECTRICITY TARIFFS

Knowledge of tariff structures is not only beneficial for the energy manager from a supply-side point of view but also from a demand-side perspective in cases where the individual business units or faculties and departments are billed for their electricity consumption.

3.3.1 Tariff Design

A conceptual view of tariff pricing terminology in figure 3.9 [34] illustrates that the tariff structure together with the tariff rates will provide the tariff. This, together with the other charges, makes up the tariff package, which, when applied to the consumption profile, gives the electricity cost.

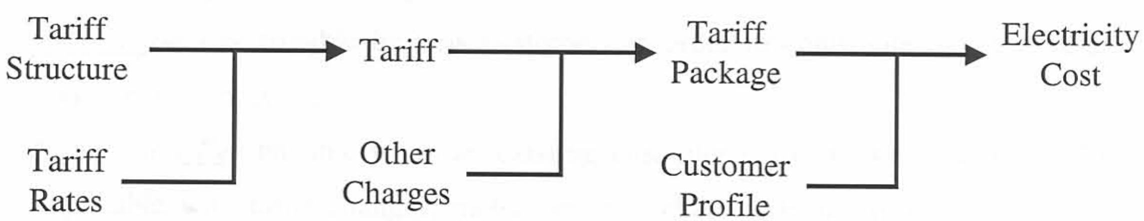

Figure 3.9: Electricity Pricing Terminology

Tariff Structure

- *Fixed charge (Flat rate)* is a fixed payment made per month independent of consumption.
- *Single Energy Rate* is a payment made for consumption only at a fixed rate.
- *Inclining Block Rate* consists of different prices for different energy usage. For example, a low block rate for the first 100 units of consumption and a high block rate for the balance of consumption.

- *Declining Block Rate* is the reverse of the inclining block rate whereby a higher initial rate is charged and a lower rate for the balance of consumption.
- *Demand Tariff* consists of a maximum demand charge and an energy rate.
- *Time-of-use (TOU) Tariffs* apply different rates at different times of the day and for different seasons (high and low demand periods).
- *Real-time Pricing (RTP)* is when the energy price changes in real time (e.g. on an hourly basis).

Tariff Rates

The tariff rates are the actual per unit amounts payable for any of the tariff charges. These tariff charges include:

- *Basic Charge*, a fixed charge (payable every month) irrespective of usage,
- *Energy Charges* for active energy consumption (e.g. kWh), and
- *Demand Charges* levied for the maximum demand.

Other Charges

The supplier will levy certain charges dependant on individual circumstances. Examples are included here.

- *Circuit Breaker Fee*, a fixed fee proportional to the size of a customer's circuit breaker. Usually, the greater the rating on the circuit breaker, the higher the fee payable.
- *Connection Fee* payable by new customers in order to contribute to the cost of the additional connections.
- *Conversion Fee* payable when an existing customer converts their supply. This is applicable with tariff changes, meter changes, changes in the installation or when a supply point is shifted.
- *Capital Charges* are the capital costs of the network that are not recovered through the tariff and are thus recovered through additional capital charges over and above the tariff. This cost may be paid by cash or by means of a monthly capital charge called a monthly rental. A capital interest rate is applied to this additional cost and customers are granted rebates in order to refund that part of the capital costs that are already included in the tariff.
- *Service Charges* include transfer fees when ownership of a conventionally metered point of supply changes hands, a call out fee due to a supply interruption when the fault

is found within the customer's installation, special meter reading fees when done at the customer's request and meter test fees which are charged when a meter is tested at the customers request.

3.3.2 The Demand Tariff (or the Two-part Tariff)

This tariff charges a customer for the amount of energy consumed as well as on the rate at which this energy is consumed. This structure recovers variable costs through a constant consumption charge (e.g. c/kWh) and a capacity cost charge (proportional to rate of use) (e.g. Rand/kW or kVA). This tariff requires metering that is able to log the maximum rate of use in addition to the normal energy metering function [14].

A great deal of information can be obtained from a demand tariff electricity account. Apart from the energy consumption and maximum demand components, other standard charges (typically meter reading fees) are also reflected on the account [36]. The date of the meter reading and the period of the account are usually required for benchmark purposes. If no meter reading date is provided, it may occur that the consumption has been estimated. Some suppliers as a result of manpower limitations have adopted this method. With this approach, the energy consumption is estimated based on historical consumption information or other statistical methods. In this instance, energy benchmarks will help to raise attention to suspect estimations on the part of the supplier. In other words, a way-off benchmark result for a particular month could raise your attention to the fact that the estimated account is incorrect and has been either over estimated or under estimated by the supplier. If discrepancies exist, it is possible to request that the supplier read (or re-read) the meter (occasionally at an additional charge).

3.3.3 The Time-of-Use Tariff

A time-of-use (TOU) tariff applies different energy consumption charges during different periods. The energy rate during each interval closely tracks the actual cost of supply. TOU tariffs recover the actual costs of providing electrical energy more fairly and accurately than two-part tariffs [14].

Energy charges can be made to vary seasonally and/or on a daily basis. TOU tariffs often have demand charges associated with them and the demand charge, like the consumption charge, is also differentiated with time.

3.3.4 Notified Demand Tariff

The notified maximum and minimum demand may be stated on the account. The notified maximum demand is the dictated maximum demand of a customer for the duration of the billing period. In other words, this is the specified maximum demand that a specific customer may not exceed. It is typically used to class customers according to varying tariff rates. The specified minimum demand is a dictated value (as a set percentage of the notified maximum demand) that will be levied as part of a maximum demand charge irrespective if a customer's demand is less than the notified minimum demand [36].

For example a customer has a notified maximum demand of 2,400 kW and a notified minimum demand of 1,680 kW which is obtained as a result of a specified 70% of maximum (i.e. 2,400 x 70%). In this example, if the customer has a maximum demand that is less than the notified minimum demand (1,680 kW), then this customer will be charged for the notified minimum demand.

3.3.5 Equivalent Cost per Unit (c/kWh)

The equivalent cost per unit is used to gain a complete understanding of the actual costs per unit of electricity that is consumed. It is calculated by dividing the sum of all the electricity costs and charges by the amount of units (kWh) consumed. In this manner, the assumptions that the cost of each unit that is consumed is equal to the energy rate only, is avoided because the other charges and costs are also considered. Occasionally the contributions of the other charges (such as those for maximum demand) to the overall electricity cost are more than that of the energy consumption alone.

Consider the electricity account for the main campus of the University of Pretoria during June 1999. During 1999, this campus was billed according to a demand tariff with energy consumption at 8.76 c/kWh and maximum demand at R44.95/kVA as follows:

Energy Consumption:	3,862,699 kWh	338,372.43
Maximum Demand:	9,965 kVA	447,926.75
Meter Reading Fee:		526.00
	Sub-total	R 786,825.18
	VAT (@ 14%)	R 110,155.53
	Grand Total	**R 896,980.71**

In this example the equivalent cost is calculated in equation 3.6.

$$Equivalent\ Cost\ per\ Unit = \frac{338{,}372.43 + 447{,}926.75 + 526.00}{3{,}862{,}699} = 20.37\ c/kWh \qquad [3.6]$$

The equivalent cost of 20.37 cents per unit implies that each unit of electricity that is consumed on this campus does not only cost 8.76 cents (the energy rate) but actually costs 11.61 cents more as a result of meter reading and maximum demand charges.

Normally the tax is not included in this calculation because it is not considered as a business expense and is usually reclaimed from the government. However, if for some reason this is not the case, then this tax should also be included as part of the electricity costs in equation 3.6.

3.4 FINANCIAL ANALYSIS

Some energy management projects might require financial investment in new equipment or the purchase of other material. The aim of economical project analysis is to provide a quantitative financial means of measurement to evaluate investments.

3.4.1 Cash Flow Diagrams

Cash flow diagrams are a graphical description of cash transactions [37]. Receipts are indicated with an upward arrow and disbursements with a downward arrow. The length of the arrow is proportional to the size of the payment and the net cash flow per period is presented. Examples are illustrated in figure 3.10.

3.4.2 Time Value of Money

The value of money is related to time and the concept of the time value of money involves shifting monetary payments to future or present equivalents [37]. The following symbols are used for the basic time value calculations:

P present value

F future value

A uniform series payments

n number of compounding periods

i effective interest rate

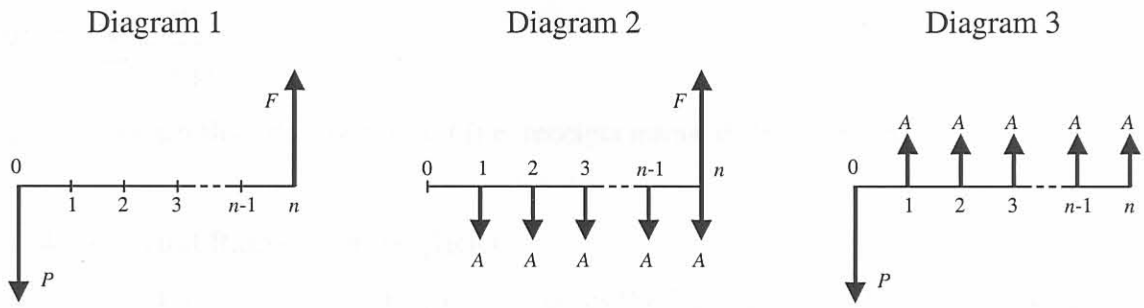

Figure 3.10: Time Value of Money Diagrams

Diagram 1

$$F = P(1+i)^n \qquad [3.7]$$

$$P = \frac{F}{(1+i)^n} \qquad [3.8]$$

Diagram 2

$$F = A\left[\frac{(1+i)^n - 1}{i}\right] \qquad [3.9]$$

$$A = F\left[\frac{i}{(1+i)^n - 1}\right] \qquad [3.10]$$

Diagram 3

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \qquad [3.11]$$

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \qquad [3.12]$$

3.4.3 Net Present Value (NPV)

Present value analysis is a method of measuring costs and savings that will occur at different times on a consistent and equitable basis for decision-making. This method determines the difference between the present values of the project revenues and costs, hence the *net* in net present value. A NPV of zero implies that the project will recover the investment as well as the interest charge on that investment. A NPV higher than zero shows that the project is worthy of further consideration and negative values show that a project will not recover its investment [37].

$$NPV = \sum_{t=0}^{n} \frac{F_t}{(1+i)^t} \qquad [3.13]$$

F_t net cash flow during period t (i.e. receipts minus disbursements)

3.4.4 Internal Rate of Return (IRR)

The internal rate of return (IRR) method solves the NPV equation for an interest rate that yields zero NPV. In other words, the IRR causes the project revenues to equal the project costs. The internal rate of return is thus the rate, i* that satisfies equation 3.14 [37].

$$NPV(i^*) = \sum_{t=0}^{n} \frac{F_t}{(1+i^*)^t} = 0 \text{ where } 0 \leq i^* \leq \infty \qquad [3.14]$$

The computation of the IRR requires a trial-and-error solution. Substituting a few discount rate values until the above equation is satisfied or until the NPV equals zero solves it. The IRR represents the equivalent rate lost (or earned) on the under recovered (or over recovered) balance of the investment. IRR can be calculated for a number of alternative projects in order to rank them. A higher IRR indicates that higher financial merit and negative figures are indicative of financial loss. Consider the sample cash flow in table 3.1.

The expression to calculate the IRR is given by the following equation:

$$NPV(i^*) = -10000 + 4000\left\{\sum_{t=1}^{4}\left[\frac{1}{(1+i^*)^t}\right]\right\} \qquad [3.15]$$

Substituting values for i^* in order to render the NPV equal to zero, yields an IRR equal to 21.86%.

Table 3.1: Sample Cash Flow

Period	Cash Flow
0	-10,000
1	4,000
2	4,000
3	4,000
4	4,000

3.4.5 Payback Period

The payback period is the amount of elapsed time, starting from the time that the initial investment is made, until the benefits exceed the initial investment [37]. Projects with shorter payback periods are definitely preferred over those with longer payback periods. However, this method should not be used as the sole selection criterion of a project unless other methods fail to clearly define the most suitable project among a number of nearly equally advantageous programs. The payback period for the cash flow in table 3.1, using an interest rate of 10% per period is given in table 3.2.

Table 3.2: Calculation of the Payback Period for Sample Cash Flow (i = 10%)

Period	Cash Flow	NPV(10%)
0	-10,000	-10,000
1	4,000	-6,364
2	4,000	-3,058
3	4,000	-53
4	4,000	2,679

The payback period is 4 periods.

3.4.6 Minimum Attractive Rate of Return (MARR)

The MARR is the percentage cut-off rate representing a yield on investments that is considered minimally acceptable [37]. The value of the MARR is usually a management decision determined from the cost of capital within the organisation and the desired percentage return on investment. If the NPV is calculated using the MARR and the result is greater than zero, it indicates that the project is viable. It follows too that if the IRR is greater than the MARR, the project will be acceptable to management.

3.5 SUMMARY

This chapter has covered the basic tools required of an energy manager. It almost goes without saying that these are not the only tools that will be needed by an energy manager but the contents of this chapter have covered those items that are energy management specific. This makes this chapter important if the role of energy manager is bestowed on an existing manager within a facilities management department at an academic institution.

Before a reduction in the energy cost is possible, the energy manager must be able to analyse and interpret the present performance of the entire campus or individual end-users.

Graphical analysis is vital in this regard because it allows for the energy manager to make a conclusion or pinpoint problematic areas very quickly.

An appreciation of the price of electricity only as a major external pressure acting in on the energy management programme of the academic institution is not sufficient. A thorough understanding of the tariff structure will ensure that the energy manager is familiar with all the opportunities with which to reduce the electricity costs per product or business function.

In a similar vein, a basic understanding of quantitative economics will ensure that considering the effects of time on the value of money more accurately plans for potential energy management projects that rely on capital investment.

A solid understanding of the tools in this chapter will enhance the aim of the next four chapters in which each one of the areas-of-activity are discussed.

CHAPTER 4: ENERGY DIAGNOSIS

"Don't be content with the what, but get to know the why and the how."

Lord Robert Baden-Powell

4.1 INTRODUCTION

In chapter 1, the diagnosis of the energy consumption was heralded as the starting point of the energy management programme. It is this area-of-activity that determines the present energy performance per product or business unit and analyses reasons for poor performance. In other words, energy diagnosis is the process of accounting for the energy on campus in terms of the financial and technical aspects. Before the energy can be accounted for, it is necessary to develop an understanding of the hierarchy of energy consumption from the individual equipment all the way through to the point of total institution consumption as shown on the left in figure 4.1. An example of each level is provided on the right in this figure.

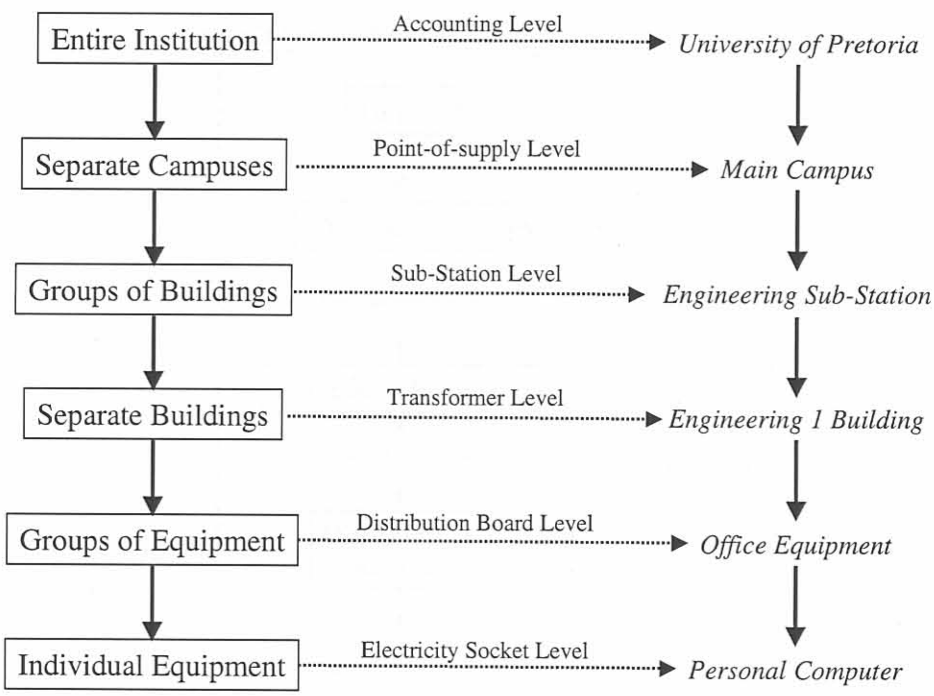

Figure 4.1: Hierarchy of Energy Diagnosis on Campus

From figure 4.1 it follows that managing the energy consumption at any of the levels will result in the management of the electricity cost of the entire institution. The point of departure of this chapter is the dissemination of energy management problems to the other areas-of-activity but before this can be accomplished, the problematic areas that are responsible for a high electricity cost per end-user need to be identified. The energy manager should be aware that not all levels in figure 4.1 are necessarily responsible for high electricity costs per product or business unit. In other words, addressing individual machinery might not be an option and as a result a solution to the electricity cost needs to be sought higher up in the diagnosis hierarchy. On the other hand, discovering faults at higher levels should, were possible, be followed all the way through to determine the source of the problem at the individual equipment level. The hierarchical levels depicted in figure 4.1 are fairly comprehensive and may not be applicable to all academic institutions, dependent on their physical size and geographical organisation.

4.2 INSIDE THE ENERGY DIAGNOSIS AREA-OF-ACTIVITY

This chapter can be divided into four sections, namely determining the specific benchmark to be calculated, acquiring the necessary data, processing this data into information by identifying contributors to the benchmark and finally disseminating it as knowledge to the other areas-of-activity. This process is illustrated in figure 4.2.

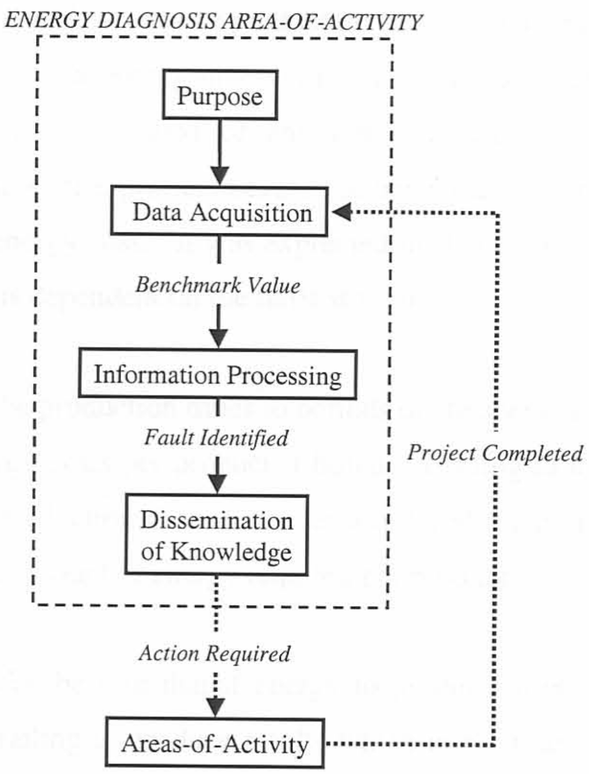

Figure 4.2: Functionality of the Energy Diagnosis Area-of-Activity

The solid arrows in figure 4.2 indicate internal operation and the dotted arrows indicate operations that occur with the other areas-of-activity. In other words, the components included in the dashed block in figure 4.2 fit into the Energy Diagnosis block of figures 2.4, 2.5 and 2.6.

Each of the four sections in the energy diagnosis area-of-activity will be discussed.

4.3 PURPOSE

It has been said that energy diagnosis is the starting point of the energy management programme. The problem lies in determining where to start with the energy diagnosis. It makes no sense in collecting data and then trying to determine where it can be used. For this reason the diagnosis hierarchy presented in figure 4.1 is very useful as a guideline to determining the starting point. The next step is to decide what is going to be calculated or determined. In other words, you need to know what it is you are looking for and the place where you should be looking.

4.3.1 Benchmarks

By definition, a norm or benchmark is a standard or point of reference [1]. It follows then that an energy benchmark at an academic institution is a performance level that links the functions on campus to the cost of energy usage. Traditionally, benchmarks have been used that link the business functions or production levels to the energy consumption only. This is not satisfactory in an energy management programme where the aim is to reduce the energy cost within the context of environmental harmony in order to enhance competitiveness and maximise profits because the benchmark is orientated around energy consumption and not energy cost. It was explained in chapter 1 that the link between the energy usage and cost is dependent on the tariff structure.

For example, altering the production times to periods of cheaper energy rates could provide a reduction in the energy costs per product if billed according to a time-of-use tariff. In this case, altering the production times has indeed reduced the cost of energy per product but has not reduced the amount of energy required per product.

From this example it can be said that if energy to production benchmarks are used, the programme would be failing to produce results which is not true. Using energy cost to production benchmarks would highlight the success of the above example.

Care should be taken not to have too many benchmarks that become very similar and as such not very useful. The other problem that occurs is that the accuracy of the benchmark can become hazy if assumptions need to be made. For example, the energy cost per student per month on a campus is not accurate because an assumption needs to be made regarding the duration and frequency of time spent by students on campus. Table 4.1 can be used as a guide for the selection of benchmarks.

Table 4.1: Benchmark Selection Guide

	Uses	Examples
Institution Level	▪ Verify supplier accounts ▪ Track trends in costs ▪ Comparison to other institutions	▪ Total Cost per Month ▪ Equivalent Cost per Unit ▪ Energy Cost per Student
Campus Level	▪ Verify supplier accounts ▪ Track trends in costs ▪ Comparison between campuses	▪ Total Cost per Month ▪ Cost per Campus per Month ▪ Equivalent Cost per Unit ▪ Energy Cost per Student
Building Level	▪ Apportion costs to buildings ▪ Comparison between buildings ▪ Comparison between different types of facilities	▪ Energy Cost per Building ▪ Energy Cost per unit of Facility Space (Office, Laboratory, Lecturing or Hostel) ▪ Energy Cost per Hostel Resident

The table focuses on two major types of benchmarks, namely those that depict electricity cost per academic facility (or business process) and those that depict electricity cost per student (or product). In this case the students of an academic institution are considered as its product and the facilities of the institution are considered as the business processes.

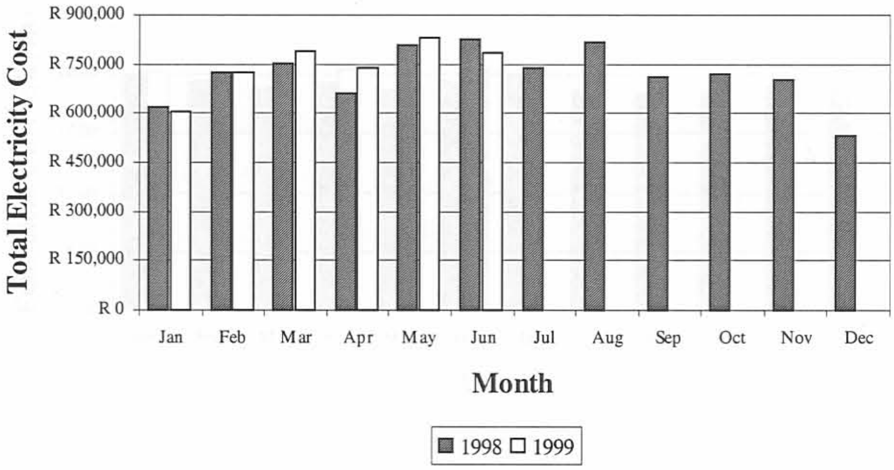

Figure 4.3: An example of the Electricity Cost from Main Campus, University of Pretoria

4.3.2 Benchmark Fluctuations

The energy costs within an academic institution will not remain constant. This is due to various reasons and includes increasing tariff rates, seasonal swing, number of days under consideration and activities on campus at the time.

Seasonal swing is the effect of seasonal change on the consumption of electrical energy [38]. The consequence of seasonal swing is that the amount of electricity, and associated cost, will not remain constant all year round, as it is dependent on the ambient air temperature. For example, the electrical space-heating load will be more prevalent in winter than in summer and vice versa with the cooling load.

The institution calendar also plays a major part. The electricity costs should subside during holiday periods when the number of students on campus is much lower. This is particularly true in cases where there are accommodation facilities for students on campus. This effect is illustrated in figure 4.3 from the University of Pretoria where students are on vacation during the months of January, April, July, September and December. Please note that the electricity costs in figure 4.3 increase from the summer months in the beginning of the year towards the winter months in the middle of the year (June, July and August). Fortunately the high electricity costs in the winter month of July are avoided due to the students being on vacation.

The energy manager must bear these factors in mind before reacting on fluctuations in the energy cost benchmarks. Normalising the benchmarks can avoid this and can be accomplished by calculating averages, such as the equivalent cost per unit, and comparing these to those of previous years or periods.

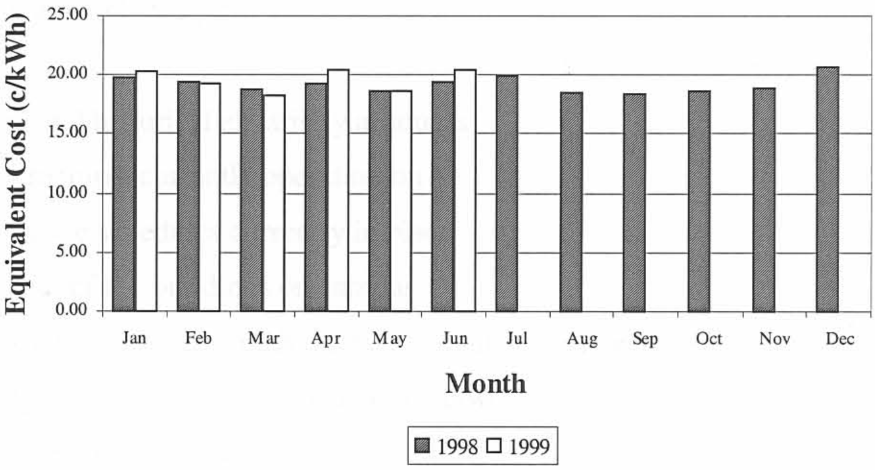

Figure 4.4: An example of Equivalent Cost per Unit of figure 4.3

Examples of benchmark normalisation are illustrated in figure 4.3 and 4.4. Incidentally it is interesting to note that the maximum equivalent cost in figure 4.4 occurs during periods when the electricity costs in figure 4.3 are low. In other words figures 4.3 and 4.4 are almost the inverse of each other. This is caused by the student vacations whereby not as much energy is being consumed during these periods but the maximum demand component of the electricity account is still large.

4.4 DATA ACQUISITION

Once the benchmarks have been selected, the data required for their calculation can be acquired. The activities of data acquisition and information processing in figure 4.2 can collectively be referred to as energy auditing. Energy auditing is a very wide field that can be split into four types namely, documentation, personnel, walk and measurement audits. Not all of the activities of each audit type are relevant to determine the benchmark values and some of them will be used during the information processing activity in order to determine the reasons for the benchmark values. Using this approach, the first step is to determine the type of information that is necessary in order to arrive at a value for the benchmark. You may find that some of the benchmarks can be calculated with relative ease from supplier electricity accounts alone whereas others require deeper analysis.

4.4.1 Documentation Audit

A documentation audit, as the name implies, involves the acquisition of any documentation that has relevance to electrical energy on campus. It may be found that this information is already available on campus but that it may lie with different departments such as the finances and facilities management departments. This type of information is usually acquired first and includes [38]:

- Existing and historical electricity accounts
- Tariff structures currently operating on
- Maintenance schedules currently in place
- The layout of the buildings on campus
- Floor plans of buildings including the amount of office space
- Drawings of the electricity reticulation network
- Electrical equipment data

4.4.2 Personnel Audit

A personnel audit involves the acquisition of information that is resident with the people on campus. This is accomplished through interviews with key personnel, conducting opinion polls and distributing questionnaires. It is very important to interview the appropriate personnel when conducting the audit. For example, it is not possible to determine the maintenance schedule by interviewing the academic staff. In essence, all the members of the campus community should be questioned but it is important to ask the correct questions at the correct level.

A questionnaire should be thoroughly planned well in advance and the information that is acquired will form a platform from where further audits can be launched. This type of audit relies on a great deal of interaction with the university community and care should be taken not to waste the time of those whose opinion is being sought.

4.4.3 Walk Audit

A walk audit is a walk-through tour of the campus in order to observe the major operational and equipment features that are being utilised. The main purpose of the walk audit is to obtain general information. It is good practice to make notes of possible energy management opportunities and faulty equipment during the walk audit. Typically, the following should be looked for during the walk audit [36, 38]:

- *Sources of Energy*

Observe which types of energy sources (e.g. electricity, coal or gas) are utilised for the various activities on campus such as food preparation, cleaning, hot water generation etc. From this the reliance and cost contribution of an operational function on any one particular energy source can be determined.

- *Controllable Equipment*

Identify equipment that can be controlled in order to avoid energy wastage or that can be operated at flexible times. This is usually equipment that is used infrequently or whose use is not necessary during certain times of the day. Examples include using sunlight instead of electrical lighting during the daytime or controlling hot water cylinders during periods of low use such as weekends.

- *Waste heat sources*

Most processes and activities have ample opportunity for waste heat recovery. Waste heat recovery means that wasted heat energy is recovered and used for another purpose such as heating water for other operational processes. Waste heat sources include air conditioners, air compressors, heaters, boilers, ovens, furnaces etc.

- *Equipment Numbers and Ratings*

An inventory should be taken of all energy consuming equipment such as lights, fridges, stoves, air-conditioners etc. In terms of electrical equipment, try and obtain the electrical rating of the equipment.

- *Counteractive Equipment Layout*

Observe the layout of the equipment in an attempt to identify processes that may either adversely affect each other or may be inefficient. Examples could include prepared food that has to be reheated or food that is allowed to air cool, which in turn affects the air-conditioning.

A database should be established of the information that has been acquired during the walk-audit for each building and floor on campus [36].

4.4.4 Measurement Audit

The measurement of the electricity consumption of end-user groups is crucial towards determining their contribution to the total electricity cost. This is even more important in the light that the benchmarks relate to the electricity cost. There are many different types of measurement equipment. These range from simple electro-mechanical energy meters that record the energy consumption only and are manually read to real-time systems that measure many parameters, such as current, voltage, power factor, active power and reactive power, and are read automatically from a central energy monitoring system.

Sometimes only measurements of the supply points are made to pinpoint problems and quantify probable savings. This might be necessary due to financial or purely practical reasons where individual campus activities cannot be measured on their own.

Investment could also be made into a real-time measurement system but this will depend on the availability of capital. Monitoring the end-use of electricity on a real-time basis can lead to many discoveries of ailments in the design or management of energy systems.

4.4.5 Benchmark Calculation Case Study

All the data necessary to calculate a benchmark may not always be available and sometimes it may be necessary to find other methods that will provide very accurate, and possibly precise, answers. This case study is one such example where an alternative approach is used to calculate the energy costs per student for two hostels for the month of June 1999 as a result of only electro-mechanical energy meters being available. This example is based at the University of Pretoria and the metering configuration for these two specific hostels is illustrated in figure 4.5.

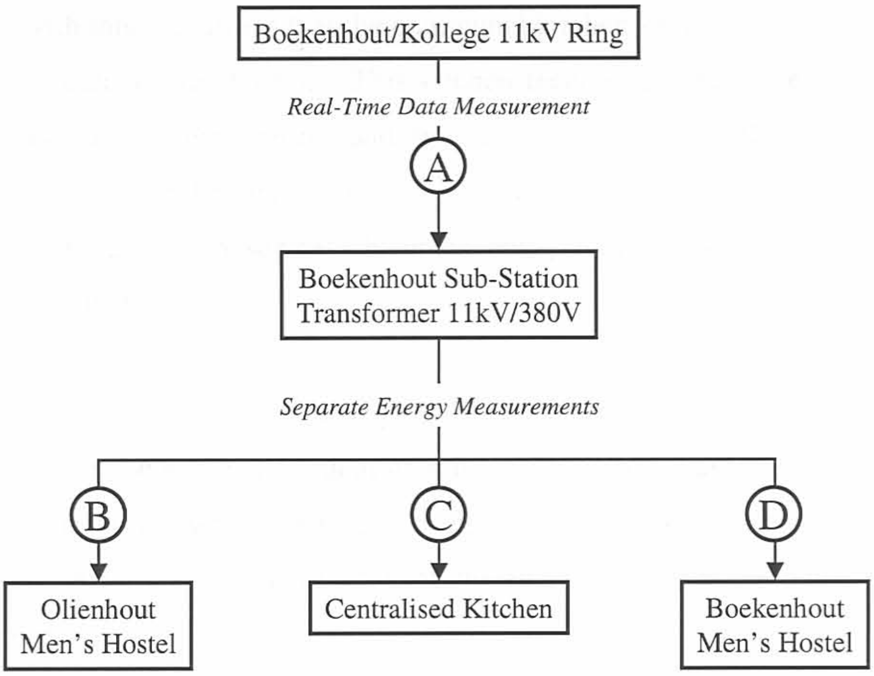

Figure 4.5: Metering Layout for the Benchmark Calculation Case Study

The University of Pretoria is billed according to a demand tariff whereby, during 1999, energy consumption is charged at a rate of 8.76 c/kWh and maximum demand is charged at a rate of R44.95 per kVA. Calculating the energy costs per student for each of these hostels, will require the energy consumption of each hostel and their contribution to the overall maximum demand of the University. Using their energy consumption only will not reflect their true total contribution to the overall cost.

The entire sub-station is measured in real-time with the energy management system of the University of Pretoria (meter A). The real-time meter enables a load profile to be constructed of the sub-station and as such the contribution that is made by this sub-station to the overall demand of the University can be determined. This principle was explained in chapter 3 under section 3.2.6 on coincident maximum demand. For this specific month, the University reached a maximum demand of 9,970 kVA at 09:30 on Tuesday 8 June 1999 of which this sub-station contributed 448 kVA. It is important to remember that only the contribution of this sub-station at the time of the overall University maximum is considered and not its independent maximum which may have occurred at a different time.

Three end-user groups are supplied from this sub-station, namely Olienhout hostel, Boekenhout hostel and their communal kitchen. Each feed point is metered but unfortunately not in real-time. In other words, the energy consumption of each end-user group is measured with an ordinary electro-mechanical energy meter (meters B, C and D).

The problem with this scenario is that the communal kitchen should not be brought into the energy costs calculation (meter C). This kitchen receives a separate electricity account from the University administration and this cost, along with all the other business overheads, is included in the meal costs that are charged to each student. In other words, the kitchen is operated as a separate business entity with the students from these two hostels as its clientele.

The goal is to calculate the energy cost per Olienhout and Boekenhout hostel resident for the month of June 1999 (i.e. R/student/month). Firstly the date and time of the total University maximum demand is needed as well as the tariff rates for energy consumption and maximum demand. Then for each of the two hostels, the following information would be required:

- Occupancy rates for the month
- Energy consumption
- Contribution to the University maximum demand

All the required information is available except the contribution of each end-user group to the overall maximum demand of the University. However, the contribution of this sub-station (meter A) at the time of the University maximum is known as well as the load profile for the entire month. Using this information, the load profile of the sub-station (meter A) is divided by its sum to deliver a factor by which the independent end-user energy measurements (meters B, C and D) can be multiplied. In other words, the total profile is divided into its three components according to their total energy consumption. This approach assumes a unity diversity factor and is based on the premise that all three loads reached a maximum demand at the same time. This method is graphically illustrated in figure 4.6 and can be accomplished using a computer based spreadsheet programme.

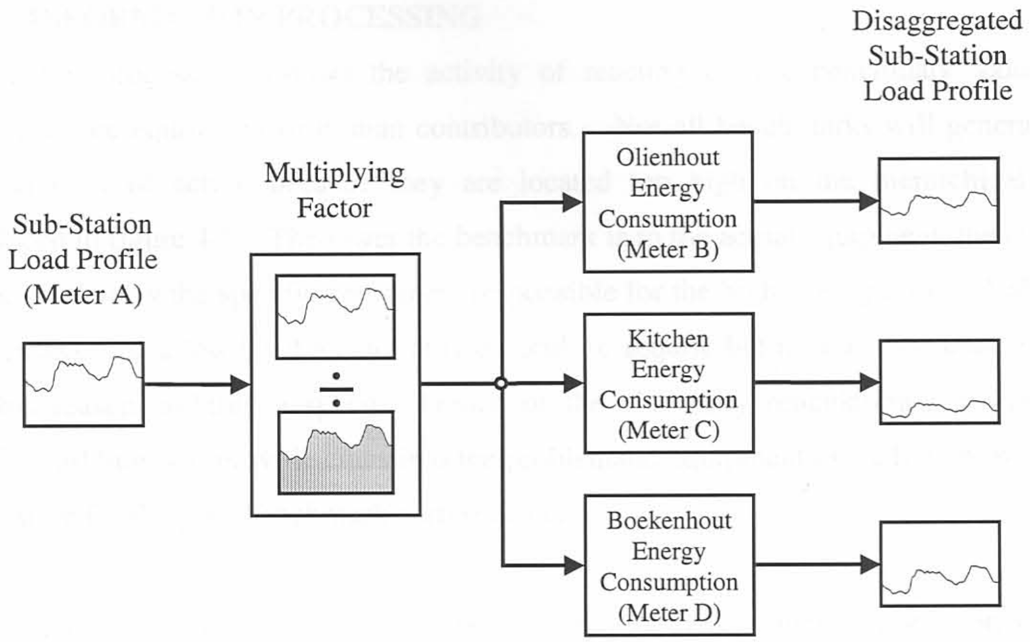

Figure 4.6: Sub-Station Disaggregation for the Benchmark Calculation Case Study

Once the individual load profiles of each end-user group has been constructed, the contribution that each one makes to the overall maximum demand of the University can be obtained. Applying the supplier tariff rates for maximum demand and energy consumption to the maximum demand contribution and separate energy consumption of each end-user group calculates the energy cost contribution of that end-user group. This value need only be divided by the number of students occupying the residence at that time to determine the energy cost per student. The results are provided in table 4.2.

Table 4.2: Results of the Energy Cost per Hostel Resident Benchmark

	Energy (kWh)	Contribution to Maximum Demand (kVA)	Total Electricity Cost	Occupancy for June 1999	Energy Cost per Student (R/student)
Boekenhout	59,160	158	R 12,294.98	271	R 45.37
Olienhout	77,314	207	R 16,067.81	269	R 59.73
Kitchen	31,182	83	R 6,480.39	⇦ Amount Billed to Kitchen	
Total Sub-Station	167,656	448	R 34,843.17	⇦ Overall Cost of Sub-Station	

From the results in table 4.2 it can be said, that for this month, each resident in Boekenhout and Olienhout Hostels cost the University R45.37 and R59.73 in electricity costs respectively. The communal kitchen contributed R 6,480.39 to the overall electricity cost of this sub-station and this sub-station contributed R 34,843.17 to the overall electricity costs of the University during this month (June 1999).

4.5 INFORMATION PROCESSING

Information processing follows the activity of reacting on the benchmark values by identifying the equipment or human contributors. Not all benchmarks will generate the same amount of action because they are located too high on the hierarchical level introduced in figure 4.1. The lower the benchmark is to the actual equipment, the easier it will be to identify the specific equipment responsible for the high energy costs. Value for benchmarks at this low level are not only difficult to acquire but may also be unnecessary. For this reason auditing a specific branch of the electricity reticulation network or a specific building will provide clues into the problematic equipment or inefficient practices responsible for the poor benchmark performance.

Occasionally other approaches can be used to make the task of identifying culprits much easier. These approaches include the use of load factors, diversity factors, scatter plots and disaggregated load profiles. This approach is particularly useful in pinpointing buildings where the benchmark is calculated from a sub-station level and there are many buildings that are supplied from that sub-station. In this manner the buildings can be prioritised and then audited from the most problematic to the least.

On a much lower level, it can also be used to prioritise electricity reticulation network branches within a single building. Figure 4.7 illustrates a disaggregated load profile of the two transformers that supply the Administration building at the University of Pretoria during the week from 14 to 20 June 1999.

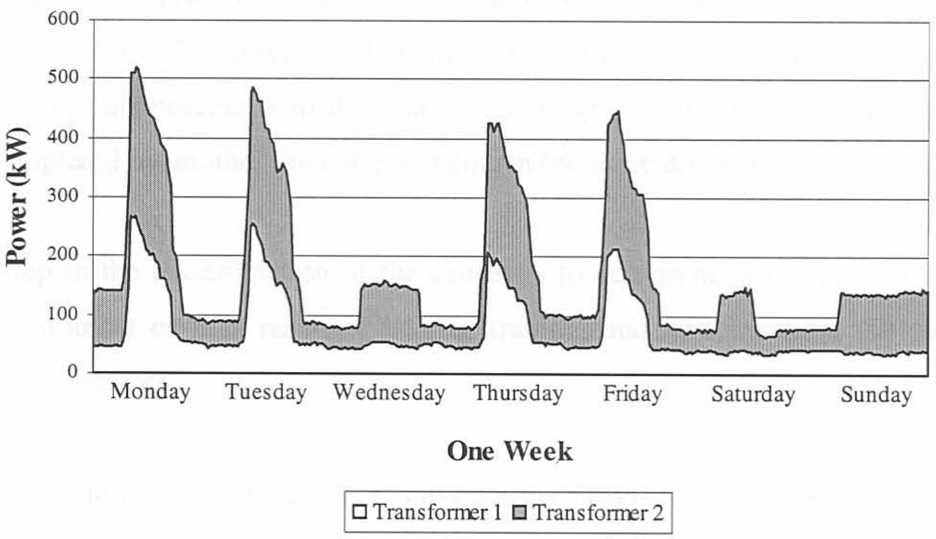

Figure 4.7: Transformers in the Administration Building, University of Pretoria

The Wednesday during this week was a public holiday with no activity on campus. This is evident as the loads on both transformers are drastically reduced. Unfortunately a sizeable portion of the load on transformer 2 is still present although this building was unoccupied during this day. In fact, one would expect the shape of the load on transformer 1 during the Wednesday, Saturday and Sunday to be present on both transformers. After closer scrutiny it has been ascertained that the load on transformer 2 includes the HVAC load from the centralised air-conditioning facility. A timer has been installed on this equipment in order to provide conditioned air during office hours in the week and during the mornings on a Saturday. Unfortunately the timer does not have any built-in intelligence to distinguish public holidays that occur during the week. This specific timer is also configured incorrectly, as the HVAC equipment is operational for the full day during Sundays. The result of this study is that the HVAC system can be identified as one of the contributors of the energy cost of this building and this information can be distributed to the other areas-of-activity.

4.6 DISSEMINATION OF KNOWLEDGE

The Energy Diagnosis area-of-activity culminates in the distribution of knowledge to the other areas-of-activity. From the calculation of a benchmark and consequent audits, the causes of the high electricity costs should have been determined at this point. Needless to say, the cause of high electricity costs in a building for example, could have been created by a multitude of factors that include various types of equipment and faulty operative procedures on the part of their human operators or occupants. A note must be made of all the causes and these passed onto the other areas-of-activity because although all of them may not be immediately addressed, they will all need to ultimately be solved. Another way of viewing this process is to think of it as issuing job numbers relating to work that must be completed by another three departments in the same division.

The first step in the dissemination of the causes is to determine whether each cause is a result of equipment or as a result of lack of training and awareness on the part of the operators or occupants.

If the cause is equipment related, it needs to be further classified according to the fault and possible solution. If the fault lies with the maintenance of the equipment, it must be passed onto the Energy Maintenance Management area-of-activity. If the solution requires existing equipment to be upgraded, controlled or additional equipment installed, then it must be passed onto the Energy Load Management area-of-activity.

Care must be taken to avoid instructions that conflict. For example, the filters on an HVAC plant might need to be cleaned and this would be passed onto the Energy Maintenance Management activity area. In this case the HVAC equipment might also need to be upgraded or possibly replaced and this would be passed onto the Energy Load Management activity area. At the outset it seems rather unwise to be maintaining filters on equipment that might be replaced. However, cognisance needs to be taken of a few points:

- The HVAC system may be replaced in its entirety or it may only be partially upgraded in which case the use of the filters may be continued.
- There is a delay in the purchase of new equipment as a result of the availability of capital that may already be reserved for another Energy Load Management project.
- The energy costs remain high all the time that new HVAC equipment is on order whereas servicing filters can be performed immediately as an interim solution.
- Cleaning and possible replacing filters requires no major capital outlay.
- Referral to the Energy Maintenance Management activity area might raise some flags to maintenance procedures that are not operating properly with other equipment in other parts of the campus.

As a result, both instructions should be dispatched accompanied by high-level communication between these two areas.

Should the cause not lie with the equipment and is ascribed to the equipment operators or building occupants, it must be passed onto the Energy Awareness and Education area-of-activity. This is however not the only reason for passing information onto this activity area. The benchmarks themselves are a great marketable tool that can be used to create awareness and generate interest in the energy management programme. Once projects have been addressed and are re-evaluated as illustrated in figure 4.2, their new benchmark values, in comparison to their initial values (including their causes and subsequent solutions), will be vital pieces of marketing information that should be exploited.

4.7 CONCLUSION

The role of this activity area is a crucial component of the energy management programme. This area does not reduce the energy costs per product or business process. It does however apportion costs to end-users through the calculation of benchmarks and then systematically identifies the reasons for that energy cost benchmark. The causes of the electricity costs are passed onto one or more other area-of-activity so that it may be addressed and solved. Once addressed, this activity of energy diagnosis is repeated in order to track the performance of the benchmark. Attention must however be paid to uncontrollable fluctuations in the benchmark values for the reasons that were explained such as seasonal swing, increases in the tariff rates and student numbers.

In conclusion it must be noted that the supply-side tariff structure and rates must be used to determine the energy cost contribution of end-user groups or per product. The example of benchmark calculation presented in this chapter used the same tariff structure (demand tariff) and rates as that of the supplier when determining the cost contribution per student.

The next chapter will address the Energy Load Management area-of-activity. This area is characterised by the expenditure of capital in order to address the high electricity costs reflected through the benchmarks.

CHAPTER 5: ENERGY LOAD MANAGEMENT

"Nothing can come of nothing: He who has laid up no materials can produce no combinations."

Sir Joshua Reynolds

5.1 INTRODUCTION

Although the Energy Load Management area-of-activity is not the starting point of the energy management programme its importance ranks supreme as it is this activity area that is most likely to produce significant improvements to the cost of energy per product or business function.

This activity area focuses on the management of the electrical load through the process of improving or controlling the equipment that uses the electrical energy. From figure 2.4 there are three buzzwords attached to this area, namely "upgrade", "control" and "install" and each refers to the interaction with the electrical equipment.

Unfortunately a limited amount of investment capital will be available within the academic institution for the implementation of load management projects. For this reason it is important to firstly evaluate all the alternatives in order to determine the best solution and then to evaluate this solution against all the other potential areas requiring investment capital. In this manner projects are evaluated on an intra-project and inter-project level.

To emphasise this methodology, three case studies will be presented in this chapter each relating to one of these activity buzzwords.

5.2 INSIDE THE ENERGY LOAD MANAGEMENT AREA-OF-ACTIVITY

This chapter reacts on the input that is received from the Energy Diagnosis and Energy Maintenance Management areas-of-activity. These commands are received as problems with specific equipment that will require the implementation of one of the buzzwords in order to improve. The first step involves finding a solution and possibly a series of alternatives. These are evaluated against each other based on their financial performance and the most beneficial option is put forward as a potential project. This project is then prioritised along with all the other potential projects in order to ensure the optimal allocation of investment capital. After prioritisation, the selected projects are implemented in order to improve the benchmark performance. This process is illustrated in figure 5.1.

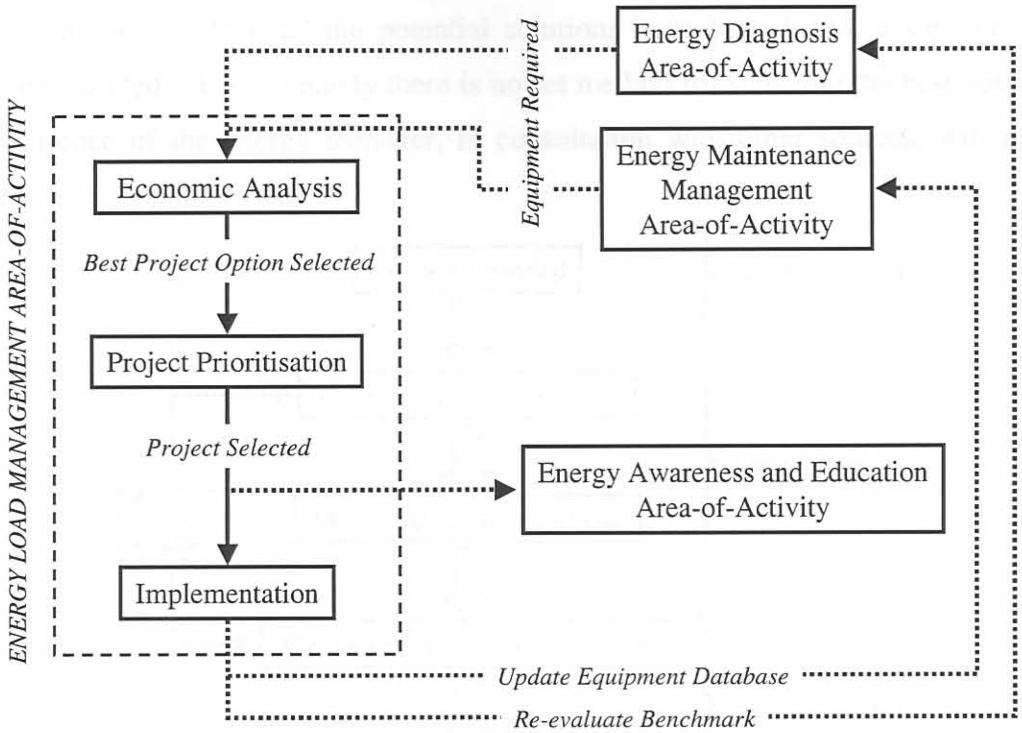

Figure 5.1: Functionality of the Energy Load Management Area-of-Activity

The solid arrows in figure 5.1 indicate internal operation and the dotted arrows indicate operations that occur with the other areas-of-activity as previously illustrated in figures 2.4, 2.5 and 2.6.

5.3 ECONOMIC ANALYSIS

According to Riggs [39], analysis starts with the identification of alternatives and the need to do something originates from asking "What needs to be done?", "What can be done?" and "What should be done?".

The input that is received from both the Energy Diagnosis and Energy Maintenance areas-of-activity is in the form of the identification of a problem relating directly to a piece of equipment. No suggestion as to its improvement is offered and this forms the starting point of the economic analysis. Broadly put, economic analysis focuses on determining various solutions, selecting the most appropriate one, presenting various alternatives and finally selecting the best approach. This process is illustrated in figure 5.2.

Once the problem has been identified, the first step involves the acquisition of all possible solutions. These can be obtained through personal experience and existing knowledge or through consultation with professional specialists both in and outside the institution and at other institutions. Once all the potential solutions have been listed, a suitable option should be selected. Unfortunately there is no set method for selecting the best option and the experience of the energy manager, in consultation with other sources, will need to suffice.

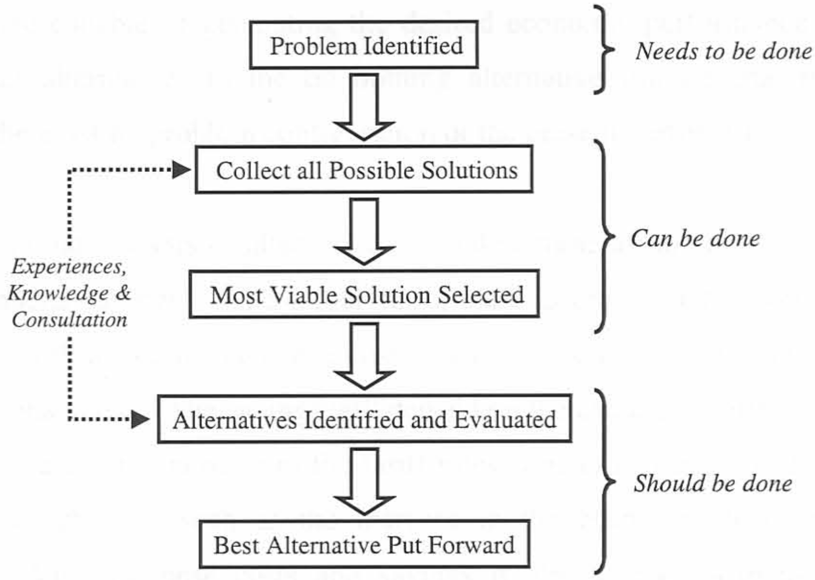

Figure 5.2: Evaluation Process from Problem Identification to Best Alternative

All decisions must bear the energy policy in mind and no option should be considered if it is contrary to the best interests of the energy management programme irrespective of its savings potential. For example, switching off all the power will ensure that the electricity costs would be zero but the production would also be zero which means the programme has failed because the energy cost per product is mathematically equal to infinity. Consider the following example of collecting potential solutions:

After noting a very consistently poor system power factor, some options could be the installation of power factor correction equipment, the reduction in the amount of inductive loads or the increase in the number of resistive loads. The first option is more feasible because it is more practically implementable without sacrificing comfort and services.

With the best solution selected, the next step involves the acquisition and evaluation of various alternatives. This step is essentially the planning phase of each potential project and the output is a fully financially evaluated project in terms of internal rate of return and net present value. This level typically involves the comparison of two or three alternatives against each other and the "do nothing alternative". Thuesen and Fabrycky [37] define the do nothing alternative as the case where the investor will "do nothing" about the projects being considered and that the funds made available by not investing will be placed on other investments that yield an Internal Rate of Return (IRR) equal to the Minimum Attractive Rate of Return (MARR) of the institution. The do nothing alternative does not mean that the funds will be "hidden under a mattress" but rather that they will be used for other projects that are capable of generating the desired economic performance. Comparing various project alternatives to the do nothing alternative implies that they are being compared to the existing problem configuration or the present performance.

The first step in the analysis of alternatives is to determine all the costs involved and the source of financial savings. The initial costs, such as those for the equipment and the installation, as well as the maintenance costs, such as labour costs and replacement costs, should all be considered. The savings will depend on the electricity tariff structure and the tariff rates. The annual increase in the tariff rates should also be considered and where applicable other changes such as the increase in the electricity load should also be considered. With all these costs and savings it almost goes without saying that a spreadsheet must be constructed that not only reflects all these parameters but compensates for their changes too. In this manner a handy tool is constructed that can be updated and used for future projects. The period of the analysis will vary and can be either monthly or annually whichever is easiest. Typically an annually based evaluation is easiest as it simplifies the time value of money calculations.

The aim of the evaluation of various alternatives is to arrive at a cash flow for which the IRR and the Net Present Value (NPV) can be determined at the MARR. Unfortunately in order to calculate the IRR, it is imperative to have a cash flow that swings from negative in the beginning of the project, to positive towards the later stages of the project. This poses somewhat of a dilemma in the case where two or more options are being considered and neither produces any real income. At this point it is necessary to quantify the term "savings". In the energy management context, a financial saving is not an income but rather a reduction in the financial accountability of the institution. In other words, achieving an energy saving simply means that you are giving out less money for energy each month. The point of the matter is that, financially speaking, you have not generated an income but merely slowed the expenditure. It seems very difficult then to arrive at a cash flow that swings from negative to positive. This is overcome by subtracting the one option from the other as shown in table 5.1.

Table 5.1: Example of Creating a Positive Cash Flow

Year	Option A	Option B	A-B
0	-1,000	0	-1,000
1	-200	-550	+350
2	-200	-550	+350
3	-200	-550	+350
4	-200	-550	+350

In this case the performance of A-B is being evaluated for both the NPV and IRR using the following evaluation criteria:

- If the NPV of A-B is greater than zero (i.e. positive), then option A should be accepted. If the NPV is negative, then option A should be rejected and option B should be accepted.
- If the IRR of A-B is greater than the MARR, then option A should be accepted. If the IRR is less than the MARR, then option A should be rejected and option B should be accepted.

If we assume a MARR of 10% for the cash flow in table 5.1, then the following values are obtained for the NPV and the IRR:

$$NPV_{A-B}(MARR) = -1{,}000 + 350\left[\frac{(1+0.1)^4 - 1}{0.1(1+0.1)^4}\right] = -1{,}000 + 1{,}109.45 = 109.45 \qquad [5.1]$$

$$NPV_{A-B}(i^*) = 0, \text{where } i^* = 14.96\% \qquad [5.2]$$

In this case Option A should be selected because the NPV (using the MARR) is greater than zero and the IRR is greater than the MARR. In this example option B would typically be the do nothing alternative because it has no initial costs arising from the investment of new technology.

All the project alternatives can be evaluated in this way to arrive at the selection of one single alternative that is considered the correct approach to the project. Examples of this methodology will be illustrated in the case studies presented in the next three sections.

5.4 EQUIPMENT UPGRADES: A LIGHTING CASE STUDY

This case study involves the upgrade of the existing lighting configuration in the library at the University of Pretoria to more modern efficient lighting. In this instance it was decided to review a total of 3000 luminaires each holding two tubular fluorescent lamps by considering a 5-year project period. The lamps are required throughout the year for 12 hours a day and 6 days of the week. Three alternatives were considered and the characteristics of each are presented in table 5.2 as follows:

Table 5.2: Characteristics of each Alternative - Lighting Case Study

	Alternative A	**Alternative B**	**Alternative C**
Description	2 x 55W, 6-foot lamps	2 x 58W, 6-foot lamps, standard	2 x 58W, 6-foot lamps, with electronic control gear
Number of Lamps per Luminaire	2	2	2
Lamp Power Rating	55 W	58 W	50 W
Lamp Life (based on a 12-hour switching cycle with 5% failures)	5,000 hours	5,000 hours	14,000 hours
Cost per Lamp	R21.00	R6.30	R15.00
Ballast Power Rating	18 W	26 W	10 W
Cost per Control Assembly	Nil	R97.80	R228.25
Power Factor of Complete Fitting	0.85	0.85	0.98

Alternative A in table 5.2 is the do-nothing alternative as where only the lamps are considered for upgrade and not the entire control assembly. The electronic control gear in Alternative C ensures that the lamps are optimally managed and thereby effectively reducing the power rating to 50W after startup [40]. In order to evaluate all three alternatives, the following cost items need to be investigated:

- Initial cost of replacing the existing equipment (alternative A) with newer equipment (alternatives B or C)
- Replacement costs of blown lamps during the 5-year project period
- The energy consumption cost of the luminaire ballast and lamps
- The contribution of the luminaire ballast and lamps to the maximum demand cost

At the time of this case study, in 1999, the University of Pretoria was billed according to a demand tariff with energy charged at a rate of 8.76 cents per kWh and maximum demand at a rate of R44.95 per kVA. These rates are expected to increase with 5% per annum.

The initial costs of each alternative are given in table 5.3 and are calculated by adding the cost of each new lamp and the cost of each new control assembly.

Table 5.3: Calculation of the Initial Costs - Lighting Case Study

	Alternative A	Alternative B	Alternative C
Number of Luminaires Required	Nil	3000	3000
Number of Lamps Required	4493*	6000	6000
Price per Control Assembly	Nil	R 97.80	R 228.25
Price per Lamp	R 21.00	R 6.30	R 15.00
Total Initial Cost	-R 94,353.00	-R 331,200.00	-R 774,750.00

*If option A is the do nothing alternative, it seems strange that there will be some initial cost. This cost is attributed to the cost of lamp replacement within the initial year (i.e. between now and the end of year 0 where the end of year 0 equals the beginning of year 1). Unfortunately, it is not known how long each lamp has been used at the time of the study and for this reason, an assumption is made. The value of 4493 lamps is the average amount of failures per year and will be explained in the next section.

The cost of replacing the lamps when they fail contains two facets, namely the cost of the lamps themselves and the labour costs of the maintenance personnel. The labour is considered because it is a major part of the business overhead at an academic institution.

Table 5.4: Calculation of the Replacement Costs - Lighting Case Study

	Alternative A	Alternative B	Alternative C
Number of Days per Week	6	6	6
Number of Hours per Day	12	12	12
Burning Hours per Year	3744	3744	3744
Lamp Life	5000	5000	14000
Number of Lamp Replacements per Year	4493	4493	1605
Labour Cost per Lamp	R 10.00	R 10.00	R 10.00
Total Lamp Replacement Cost: Year 1	-R 139,276.80	-R 73,232.64	-R 40,114.29
Increase in Lamp Cost and Labour Rate per year	10%	10%	10%

If each lamp will be required to burn for a total of 3,744 hours per year, it seems odd that there will be any lamp replacements in the first year because the life of each lamp is 5,000 hours for alternatives A and B and 14,000 hours for alternative C. Statistically speaking, there may be a few failures in the first year due to production tolerances but these are not being considered here. If a 5-year period is considered, the total burning hours of each lamp would be as follows:

$$\begin{aligned} \textit{Total Hours}_{\,per\,lamp} &= 12 \textit{ hours per day} \times 6 \textit{ days per week} \times 52 \textit{ weeks} \times 5 \textit{ years} \\ &= 18{,}720 \textit{ hours} \end{aligned} \qquad [5.3]$$

The total number of replacements required for each lamp is obtained from dividing the total number of burning hours of each lamp by the lamp life. For alternatives A and B, this would yield the following result:

$$\textit{Replacements}_{\,per\,lamp} = \frac{18{,}720}{\textit{Lamp Life}} = \frac{18{,}720}{5{,}000} = 3.74 \qquad [5.4]$$

In other words, over a 5-year period, each lamp would require approximately 4 replacements. Multiplied by the total number of lamps and dividing this over 5 years yields a replacement requirement of 4,493 lamps per year. The replacements for the first year have been included in order to ease the financial calculations and excludes the assumption made for the initial cost of alternative A. The cost of the lamps and the labour rate is expected to increase by 10% per annum. The calculations can be easily amended for cases where the labour cost and lamp costs are expected to increase with differing percentages. The cost of the energy consumption is given in table 5.5.

Table 5.5: Calculation of the Energy Costs - Lighting Case Study

	Alternative A	**Alternative B**	**Alternative C**
Ballast Load per Luminaire (kW)	0.018	0.026	0.010
Lamp Load per Luminaire (kW)	0.110	0.116	0.100
Total Load per Luminaire (kW)	0.128	0.142	0.110
Total Load per year of all lamps (kWh)	1,437,696	1,594,944	1,235,520
Cost per Unit (c/kWh)	8.76	8.76	8.76
Total Energy Cost: Year 1	-R 125,942.17	-R 139,717.09	-R 108,231.55
Increase in Energy Rate per Year	5%	5%	5%

The amount of energy that is consumed in table 5.5 is calculated by multiplying the total load per luminaire by the number of luminaires and the number of burning hours in the year.

The final cost that needs to be considered is the contribution of these lamps to the overall maximum demand of the University. The calculation is given in table 5.6. The power factor plays a crucial part in these calculations in order to determine the apparent power (kVA) of the lamps. This is necessary because the maximum demand charge is levied per kVA. The apparent power of the lamps is obtained by dividing the active power (kW) calculated in table 5.5 by the power factor in accordance with equation 3.1.

Table 5.6: Calculation of the Maximum Demand Costs - Lighting Case Study

	Alternative A	Alternative B	Alternative C
Power Factor	0.85	0.85	0.98
Load per luminaire (kVA)	0.151	0.167	0.112
Total Load (kVA)	451.76	501.18	336.73
Cost per kVA	R 44.95	R 44.95	R 44.95
Total MD Cost: Year 1	-R 243,681.88	-R 270,334.59	-R 181,634.69
Increase in MD Rate per Year	5%	5%	5%
Number of Years	5	5	5

Having calculated all the relevant costs for the first year, a summary table of each alternative can be constructed over the entire project lifetime bringing the increases in electricity tariff into account. Table 5.7 shows the summary table for alternative A.

Table 5.7: Cost Summary Table of Alternative A - Lighting Case Study

Year	Initial Cost	Replacement Cost	Energy Cost	Demand Cost	Total Cash Flow
0	-R 94,353.00				-R 94,353.00
1		-R 139,276.80	-R 125,942.17	-R 243,681.88	-R 508,900.85
2		-R 153,204.48	-R 132,239.28	-R 255,865.98	-R 541,309.73
3		-R 168,524.93	-R 138,851.24	-R 268,659.28	-R 576,035.45
4		-R 185,377.42	-R 145,793.80	-R 282,092.24	-R 613,263.46
5		-R 203,915.16	-R 153,083.49	-R 296,196.85	-R 653,195.51

The total cash flows for each alternative is given in table 5.8. All the entries are negative and subtracting them from each other produces three cash flows that swing from negative to positive that can be evaluated for NPV, IRR and payback period.

Table 5.8: Resultant Evaluation Cash Flows - Lighting Case Study

Year	Alternative A	Alternative B	Alternative C	B-A	C-A	C-B
0	-R 94,353.00	-R 331,200.00	-R 774,750.00	-R 236,847.00	-R 680,397.00	-R 443,550.00
1	-R 508,900.85	-R 483,284.32	-R 329,980.53	R 25,616.53	R 178,920.32	R 153,303.79
2	-R 541,309.73	-R 511,110.17	-R 348,485.27	R 30,199.56	R 192,824.46	R 162,624.90
3	-R 576,035.45	-R 540,693.47	-R 368,115.82	R 35,341.97	R 207,919.62	R 172,577.65
4	-R 613,263.46	-R 572,158.72	-R 388,948.53	R 41,104.74	R 224,314.94	R 183,210.20
5	-R 653,195.51	-R 605,640.29	-R 411,065.56	R 47,555.22	R 242,129.95	R 194,574.73

Using a MARR of 12%, the results of the NPV and IRR are obtained for each of the resultant cash flows and are presented in table 5.9.

Table 5.9: Financial Evaluation - Lighting Case Study

	B-A	C-A	C-B
NPV	-R 99,676.39	R 54,475.07	R 154,151.47
IRR	-7.82%	15.37%	26.08%
Payback Period	No Payback	5 years	4 years

Using table 5.9, the three alternatives can be easily compared to each other. From the poor performance of alternative B-A, alternative A is better than alternative B. The choice then lies between alternatives C and A of which C is better from the performance of the C-A alternative. The IRR of this evaluation (15.37%) is greater than the MARR of 12%. The last column (alternative C-B) is insignificant because alternative A had already outperformed alternative B even though it has the shortest payback period.

In conclusion it can be said that alternative C has a much lower replacement, energy consumption and demand cost even though the initial costs are dramatically higher than either of the other two options. The improved reliability of the lamps, high efficiency of the ballast and high power factor of the control assembly cause this. All of these factors contribute to its financial superiority.

5.5 DIRECT EQUIPMENT CONTROL: A HOT WATER CASE STUDY

By having load control capability, an institution can reduce the electricity costs of their campus. This is only possible where the tariff structure allows for it. When billed according to a time-of-use (TOU) tariff, the emphasis of load control will primarily be on shifting energy to a cheaper tariff period. When billed according to a demand tariff the emphasis will be on reducing the maximum demand of the total load. The TOU tariff may also have a maximum demand component that will further motivate the ability to control load. The primary reasons for controlling the hot water cylinders in the residential hostels, as opposed to other loads, at the University of Pretoria are as follows:

- The hot water load is a shiftable load (see figure 1.1), which implies that it is able to store energy. This will provide some measure of error leeway when correcting the models (and control strategies) for errors.
- Control of the hot water load is invisible to the hostel residents. This is ascribed to the "psychology of control" [41].

Hot water load control involves the subdivision of the total hot water load into a series of control channels or groups. These groups are switched and manipulated in order to manage the total load. Each group is prioritised according to the installed capacity and the historical dynamics of that group. A "building-block" approach is used to restore each group in a controlled manner so as to limit the effects of the cold-load pickup [42, 43]. Typically a maximum demand control target is set and the channels controlled accordingly [44]. For example, when the total load exceeds the set target, the load controller will begin switching off channels according to a prioritised order. Should the present demand require more than one channel to be shed, the load controller sheds the next channel in the priority list. The length of time that cylinders are shed will depend on the instantaneous load – where necessary the channels will remain off while the demand is high.

In this case study the potential savings from controlling the hot water load at a single hostel at the University of Pretoria, namely Erika hostel, will be considered. During a walk audit it was observed that a total of 240 kW of hot water equipment is installed in this hostel in the form of sixty 4kW cylinders each with a 200-litre capacity. However, after conducting a test of the installed capacity, it was noted that only 191 kW is available to be controlled from the existing centralised relay. This is due to system fatigue where an old outdated system was not maintained and eventually not even used resulting in the system being bypassed during later maintenance work. The results of the installed capacity test are illustrated in figure 5.3.

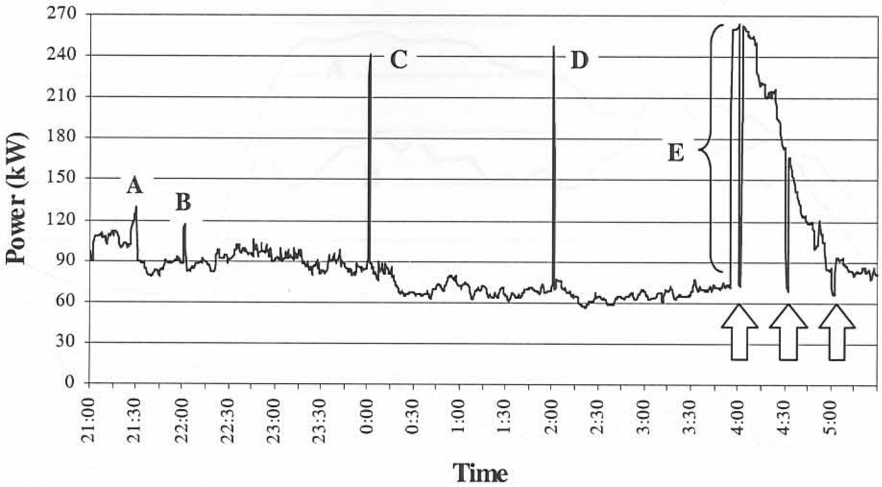

Figure 5.3: Installed Capacity Test of the Hot Water Load at Erika Hostel

This specific test involved switching all the hot water cylinders off at 21:30 (point A) and then conducting three 1-minute spikes at 22:00, 0:00 and 02:00 (points B, C and D respectively). The entire hot water load was restored at 03:55 to ensure that the residents would have enough hot water when they needed it in the morning. The difference between the peak load and the base load (point E) provides the measure of the installed capacity of the hot water load. Figure 5.3 illustrates the load restoration curve that occurs from 03:55, once the load was restored, as the individual cylinders reach their desired temperatures and switch off. The arrows in figure 5.3 indicate where regular half-hourly notches have switched in order to determine the shape of the hot water load profile.

To maximise the savings, it is planned to switch off the entire hot water load available at the time that that the University reaches a maximum. In other words, the contribution that the hot water load of this specific hostel makes towards the overall demand of the University will be zero. The savings is then the difference between what the load was and what it would have been had the cylinders been allowed to operate multiplied by the maximum demand rate of R44.95. The problem lies in trying to determine the amount of load that can be switched off. The hot water load, made up of a diverse array of cylinders, is dependent on the hot water consumption pattern that varies with the different days of the week and seasons. To determine the hot water load, use is made of a series of notch tests [45] where the hot water load is switched off for 2 minutes on the half-hour and the resultant load profile measured. Figure 5.4 illustrates the overall University load on the left-hand axis and the total hostel load and hostel hot water load on the right-hand side for a corresponding sample day.

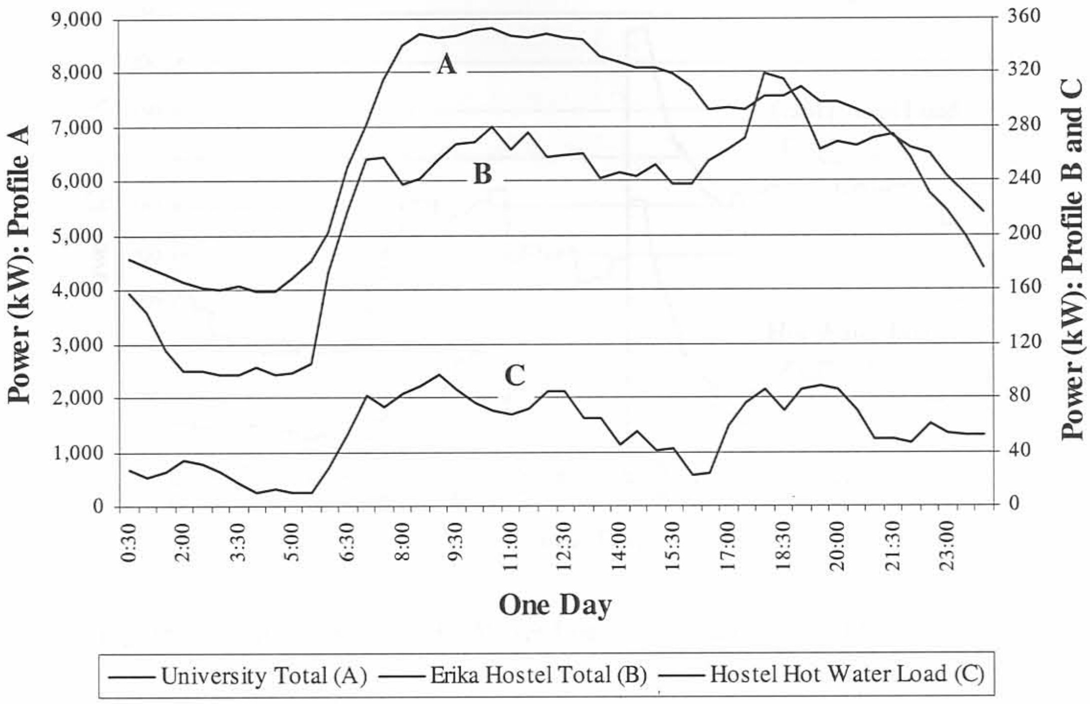

Figure 5.4: Hot Water Load in Comparsion to the Total Hostel Load and Campus Load

On this specific day, the overall University load reached a maximum at 10:30 of 8,808 kW. The contribution of the hot water load of the hostel at that time was 69.65 kW and the total hostel load was 280 kW. Switching off this hot water load component and restoring much later in order to avoid the fairly flat midday profile of the total University load, the resultant hostel profile is illustrated in figure 5.5. As a result of the load being left off between 09:30 and 13:00, the full 191 kW hot water installed capacity is switched on when the load is restored. As the individual cylinders get up to their set temperatures, they start switching off. The model output with a 1-minute resolution and working in 30-minute billing intervals causes the staggered profile illustrated in figure 5.5.

In this example, all the available hot water load is shed at the time of the system peak producing a saving of R 3,130.77 for this specific month. The maximum demand rate in kVA was used and applied to kW values because the model that has been setup to evaluate these savings is based on active power values. This approximation is valid because the power factor at the University is unity as a result of power factor correction equipment. Power factor correction will be discussed in detail in the next case study.

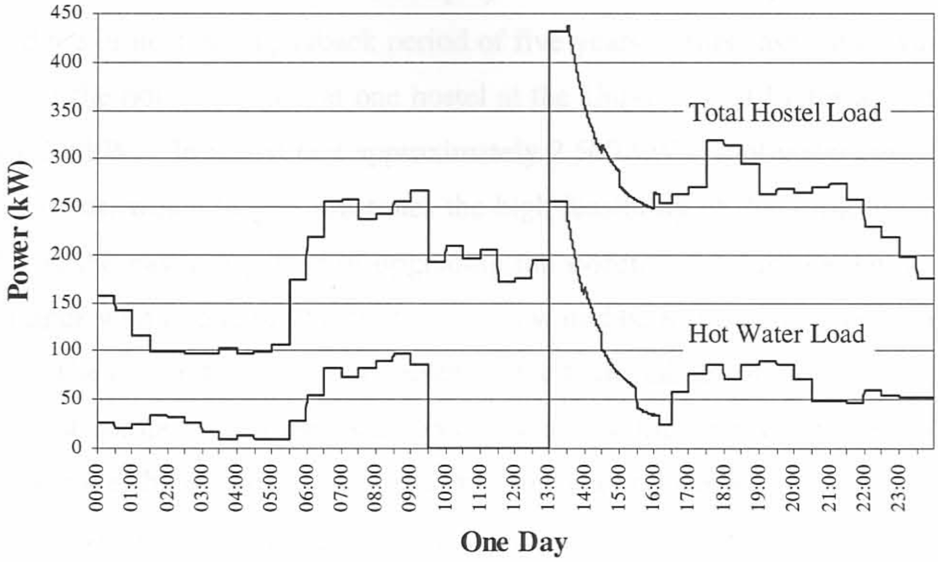

Figure 5.5: The Controlled Hot Water Load and Resultant Total Hostel Load

For the purposes of financial evaluation, the assumption is made that a similar amount of savings can be realised each month of the year. This implies that controlling the hot water cylinders in this hostel alone would produce a total saving of R 37,569.21 in the first year. The annual electricity tariff increase, assumed to be 5%, would ensure that the savings would also increase each year.

The initial cost of the system is based on the requirement for a relay switch per cylinder capable of being activated via radio and the control and communications hardware too. The centralised computer load controller is the most expensive part of the system and is required irrespective of whether a single relay or multitude of relays are being controlled. In this case study, a total of 60 switching relays are required. Table 5.10 shows the summary table for the hot water control equipment.

Table 5.10: Cost Summary Table – Hot Water Control Case Study

Year	Initial Cost	Savings	Total Cash Flow
0	-R 133,000.00		-R 133,000.00
1		R 37,569.21	R 37,569.21
2		R 39,447.67	R 39,447.67
3		R 41,420.05	R 41,420.05
4		R 43,491.06	R 43,491.06
5		R 45,665.61	R 45,665.61

Using a MARR of 12%, the NPV of the project amounts to R 13,414.82. The IRR is 16.31% and the project has a payback period of five years. This case study was based on the control of the hot water load at one hostel at the University of Pretoria with a control capacity of 240kW. In actual fact approximately 2,500 kW of hot water capacity can be found on campus, which further illustrates the high feasibility of this project. It has been estimated that the payback period of upgrading the system to control the entire hot water load on campus with a total of 350 control relays would be just over one year with an IRR of 90.30%. The reason for this improvement in the financial performance is caused by the high fixed cost component of the load control system in the form of the communications and load controller hardware. These systems are required irrespective of the number of control points whereby increasing the number of control relays reduces the fixed cost per point. The control relays or load switches themselves are very cheap in comparison.

5.6 INSTALLATION OF NEW EQUIPMENT: A POWER FACTOR CORRECTION CASE STUDY

This case study concerns the installation of power factor correction (PFC) equipment at the supply point of the Medical Campus of the University of Pretoria. The calculations in this case study are based upon actual monthly load data gathered by the City Council of Pretoria during 1997. This case study reviews the financial implication of installing power factor correction against the case if this equipment is not installed. The latter is the do nothing alternative.

PFC is based on the principle of installing a capacitor bank, which can absorb the reactive power component of the load. Referring to the power triangle in figure 3.6, the concept of power factor correction is easily explained in figure 5.6.

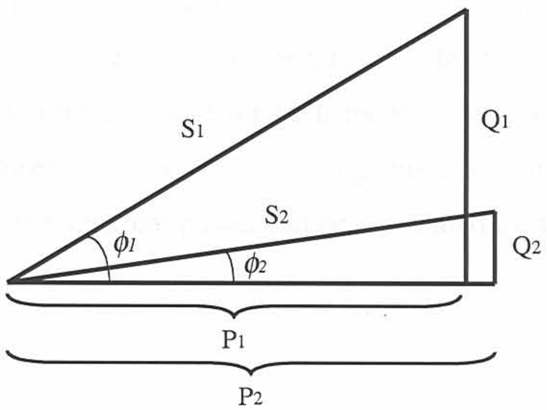

Figure 5.6: Effect of Power Factor Correction on the Power Triangle

Theoretically, to improve the power factor the active power, P_1, stays the same but the reactive power will decrease from Q_1 to Q_2 and the apparent power from S_1 to S_2. In practice however, the PFC equipment consumes active energy too, which results in a marginal increase in the amount of active power from P_1 to P_2. Modern PFC equipment is much more efficient ensuring a much lower energy consumption. The most critical facet to bear in mind is that a charge of R44.95 per kVA is levied on the maximum demand. In other words, improving the power factor (or reducing the amount of reactive power Q) will ensure that the demand (or apparent power S) is also reduced thus producing a financial "saving". From a technical point of view, a low power factor can have the following disadvantages [14, 46, 47]:

- Overloaded generators, transformers and distribution lines causing wear and tear of equipment
- Voltage drops and increased power losses
- Reduced load-handling capability, or capacity, of the electrical system

The following financial factors must be brought into account in order to evaluate the feasibility of PFC equipment:

- Initial cost of the PFC equipment including the installation costs
- Maintenance costs for the servicing of the PFC equipment
- The reduction in the maximum demand charges

To determine the savings, it is necessary to have the measurements for either the active power or the apparent power. Ideally both are required in order to determine the present power factor. In order to ease the calculations, it is assumed that the PFC equipment does not contribute to the total active energy consumption. In this instance both the apparent and active power values were available for each month. It is assumed that the PFC will maintain an average power factor of 98%. Using this assumption and the existing load data, the new values for the apparent power can be calculated using the following equation:

$$S_2 = \frac{P_1}{PF_2} = \frac{P_1}{0.98} \qquad [5.5]$$

Once the new values for the apparent power have been calculated, determining the difference between the maximum demand if no PFC was installed with that should PFC have been in place produces the savings. Figure 5.6 illustrates the load at the Medical Campus during January 1997 without PFC and the potential load had PFC been installed.

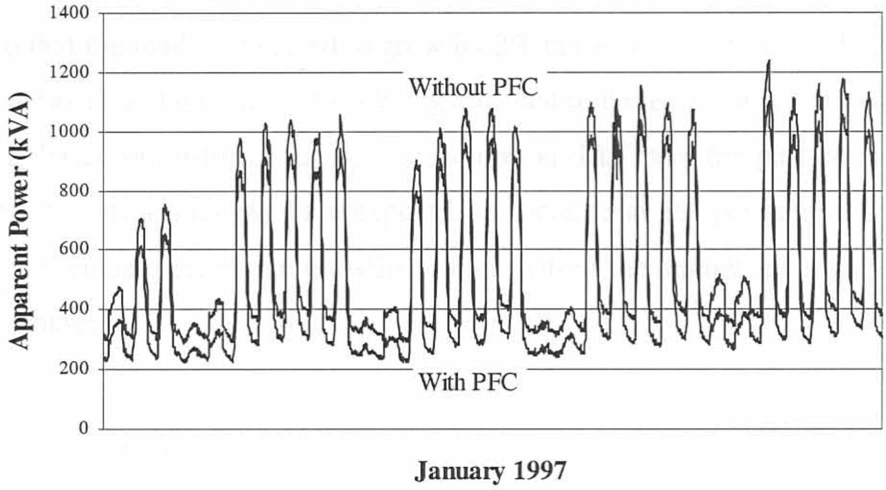

Figure 5.7: Effect of Power Factor Correction on the Load Profile

For the specific month illustrated in figure 5.7, the difference in the maximum demand is 136.82 kVA which would create a saving of R 6,149.90 when multiplied by the maximum demand rate of R44.95 per kVA. Table 5.11 illustrates the savings for each month when calculated in this manner.

Table 5.11: Monthly Savings – Power Factor Correction Case Study

Month (1997)	Load Reduction (kVA)	Savings
January	136.82	R 6,149.90
February	128.78	R 5,788.82
March	128.64	R 5,782.19
April	63.07	R 2,834.92
May	31.07	R 1,396.76
June	38.76	R 1,742.13
July	31.72	R 1,425.72
August	44.82	R 2,014.54
September	104.42	R 4,693.55
October	119.02	R 5,349.94
November	121.01	R 5,439.57
December	105.00	R 4,719.55
	Total Annual Savings	**R 47,337.59**

The values in table 5.11 vary with each month and can be ascribed to the different types of load during the annual seasons. A high inductive air conditioning load is present during the hot summer months and a greater resistive space heater load is present during the colder winter months.

It is assumed that the load is expected to grow by 2% per annum due to an expansion in the reticulation network and additional load being attached to the existing reticulation network. This figure is based on historical energy consumption data from the past couple of years. Added to this, the electricity rates are expected to increase at 5% per annum. In order to transpose these annual percentage growths to a growth in the annual savings, equation 5.6 can be used where:

$$R_n = S \times \left[(1+s)\times(1+t)\right]^n \qquad [5.6]$$

R_n savings for specific year n (Rand)

S total savings from the first year (R 47,337.59)

s annual percentage load growth (2%)

t annual percentage increase in the maximum demand rate (5%)

n number of years

The present maximum reactive load that needs to be absorbed is approximately 387 kVAr. Based on the 2% load growth, it is decided to use a 550-kVAr capacitor bank that will have a projected useful lifetime of 17 years. The capital costs of the PFC equipment are in the region of R95 per kVAr and include the supply, installation and commissioning. The total initial cost is therefore estimated at R 52,250.00.

It is estimated that the maintenance of the equipment will require 2 hours a month at a rate of R200.00 per hour. This amounts to R 4,800.00 per year and is assumed to increase at 10% per annum. As previously mentioned, the capacitor bank does consume energy (kWh) while performing its function but this will be neglected due to the size of the capacitor bank in question and the fact that modern equipment of this kind is highly efficient. The salvage value of the capacitor bank is not brought into consideration because it is unknown whether a demand for this type of equipment will exist in the future. Any receipts that are created from the salvage of this equipment should be seen as project bonus and could be used at that time to fund the next project of this nature. Table 5.12 shows the summary table for the PFC equipment.

Table 5.12: Cost Summary Table – Power Factor Correction Case Study

Year	Initial Cost	Maintenance	Savings	Total Cash Flow
0	-R 52,250.00			-R 52,250.00
1		-R 4,800.00	R 47,337.59	R 42,537.59
2		-R 5,280.00	R 50,651.22	R 45,371.22
3		-R 5,808.00	R 54,196.81	R 48,388.81
4		-R 6,388.80	R 57,990.58	R 51,601.78
5		-R 7,027.68	R 62,049.92	R 55,022.24

Using a MARR of 12%, the NPV of the project amounts to R 107,461.44. The IRR is a staggering 82.52% and the project has a payback period of just over one year. This case study considered the financial evaluation of the installation of PFC compared to the case where no equipment was installed or the do nothing alternative. The results of the study show conclusively that this is a highly feasible project.

5.7 PROJECT PRIORITISATION

Having completed the economic analysis, the best alternative of each energy management project is put forward and the next step involves the prioritisation of all of these projects. Prioritising the projects is essential to determine the order in which energy projects will be undertaken and implemented particularly in the light of limited financial resources.

The three case studies that were presented in the previous sections provided three potential projects all of whom are financially viable with good all round performance. The problem lies in deciding which of these projects is more suited to be immediately undertaken. The purpose of prioritising the energy management projects is to ensure that those projects that are selected will maximise the wealth of the institution. This is known as capital rationing [48] and will gain support for the energy management programme and ensure its future sustainability. The object of capital rationing is to select the group of projects that provides the highest overall NPV and does not require more funds than are budgeted. There are two types of approaches to capital rationing, namely the IRR method and the NPV method [39, 48]. Each will be explained using the performance of the three case studies, as summarised in table 5.13, as an example.

Table 5.13: Summary of the Financial Analysis of the Case Studies

	Initial Investment	NPV (@ 12%)	IRR
Efficient Lighting	R 774,750.00	R 54,475.07	15.37%
Hot Water Control	R 133,000.00	R 13,414.82	16.31%
Power Factor Correction	R 52,250.00	R 107,461.44	82.52%

The IRR approach involves plotting projects in descending order according to their IRR against the amount of initial capital investment. This plot is called the investment opportunity schedule and is illustrated in figure 5.8 for the three projects in table 5.13.

By drawing a horizontal line at the MARR of 12% (line A) and a vertical line at the amount of capital available for investment, the projects most suitable will be selected. If the budgetary amount for projects was limited to R 100,000.00 (line B), then only the power factor correction project should be undertaken. If the budget was set at R 400,000.00 (line C), then, according to the IRR method, both the power factor correction and the hot water control projects should be undertaken.

It is fairly evident that this method is not necessarily the best approach. In the case where the investment amount was limited to R 100,000.00, only R 52,250.00 was required for the power factor correction project leaving an amount of R 47,750.00 unused. If the budget for investment was increased from R 100,000.00 to R 185,250.00 then both the power factor correction and the hot water control projects could have been completed within the budget constraints.

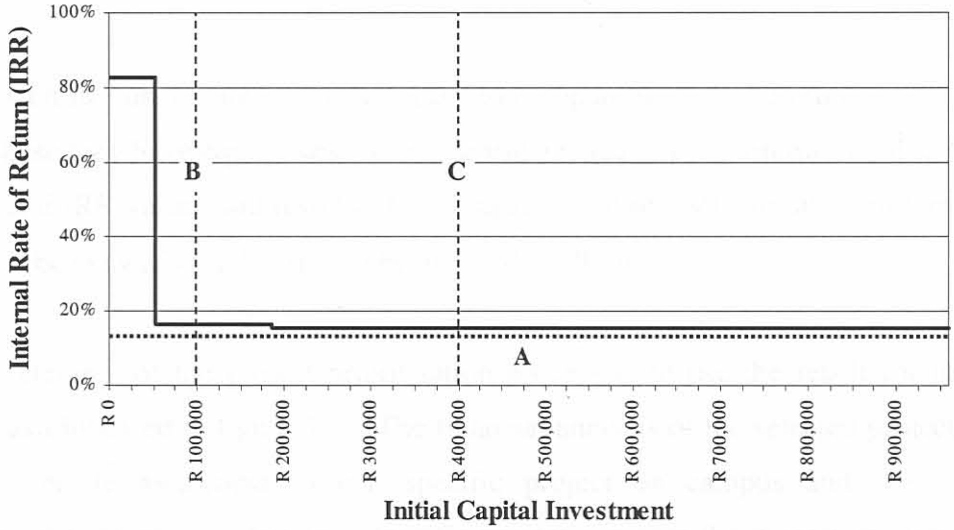

Figure 5.8: Investment Opportunity Schedule for Projects in Table 5.13

The NPV approach is based on determining the combination of projects with the highest overall NPV while still meeting the capital investment budget constraints. Using this method, the combination of projects that will provide the highest overall NPV would be the power factor correction and hot water control projects if R 400,000.00 was available for investment or the power factor correction project if only R 100,000.00 was available for investment. In this example, the results of the NPV method mirror those of the IRR method. Note that the hot water control project is selected above the efficient lighting project even though the NPV of the efficient lighting is much greater. This is done in order to make full use of the investment capital, which is the emphasis of the NPV method.

Although both methods produced similar results, their feasibility becomes more apparent in the light of a greater number of projects. Selecting between three projects such as these is easy but selecting between a hundred is more complex. The question still arises as to which method should be used to provide solid suggestions for investment. According to Droms [49], the answer to the problem is inherent in the mathematics of the methods. Mathematically, the NPV method used here assumes that all cash receipts (or savings) are re-invested at the MARR of the institution. The IRR method assumes that all receipts are re-invested at the IRR of the project. Therefore the selection of the method depends on which assumption is closest to reality. The choice should be based on which re-investment rate is closest to the rate that the institution will be able to earn on the cash flows or savings generated by the project. Following this rule will result in basing decisions on the investments that will maximise the value of the institution. In this specific instance, at the University of Pretoria, the NPV method is the most suitable evaluation method with which to evaluate these three projects.

In conclusion it must be noted that it is easy to compare these three projects against each other because they have equal lives. Considering unequal project lifetimes will affect both the NPV and IRR values and result in the comparison of projects on different terms. The results will be skewed and this should be avoided at all times.

The final element of the project prioritisation process is to use the result for marketing purposes as illustrated in figure 5.1. The financial analysis of the selected projects can be used to generate awareness to that specific project on campus and where needed advertising the intent to undertake a specific project can ease the project implementation. For example, advertising that the office lights in a specific building are to be upgraded could ensure that the building occupants take the necessary security precautions and ensure that the project technicians have access to all the offices. This makes the project implementation phase that much easier and reduces the number of complaints from the occupants.

5.8 IMPLEMENTATION

At this point various options have been considered, alternatives weighed off against each other, quotations and advice has been received, the best alternatives put forward as projects and these projects all weighed off against each other and the availability of investment capital. The energy load management area-of-activity culminates in the implementation of the projects according to their priority.

All the economic planning for each project should already be complete at this stage and all that remains is giving the go-ahead for project implementation. Every institution will have their own set of procedures for the awarding of contracts to external contractors and these must be adhered too. For any project it is essential that a legally binding contract be put into place. South African law defines a contract for the letting and hiring of work as a reciprocal agreement between a provider of work and a contractor in which the latter agrees to build, manufacture, repair, modify or maintain a corporeal thing within an agreed period of time in exchange for remuneration.

The specific aspects of this type of contract are [50]:

- It is an agreement for the completion of a specific piece of work in respect of a corporeal thing.
- The contractor's only duty is to do the work in accordance with the particular specifications of the contract.
- The contractor does the work in exchange for remuneration either in the form of a lump sum or a scale or formula according to which the remuneration is determined.
- The work must be completed within the agreed period of time or a reasonable time.

A contractor commits breach of contract if he fails to perform his contractual duties. In this event the institution is entitled to the following remedies:

- Damages where, for example, a contractor's tender has been accepted and he refuses to start on the project, the institution is entitled to claim the difference, if any, between the contractor's tender price and the new tender price of another contractor.
- Rescission of the contract where the institution may cancel the contract under the circumstances of the contract breach where the timeous performance is of the essence to the contract or where the institution acquires a right to resile by serving a notice of rescission on the contractor. In addition to cancellation, the institution may claim damages.
- Specific performance where the institution withholds a percentage of the contract price, termed retaining fees, as security for the proper performance of the contractor of all of his contractual duties.

On the other hand, the institution could also be in breach of contract, in which case the contractor is entitled to similar remedies, namely cancellation and specific performance combined with a claim for damages. The contractor also has an additional remedy in the form of a lien over the object made by him whereby he may keep the object in his possession until he is remunerated.

Once the contractor has completed the project and the necessary commissioning and hand-over taken place, it is vital that all of the equipment specifications and maintenance requirements are obtained from the contractor in order for them to be passed onto the Energy Maintenance Management area-of-activity. With the completion of the project, feedback should also be made to the Energy Diagnosis area-of-activity in order for the energy benchmarks of the specific product or business process to be re-evaluated

5.9 CONCLUSION

This chapter has explained both the inner workings of the Energy Load Management area-of-activity and the relationship with the other activity areas.

The process from considering many alternatives and the economic analysis of various project options to arrive at a list of energy management projects has been introduced. Although there are many different types of equipment that use electrical energy, the three case studies presented in this chapter all have the potential to reduce costs and provide a measure of savings.

The mistake of ignoring the time value of money is very often made when calculating the economic performance of project. This results in a skewed expectancy that is usually over-optimistic. Considering the effects of the cost capital ensures greater accuracy when it comes to project planning. In fact sometimes a conservative approach will ensure that the projects that are undertaken will provide better results by reducing the energy cost per student or campus building. The positive results will ensure the support from the institution management for the energy management programme.

The implementation phase of the energy management projects must be conducted with the correct internal and external legal and administrative procedures to ensure that there are no financial and equipment losses or delays. Correct planning and respect for administrative delays will help to avoid this.

Although it is possible to say that this activity area is the one requiring the most amount of effort, many institutions fail to expand it to the energy maintenance activity area. Not only does this lead to an incomplete energy management programme but invariably sees the equipment that has been acquired becoming obsolete and unusable rendering the capital investment worthless.

The next chapter will focus on the Energy Maintenance Management area-of-activity and address the maintenance aspects relating to the electrical equipment responsible for generating the electricity costs.

CHAPTER 6: ENERGY MAINTENANCE MANAGEMENT

"Our failure rate is one-in-a-million, but what do we tell that one customer?"
IBM

6.1 INTRODUCTION

The previous chapter introduced the Energy Load Management area-of-activity as the area most likely to produce the reduction in the electricity cost per student or academic faculty. From chapter 1 it was noted that although this is the goal of the energy management programme, the programme is not complete without addressing both the needs of the personnel and students through energy education, and ensuring that the electricity network and all equipment attached to it is maintained.

The case examples in chapter 1 referred to some institutions that do not consider the maintenance of the electricity systems on campus as part of the energy management programme whereby the facilities department of the institution addresses the maintenance component. Unfortunately no direct link is made between the two and as such, the maintenance aspects of the energy management programme become forgotten leading to poor energy benchmarks and the appearance of bad maintenance on campus as a result of equipment attrition from information loss.

In all practicality, the maintenance of the electrical equipment must fall under the auspices of the facilities department for the simple reason that respect must be paid to the existing maintenance schedules and that the procurement and stores duties are centralised. However, this is mainly acceptable if the link between the every-day maintenance on campus and the energy management programme is made clear.

This chapter firstly looks at the maintenance on campus as a separate business activity and then links the energy management programme to this activity. The importance of maintenance is based on the simple logic that without the electricity reticulation systems, there is no energy to manage in the first place. According to Kennedy [51], a good electricity system maintenance programme can save the institution a substantial amount of money in wasted electricity, lost production and the additional expense caused by preventable equipment breakdowns. Other benefits include general cleanliness, improved personnel and student morale and increased safety and reliability.

6.2 INSTITUTION MAINTENANCE

The maintenance on campus contains two basic elements namely breakdown maintenance and preventive maintenance. Both are based on a maintenance body of knowledge as illustrated in figure 6.1.

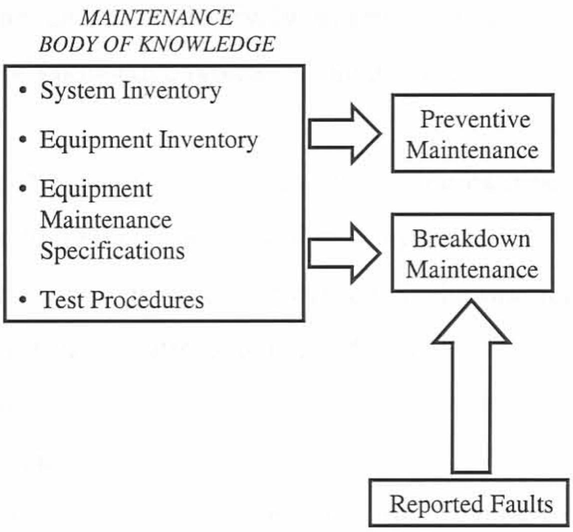

Figure 6.1: Basic Representation of the Maintenance Function of an Academic Institution

The structure of the maintenance activity on campus presented in figure 6.1 is a basic representation and may have omitted certain maintenance items. The detailed functions of facility maintenance are the subject of separate study and not the focus of this study. It must be respected though and the link clearly defined.

Preventive maintenance is defined by Westerkamp [52] as the systematic planning, annual scheduling at regular intervals and on-time completion of needed cleaning, lubricating, repairing and replacing of components in order to:

- Minimise production losses caused by breakdowns
- Prolong the useful life of capital assets
- Lower overall costs

Breakdown maintenance is explained by Stewart [53] as the maintenance that is required when equipment is allowed to continue in service until it cannot perform its normal function any longer. The name is self-explanatory and examples include lighting lamps that burn out or windows that are broken. Breakdown maintenance usually occurs on the input of some form of fault reporting received from building occupants or residents. If not already in operation, a customer care-line should be established that can incorporate electricity faults and other maintenance problems.

Knowledge of the equipment within the institution is vital to the success of the maintenance programme and is collectively grouped under the maintenance body of knowledge. The body of knowledge typically contains the following information:

- System inventory of the layout of all reticulation systems from point of supply to end-use application including all components of each system
- Equipment inventory of all equipment on campus including quantities, suppliers, stock requirement and performance ratings and specifications
- Library of the maintenance requirements of equipment as recommended by the manufacturers and suppliers
- Library of test procedures for all equipment requiring regular maintenance

The body of knowledge should be further expanded to include the capture of the experiences of the maintenance personnel on campus. This should be done to prevent "Technology on the Hoof" whereby, according to Botha [54], the information and experiences of the personnel on campus are not lost when staff members are no longer attached to the institution.

In closing this section, it is important to remember that maintenance at an academic institution does not only address the electrical equipment on campus but attends to all assets such as lecture halls, institution vehicles and civil construction items (buildings and roads) too.

No maintenance can commence on campus until the maintenance body of knowledge has been established. As an example, the University of Pretoria, through its programme of privatisation and outsourcing of maintenance duties by the end of 1998 had suffered a major setback through "technology on the hoof". The outsourcing saw maintenance companies being awarded contracts for specific maintenance tasks through in-house contract managers retained for this purpose. During the privatisation, most of the knowledge of the 380V electricity distribution system, once it was transformed from the 11kV sub-station level, was lost. To remedy this problem, great attention was paid to acquiring this vital information through a series of sub-station walk audits aimed at identifying each circuit on the secondary side. Unmarked circuit breakers were switched off, after localised power outage warnings, to identify the end-user groups supplied by them and this information meticulously documented.

6.3 INSIDE THE ENERGY MAINTENANCE MANAGEMENT AREA-OF-ACTIVITY

Kennedy [51] explains that there are four steps in developing a maintenance programme for the energy systems. The first step is to determine the present condition of the existing campus. This includes a detailed examination of each of the major energy-consuming systems. The second step is the preparation of a list of routine maintenance tables with an estimate of the number of times each task must be performed. The third step involves the incorporation of this list into a regular schedule for the accomplishment of the desired maintenance and finally culminating in the monitoring of the programme once it has been initiated as the final fourth step.

This thinking, when applied to the systematic approach of the energy management programme, is mostly already applied through the Energy Diagnosis area-of-activity and the existing maintenance activities of the facilities department on campus. Once again it is important to remember that the maintenance of the energy systems must fall into the other maintenance requirements on campus as illustrated in figure 6.2.

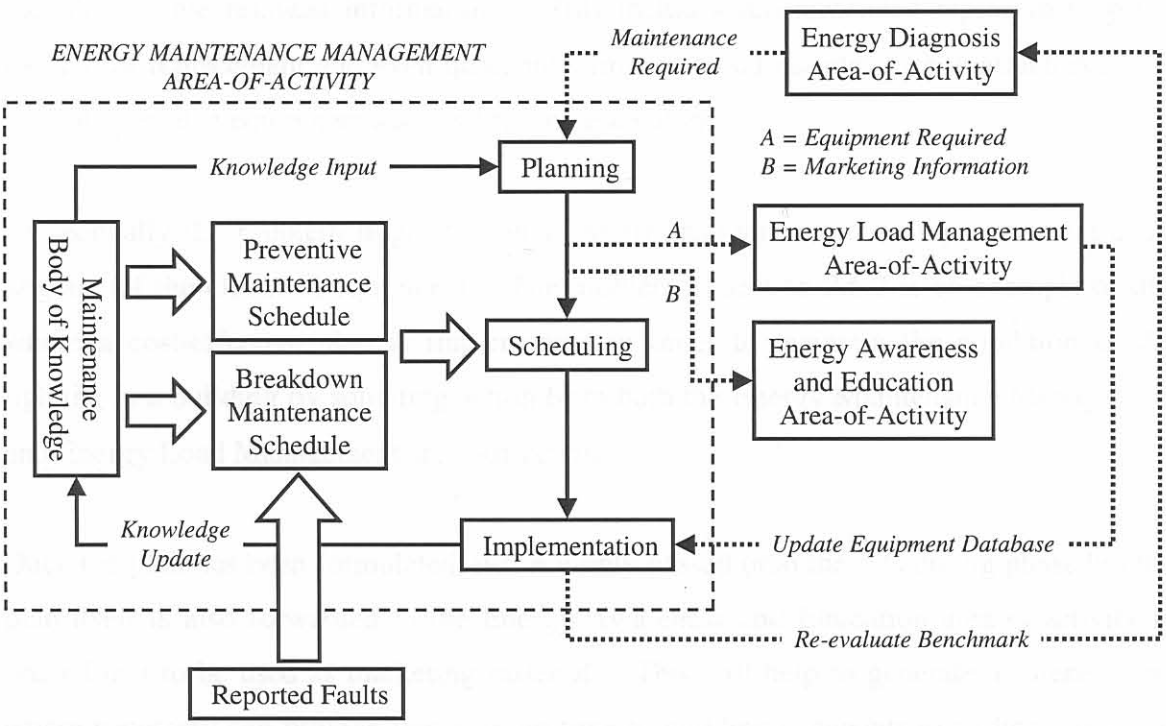

Figure 6.2: Functionality of the Energy Maintenance Management Area-of-Activity

The maintenance component of the energy management programme reacts on the commands that are received from the Energy Diagnosis area-of-activity. Here the solution to the problem is planned based on the input from the body of knowledge. The plan is integrated into the existing maintenance schedule of the institution and then implemented. Incorporating the implementation into the maintenance schedule of the institution ensures the recovery of vital equipment information into the existing body of knowledge. The solid arrows in figure 6.2 indicate internal operation and the dotted arrows indicate operations that occur with the other areas-of-activity as previously illustrated in figures 2.4, 2.5 and 2.6.

6.4 PLANNING

The first part of the Energy Maintenance Management area-of-activity relies on the input of faults from the Energy Diagnosis activity area. These faults will have been noticed during building the auditing phase of Energy Diagnosis activity area and identified as contributors towards high electricity cost and poor benchmark performance.

Once the fault has been received, the solution needs to be found. The maintenance body of knowledge provides input into this planning stage in terms of equipment maintenance specifications and recommended maintenance procedures. At the conclusion of the planning stage a solution to the problem must be put forward, in the form of a job card, that includes all the relevant information. This includes recommended replacement parts, method of replacement and even quotations from external maintenance contractors in the case of specialist equipment such as lifts and escalators.

Occasionally the problem might not only require maintenance but may also require the upgrade of the electrical equipment. The problem in section 2.6.2 is an example of this where a cost-effective plan is implemented in order to maintain the condition of the lighting in a building by soliciting action from both the Energy Maintenance Management and Energy Load Management areas-of-activity.

Once the plan has been formulated, it is not only passed onto the scheduling phase but the plan itself is also forwarded to the Energy Awareness and Education area-of-activity in order for it to be used as marketing material. This will help to generate awareness and where necessary can provide fair warning time to building occupants regarding work that is about to be done.

Naturally, other than those received from the Energy Diagnosis activity area, other faults with electrical equipment will also be received from the building occupants through a customer care-line operated by the facilities management department. These customer faults will run their normal course in the breakdown maintenance schedule of the facilities management department.

6.5 SCHEDULING

From the planning stage, a series of job cards will arrive at the scheduling phase of the Energy Maintenance Management activity area. Here these jobs need to be incorporated into the existing maintenance schedules of the University (both preventive and breakdown).

For example, the cleaning of electrical lamps might be submitted as a job card but this activity is already scheduled to take place anyhow as part of the existing preventive maintenance schedule and that no place need to be found immediately. The existing schedule can be rearranged if it is felt that the task on hand should be fast-tracked but respect must always be paid to the other maintenance requirements on campus.

6.6 IMPLEMENTATION

Once all of the jobs, from faults identified as part of the energy management programme and those as part of the existing preventive and breakdown maintenance programme of the institution, have been prioritised, the next step involves their implementation. The implementation is fairly simple as all of the planning has been completed based on the maintenance body of knowledge.

The final step of the implementation phase is the export of all of the important documentation to the maintenance body of knowledge. Information will also be continually received from the Energy Load Management activity area where new electrical equipment upgrades and installations will have taken place and all maintenance procedures, specifications, system drawings and equipment numbers and ratings will be required in order to update the body of knowledge. This information is then used to ammend the preventive maintenance schedule in order to incorporate any new equipment.

On completion of each maintenance task, the energy benchmark can be re-evaluated in the Energy Diagnosis activity area in order to determine the impact on the energy benchmark.

6.7 MAINTENANCE EXAMPLES

Regular maintenance not only has a positive effect on the electricity benchmarks but on the reliability and sustainability of the electricity reticulation system in general. This will be highlighted in the following 3 examples of where maintenance can play a positive role, or the absence thereof can have disastrous effects.

6.7.1 Building Preventive Maintenance

From the definition of preventive maintenance in section 6.2, it was mentioned that regular maintenance helps to extend the useful life of an asset or piece of equipment. Maintenance that becomes deferred could lead to assets, including electricity reticulation systems, being degraded to a point that is beyond their financial viability whereby the sum of all of the maintenance costs required to render the asset operational is greater than the value of that asset. The effect of preventive maintenance on a building that is conducted in a pro-active manner is illustrated in figure 6.3. This illustration holds true for the electricity reticulation system, and associated costs, too.

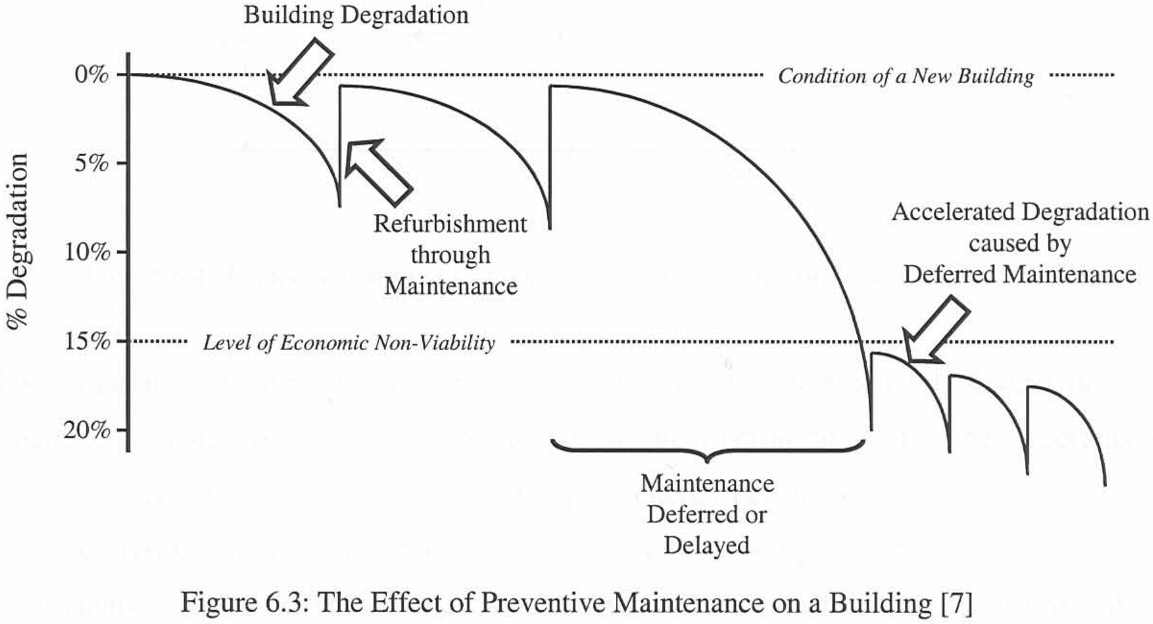

Figure 6.3: The Effect of Preventive Maintenance on a Building [7]

If the maintenance schedule is not set up correctly or is not adhered to, then the situation is reached whereby a building or other asset no longer retains any of its original value and major funding is required to restore this building to a point of economic viability. In this instance it usually makes financial sense to replace the asset altogether. Unfortunately, this is not always possible with certain assets such as buildings and is usually done at a far greater cost than the regular maintenance would have cost. Once an asset has passed a state of economic viability, the degradation occurs at a much faster rate, which in turn requires more funding.

6.7.2 Lighting Maintenance

Regular maintenance helps to ensure that the electricity benchmarks are reduced through a process of increasing the efficiency of electrical equipment. In the case of electrical lighting, the effectiveness of the lamps is affected by both the operational ageing of the lamps and the collection of dirt. The effect of this is illustrated in figure 6.4.

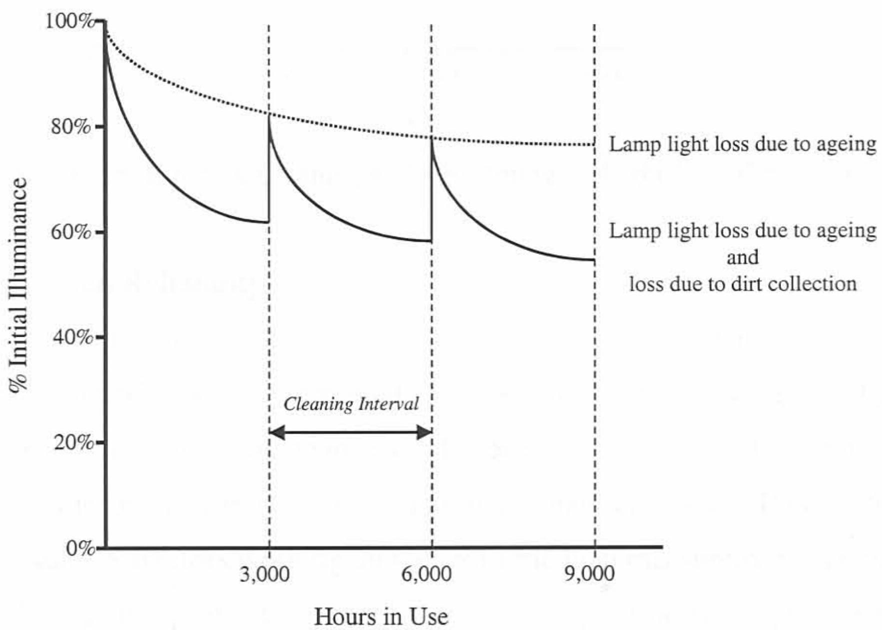

Figure 6.4: Typical Light Loss Curves due to Lamp Ageing and Dirt Collection [55]

To counteract this problem, the lamps could be cleaned more frequently and, if deemed financially viable, could be considered for replacement before the end of their operational life. This could be motivated from both a poor energy benchmark in terms of electricity cost required for lighting or in terms of unsatisfactory working conditions in terms of low illuminance. The effect of regular cleaning and lamp retrofitting is illustrated in figure 6.5.

Although cleaning lamps is not always practical, it will increase the efficiency of the lighting in terms of the amount of light that is obtained per unit of electrical energy consumed. Cleaning the lamps can be carried out with the minimum amount of disruption, requires little training on the part of maintenance personnel and ensures that the condition of the electrical lamps are visually more satisfactory.

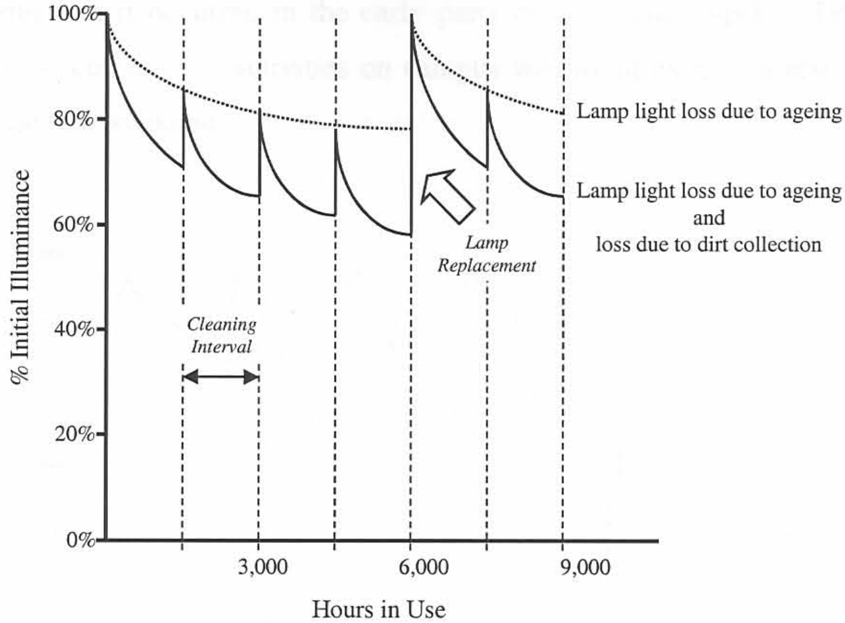

Figure 6.5: Effect of Cleaning and Retrofitting on Light Loss Curves [55]

6.7.3 Sub-Station Reliability

The final example involves a case where slow reaction to a reported suspicious fault lead to the electricity supply being interrupted to the entire main campus at the University of Pretoria. During routine maintenance of the energy measurement system, an unusual noise was noted in one of the 11kV sub-stations on main campus. This noise was noted by one of the sub-contractors working on the real-time load measurement system. Initially it was thought that the problem lay with the uninterrupted power supply (UPS) used to supply backup power to real-time load measurement equipment in this sub-station. However, after conducting the necessary investigation, the UPS was cleared and the fault ascribed to irregular corona on the busbars. In concluding his tasks, the sub-contractor reported his suspicions to the facility management personnel on campus who are responsible for the integrity of the sub-stations.

The fault was reported during the month of May 1999. The fault was not immediately addressed and a few months later, on Friday 16 July 1999, a general protection fault occurred and all power to the entire campus was lost. Figure 6.6 illustrates the load profile of the University load for the week of the fault.

Upon investigation, it was ascertained that some of the voltage transformation equipment had been incorrectly installed in the sub-station and this had lead to the general fault. The power from this specific sub-station was disrupted for a full 24-hours which could have been disastrous had it occurred in the early parts of a working week. Fortunately the disruption to the commercial activities on campus was minimised as a result of the fault occurring close to a weekend.

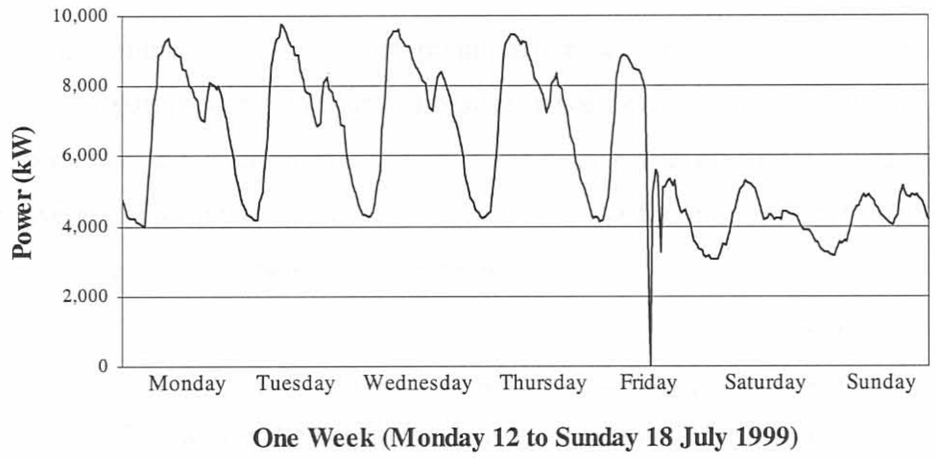

Figure 6.6: Power Outage at the University of Pretoria – Friday 16 July 1999

It can be concluded that the reaction time to reported faults must be minimised at all costs. Failure to recognise the full potential impact of reported faults could lead to major problems and increased costs. Furthermore, the facility management department must take ownership of the integrity of the electricity system and ensure that all work conforms to all certified safety standards.

6.8 CONCLUSION

By following the systematic approach to this activity area, the link between the existing maintenance on campus and the maintenance required from the energy management programme is clearly defined.

This link ensures that there is no information loss or "technology on the hoof". The capture of all of the maintenance information not only prolongs the operability of the electricity systems but ensures the sustainability of the energy management programme.

The facilities management department must take ownership of the maintenance on campus and must expand this ownership to include the electrical equipment. The maintenance of the electrical equipment can have a very positive effect on the energy management programme. On the other hand, the potential disastrous effects that poor, cumbersome maintenance could have should be also acknowledged. In this manner all maintenance and planning decisions on campus must take the energy management programme into account. The facilities management department should wear their energy management caps when approving new equipment and buildings.

In conclusion, it must be said that the maintenance activity of the energy management programme is of paramount importance because it not only ensures greater reliability and increased occupant satisfaction but it strives to reduce the electricity cost in terms of electricity use and equipment capital costs. All of these features are part of the goal of a comprehensive energy management programme.

In the next chapter, the final component of a complete energy management programme will be addressed that targets the people on campus through marketing and training.

CHAPTER 7: ENERGY AWARENESS AND EDUCATION

"Not advertising is like winking in the dark. You know what is happening but no-one else does."
Nigel H. Martin

7.1 INTRODUCTION

In figure 2.1, it was shown that the only way to reduce the electricity cost per product or business function is to address both the electrical equipment and the people that use the equipment. The Energy Load Management and Energy Maintenance Management activity areas concentrated on projects and activities aimed specifically at the equipment but this activity area however, is aimed solely at the people on campus that form part of the institution community.

The goal of this activity area is for all the people on campus to take ownership for the reduction in the electricity cost per product by ensuring that they each do their part. This is achieved through both generating general awareness of the energy management programme and through energy education aimed at the transferral of specific energy management skills.

Unfortunately, the amount of savings that result from this activity area are immeasurable but failure to undertake this activity area will result in the energy management programme not only being incomplete but also not reaching its full potential. The students and staff on campus can only participate in an energy management programme if they are made aware of it and given specific skills with which to help. This chapter will firstly look at creating a marketing strategy followed by a closer look into the process involved in this activity area.

7.2 A MARKETING STRATEGY

As mentioned in the previous section, the purpose of this activity area is to instill a sense of ownership for electricity on campus and this is achieved through generating general awareness of the energy management programme and the education of the people who use the electricity. But how is this done?

From chapter 1 it was recognised that every institution is different with its own culture on campus and that no single plan or strategy will fit any two campuses in exactly the same way. The secret to devising a marketing strategy is to use the inherent culture on campus as a medium for establishing an energy efficient culture. If the campus culture is vibrant and active, then the material must also be vibrant. Boring material will stand no chance amongst the volumes of other material on campus.

From the outset it is very important that all marketing material that is distributed is capable of being identified as part of the energy management programme on campus. This can be achieved by designing a cartoon character and possibly even thinking up a slogan for the programme. Figure 7.1 illustrates the cartoon character used with the energy management programme at the University of Pretoria. The cartoon character helps the students and staff to identify which material is part of the energy management programme on campus and is taken from a caricature sketch of one of the staff members involved with the energy management programme.

Figure 7.1: Cartoon Character from the University of Pretoria

The information that is distributed on campus will either be done on a regular interval e.g. monthly reports, or will be distributed when input is received or a specific need arises e.g. one-run posters. A combination of both frequencies will inevitably be required. Appendix A and B include an example of material, from the University of Pretoria, that is distributed to the members of the energy co-ordination committee on a monthly basis in the form of an "Energywise Report" and "Hostelwise Report" respectively.

In summary, a great deal of benefit will be obtained from consulting with specialists on campus as to the correct marketing strategy. Academic institutions have an advantage in the sense that they posses an environment of open-mindedness where new ideas and approaches can not only be tested but stand more chance of succeeding.

7.3 INSIDE THE ENERGY AWARENESS AND EDUCATION AREA-OF-ACTIVITY

The processes of this activity area are fairly simple in comparison to the other activity areas. There are four steps, namely identifying the target market, selecting the appropriate medium, designing the message and lastly transmitting this message along the medium that has been selected. This process is illustrated in figure 7.2.

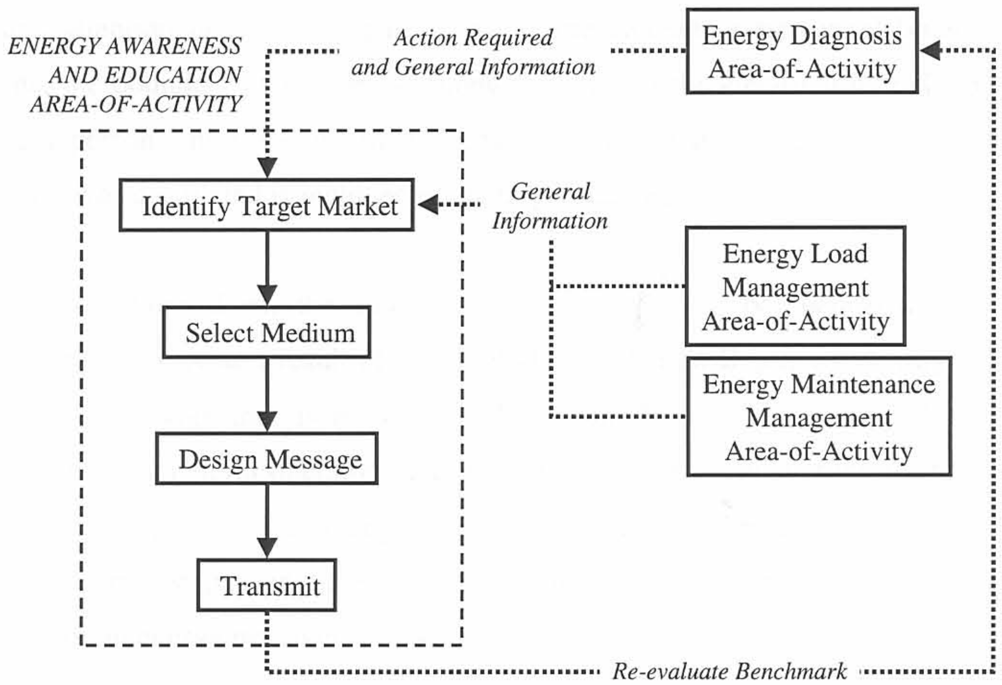

Figure 7.2: Functionality of the Energy Awareness and Education Area-of-Activity

This activity area receives two types of input. The first type is as a result of specific problems that contribute towards poor electricity benchmarks. These would have been identified by the Energy Diagnosis activity area and require training on the part of the people on campus to help remedy the situation. An example of this is leaving office lights on when going home in the evening. The second type of information consists of general information that is received from all of the other activity areas. For example, project plans from the Energy Load Management area-of-activity or examples of poor maintenance from the Energy Maintenance Management area-of-activity.

The solid arrows in figure 7.2 indicate internal operation and the dotted arrows indicate operations that occur with the other areas-of-activity as previously illustrated in figures 2.4, 2.5 and 2.6.

7.4 IDENTIFYING THE TARGET MARKET

The first step from when general information is received from the other activity areas, or when specific action is required from the Energy Diagnosis activity area, is to decide where the attention must be focused. In other words, the target market must be identified. Being able to pinpoint the fault areas will ensure that the communication mediums are not overloaded and that the people on campus do not receive too much information. For example, poor benchmarks in the student hostels are the problem of those students residing there and attention need not be paid to the entire student or personnel bodies. As a guideline, the boundary can be drawn along the lines of the electrical reticulation system where any person who uses electrical equipment at levels lower than the point where the benchmark was calculated is included in the target market.

Once this has been done, the cause of the problem must be identified as either an awareness problem or as a result of a lack of skills. This will help to identify the correct medium and message that is required. For example, if the commercial vendors on campus, such as cafeteria operators, are being targeted, they might first need to be made aware of the energy issues on campus before they are trained to understand an electricity account. The first part involves awareness and the second involves education in the transferral of an energy management skill.

7.5 SELECTING A MEDIUM

Once it has been ascertained where the attention must be focussed and the type of message that is required, be it for general awareness or specific skill education, the ideal medium or combination of mediums can be selected.

An academic institution is fortunate in the sense that there may be many communication channels available on campus that would not normally be available to every-day commercial companies. These include access to campus newspapers, campus radio stations and possibly even campus television studios. Naturally the normal options of printed media and the Internet are available for the distribution of posters, flyers, reports and articles.

Many institutions have established energy websites on the Internet and this makes it very easy to distribute the latest energy management material and ensure that it is easily updated. The costs associated with printed media are also avoided. Care must be taken however when making use of electronic mail (or e-mail) distribution because, although the costs to the energy management programme are very low, it could create an annoyance amongst the recipients if they are continually bombarded with information. Distributing too much information too regularly will result in the recipients simply deleting the item before reading it. This defeats the purpose of the electronic mail in the first place.

Many other mediums should be considered and the energy management programme will have great success if innovative ways are found to get the message across such as:

- Placing energy management suggestions and tips on the inside of fast-food packaging on campus
- Conducting forums and undertaking presentations to key members of the student body and staff
- Undertaking radio interviews and advertisement spots regarding energy management on campus
- Distributing marketing gadgets on campus such as computer mouse-pads, T-shirts, stickers, fridge magnets, pocket protectors, pens etc.

7.6 DESIGNING THE MESSAGE

Before the final message can be transmitted or distributed, it needs to be designed in an innovative way. The information that is going to be distributed on a regular basis will typically be done in a standard format on the same communication channels. Develop the layout of these reports first and then continually try and improve them by encouraging input from the recipients.

Combining the energy management messages with other events on campus or topical news items will provide some good opportunities to get the message across. Attaching incentives is also a possibility. For example, when distributing a poster or flyer regarding Compact Fluorescent Lamps (CFLs) such as the one on appendix C, a lighting manufacturer can be approached to provide CFLs at a reduced price for every person showing their student or personnel card (and a copy of the flyer). This will increase the market presence of the manufacturer and will encourage students and personnel members to participate because they will be able to get these lamps for their homes at special prices. In this specific project, acquiring efficient lamps for the homes of students and personnel members will not address the electricity benchmarks on campus but will make the target audience more receptive to suggestions, ideas and requests in the future. In this manner an environment of information transfer is created. Examples of posters that are used to generate awareness and impart some skills at the University of Pretoria are included in appendix D and E. Campaigning for a sponsor for individual marketing projects will help to reduce the costs of the energy awareness and education campaign such as sponsors for T-shirts for the members of the Energy Action Team described in section 2.7.

7.7 CASE STUDIES

The goal of this Energy Awareness and Education activity area is for all the people on campus to take ownership for the energy management programme. In the previous sections, two types of messages were identified, namely those for awareness and those for the transferral of energy management skills. This section will deal with two case studies from the University of Pretoria that highlight the potential of this activity area.

7.7.1 Separate Metering and Billing of Vendors

One of the most powerful methods in which to make people take ownership for their electricity is to make them financially accountable for it. This does not mean that each student on campus receives an electricity account but rather that the electricity portion of the class fees and hostel residency fees are clearly reflected on student accounts. Taking this one step further would be to issue each faculty with a monthly electricity account that has to be paid for from the budget of that faculty. This may sound strange in principle but is already applied for other services such as telephones and Internet connections at the University of Pretoria. This is termed "separate metering and billing" and involves the recovery of the total institution electricity costs from the various faculties and departments in relation to their contribution to the total costs.

According to the National Electricity Regulator (NER) in South Africa [56], it is necessary to find a compromise between the following points when designing a tariff structure:

- The need to accurately reflect costs
- The need to ensure equity and fairness
- The need for a practically implementable tariff
- The need to utilise appropriate metering and supply technology
- The need for an understandable tariff
- The customer's ability to pay

These points were used as guidelines at the University of Pretoria when designing internal tariff structures for separate metering and billing. At the University, the catering functions on campus such as cafeterias and restaurants are outsourced to private companies. These companies, termed independent commercial vendors, receive a monthly account from the University for rent, water and electricity. Unfortunately for these companies, they effectively only have a large client base for eight months of the year while the students are attending lectures on campus. For this reason, it was decided to apply an electricity tariff where they pay for their monthly contribution to the overall electricity account of the University. The University is billed according to a demand tariff and therefore each vendor is billed according to their energy consumption and only their contribution to the overall maximum demand. Figure 7.3 illustrates the load profiles of three of the vendors on the day that the University reached its maximum demand for the month of June 1999.

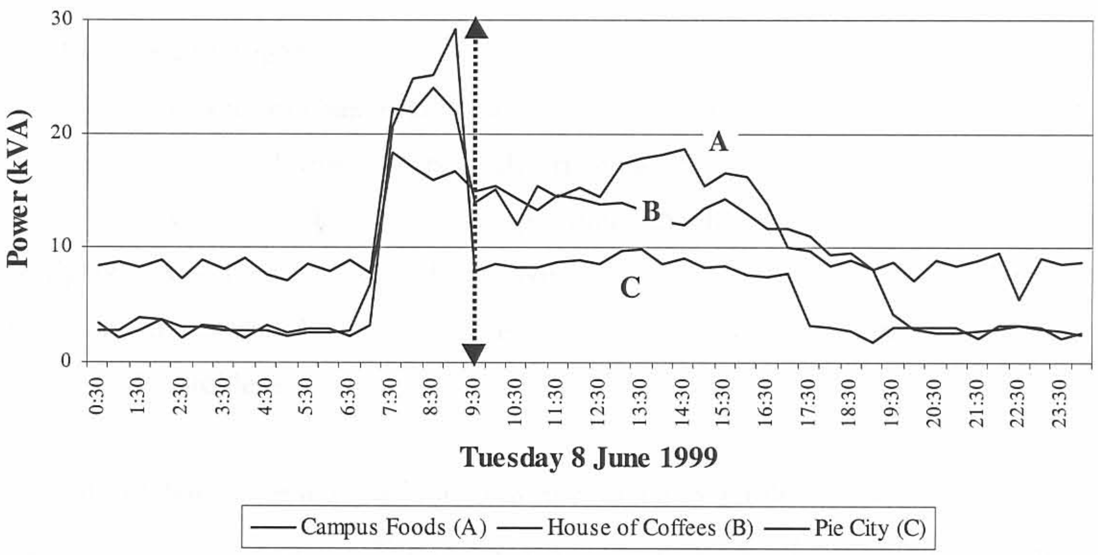

Figure 7.3: Vendor Load Profiles on Day of University Maximum Demand

From the profiles it is evident that these vendors would have to pay a lot more for electricity if they had to pay for their individual maximum demands and not only for their contribution to the system maximum demand that occurred at 09:30. Their individual demands are of no consequence to the overall demand provided that it does not occur at the exact same time interval. The tariff rates of the University are applied to these vendors on a back-to-back basis in order to remain consistent with changes in the supply costs. The energy rate, however, is increased by 5% in order to compensate for distribution losses through the 11kV network on campus.

One problem that did exist was that not all of the vendors have their electricity consumption measured with the real-time energy management system on campus. Most of the vendors have only their energy consumption measured with an electromechanical meter. For this reason it was decided that the combined equivalent cost per unit (see section 3.3.5) of the three vendors, illustrated in figure 7.3, would be used as the energy rate for all of the other vendors until funds can be procured to measure their respective electricity load profiles in real-time.

It should be noted that before this tariff structure was implemented, all the vendors were first consulted and time was spent explaining the exact workings of the new tariff structure. This facilitated the easy introduction of the tariff structure and has eliminated many complaints on their part because a win-win situation was created.

7.7.2 Light Audit Night

The University of Pretoria has a large base load of approximately 4MVA, or 40% of the peak demand. Although many types of electrical equipment contribute towards this ever-present load, it was also noticed that many personnel members were not switching off their office lights and other equipment when leaving work in the evenings. Some basic skills coupled with a general shortage of awareness of the electricity costs of campus were identified as the problem.

It was realised that something innovative must be done to get the necessary attention of all of the personnel members. For this reason, the concept of "light audit night" was developed whereby the Energy Action Team conducted an evening walk audit of all of the major buildings on campus and attached friendly posters to the door of offices that had their lights burning encouraging the occupants to alter their present pattern. An example of the poster is illustrated in figure 7.4.

During the evening, a total of approximately 56kW of unnecessary office lighting was discovered burning. The true success of the project however was the number of responses that the posters generated. Many people contacted the Energy Action Team either requesting additional information or to provide information regarding other areas of where energy is being wasted (not necessarily related to lighting only). Some departments even collected the posters off the office doors and had them mounted in the passageways as a continual reminder to the occupants of the building.

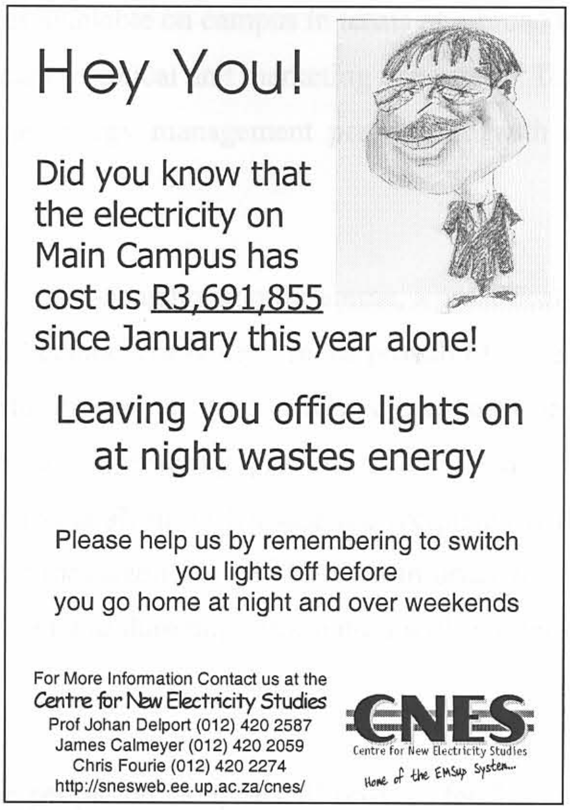

Figure 7.4: Door Poster from Light Audit Night

The general response was overwhelming based on the fact that most personnel members are more responsive when they realise that people such as the Energy Action Team are prepared to put in a little bit extra of their time in order to make a difference. In this instance, the innovative way of distributing the message worked.

7.8 CONCLUSION

It is important that the function of this activity area is not considered as insignificant or secondary in relation to the other areas-of-activity. Sometimes this aspect of the energy management programme is neglected because the returns in terms of an improved electricity benchmark are not easily quantifiable or measurable.

In chapter 6, under the Energy Maintenance Management area-of-activity, the establishment of a customer care-line was introduced. Instilling ownership for the energy management programme through the generation of awareness will help to ensure that the people on campus are prepared to take the effort to use the care-line to report faults with the electrical (and other) equipment on campus.

There are many resources available on campus in terms of a broad range of communication mediums and the necessary technical and marketing expertise. These resources should be harnessed to provide the energy management programme with a style unique to each specific institution.

From the onset of the energy management programme, a great deal of information in terms of facts and figures will become available. In all probability, the amount of information will outweigh the opportunities to use it and extreme care must be taken not to use all the available material when an opportunity presents itself. In other words, information overload must be prevented at all times because the recipients will not be able digest too much information. Each message must be absorbed in order for the energy management programme to be successful and dumping information will in effect kill the good efforts of this activity area.

More often than not, the people on campus will provide feedback in the form of ideas or opinions. The energy manager and his team must encourage this feedback even though it may not always be positive. All commentary should be used in a positive manner in an attempt to improve the methods and messages that are being distributed on campus.

Encouraging feedback is a good way of inviting the people on campus to take ownership for the energy management programme. This is achieved by making sure that all the necessary contact information (and possibly the address of the energy management Internet page) is included in all material that is distributed on campus.

The culmination of this chapter brings to a close the detailed working of each of the areas-of-activity. The next chapter will look specifically at the evaluation of the energy management programme as a vital feedback link back to the energy policy of the institution.

CHAPTER 8: EVALUATING THE ENERGY MANAGEMENT ACTIVITIES

"Good enough, is the enemy of all progress"

John H. Patterson

8.1 INTRODUCTION

In chapter 2 the philosophy behind a complete energy management programme was introduced. This approach sees a close relationship between the energy policy and the energy strategy. The energy strategy is based on four areas-of-activity and each one of these areas was explained in chapters 4 through to 7.

In reference to figure 2.5, all areas have been covered elsewhere in this thesis except for the programme feedback link between the energy strategy and the energy policy. This link is vital if the energy management programme is to be considered complete. In chapter 2 it was said that the energy policy determines the destination of the energy management programme and the energy strategy determines the route. If this is truly so, then it is imperative that the goals of the programme are evaluated to ensure that they are applicable. For example, if a target has been included in the energy policy, it should be ammended or removed when that target is reached.

This chapter will look at methods of firstly evaluating the energy strategy, then the energy policy and finally the energy management programme in its entirety. In conclusion to this chapter, discussion is focussed on the issue of acquiring funding and the employment of savings that have been realised as a result of the energy management programme.

8.2 EVALUATING THE ENERGY STRATEGY

The energy strategy is deemed as the starting point because it is here that faults are found with the electrical energy on campus and addressed through various projects in terms of load management, maintenance management or awareness and education. If the projects are successfully planned and implemented then the benchmarks will improve. If this is achieved then the energy strategy is successful and, if suitably selected, the goals of the energy management policy will have been achieved leading to a successful programme.

In terms of evaluation, it is firstly necessary to evaluate the energy performance of an academic institution against itself and secondly it is useful to evaluate the energy performance of the institution against other institutions both locally and abroad. Both of these internal and external evaluations will be discussed.

8.2.1 Internal Evaluation: Intra-Institution Comparison

The most significant part of the evaluation process is the evaluation of the benchmark performance of the institution against its historical performance. This is after all the purpose of the energy management programme and improved benchmarks, that relate the cost of electricity to the students and business functions on campus, naturally imply a reduction on the energy cost per student or academic facility.

The benchmarks were introduced in section 4.3 and note must be made of the possible fluctuations in the benchmark values due to seasonal swing, tariff rates and the academic calendar. For this reason it is advised to only react on poor benchmark performance that has been observed over a longer time period or at the conclusion of each energy management project that has been initiated under the Energy Load Management, Energy Maintenance Management and Energy Awareness and Education areas-of-activity.

To assist in analysis of the energy benchmarks and energy management projects, the flowchart in figure 8.1 can be used as a guideline.

Question 1: Has the cause of the poor benchmark been established in terms of equipment or people? If not, this is the first problem and use should be made of the various types of audits covered in section 4.4 and the processing of this information in section 4.5 in order to find the cause. If this has already been done, proceed to question 2.

Question 2: Has the cause been ascribed to a specific area-of-activity? If not, this is the second problem and use should be made of the guidelines in section 4.6 in order for the problem to be addressed through the correct area-of-activity. If the information has been ascribed to a specific activity area, then proceed to question 3.

Question 3: Has a solution to the problem commenced or started to be implemented? If a solution in the form of an energy management project is underway, then proceed to question 4. If not, it is necessary to determine the cause for the project not commencing by proceeding to question 6.

Question 4: Has the solution, or project, been concluded? If the project has not been concluded then it is still in progress and the result will be unknown until such time as the project has indeed been completed. If the project has been completed, then proceed to question 5.

Question 5: Was the project successful in the sense that it altered the load shape, increased the efficiency of electrical equipment, created awareness or imparted energy management skills on campus? If not, then proceed to question 7. If the project was successful then there are no problems with this specific project and the overall fault lies elsewhere with other projects.

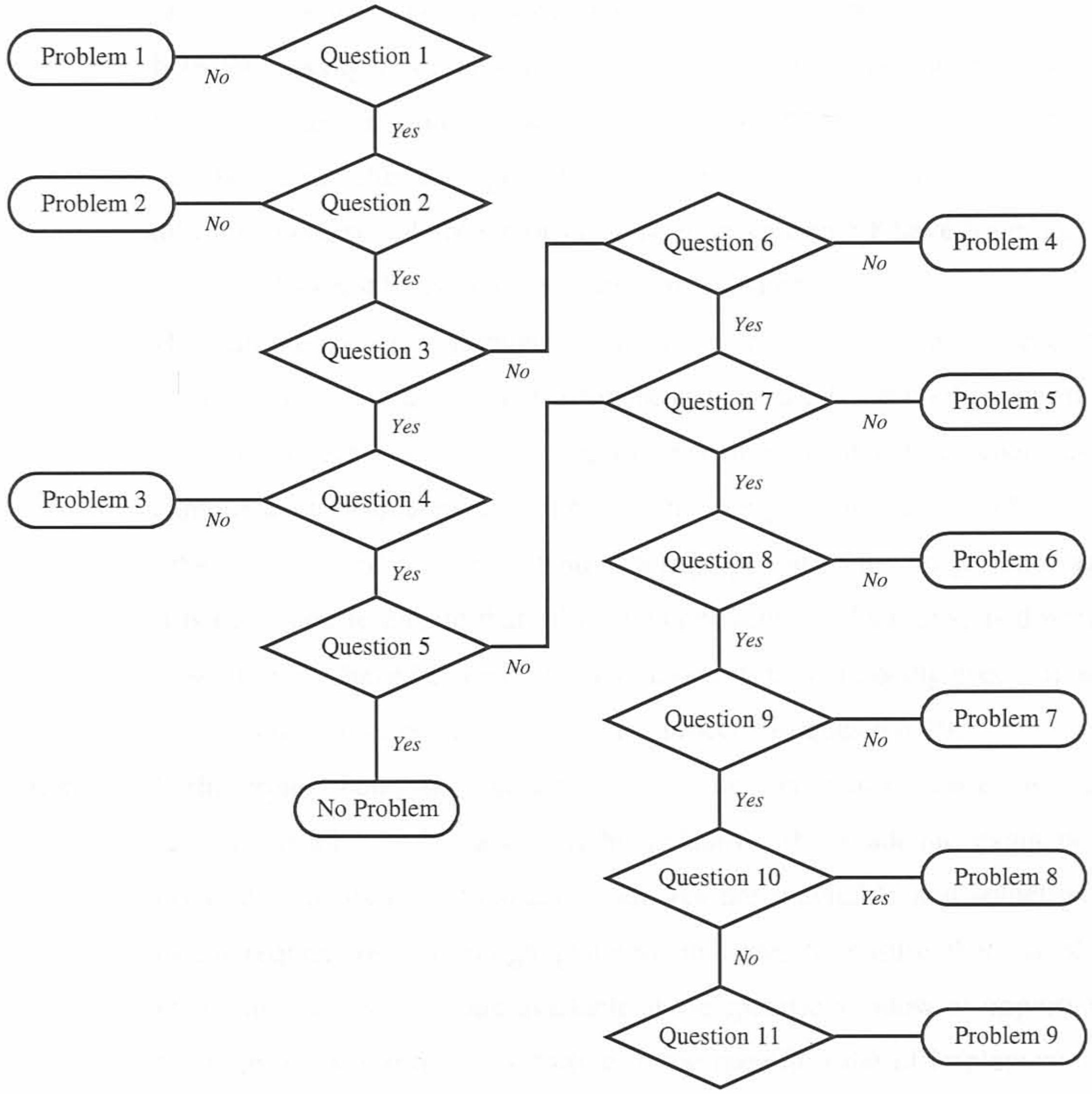

Figure 8.1: Benchmark Evaluation Flowchart

Question 6: Is the project deemed financially viable? The methodology for the economic analysis of projects was discussed in section 5.3 using the economic formulas from chapter 3. If the project is deemed as not being financially viable for the energy management programme, then no further inquiry is necessary. On the other hand, if the project is indeed financially viable, then proceed to question 7 in order to determine the cause of poor project performance.

Question 7: Have all of the funds for the project been made available? A lack of funding for material and labour is an obvious component of poor project performance. Included here is all of the initial capital required as well as other funds that may be required throughout the project such as maintenance costs etc. If the funds have been available, then proceed to question 8.

Question 8: Have all the materials and equipment been made available? For example, all of the funds might be available but there will be delays in the time between placing an order with a sub-contractor and expecting delivery as a result of scheduling on the part of the contractor or because equipment must first be manufactured, imported or acquired. In any event make sure that all of the contractual obligations discussed in section 5.8 have been met. If the fault does not lie here, then proceed to question 9.

Question 9: Have all the necessary human resources been available for the project either internally or externally if contractors have been used? It could occur that a specific project needs to fit into the existing maintenance schedules on campus as discussed in section 6.5 or that the personnel are still busy with other projects and can only attend to this project at a later stage. Once again it is necessary to ensure that all of the contractual obligations, as discussed in section 5.8, have been met if external contractors are being used. If all of the resources have been available, then proceed to question 10.

Question 10: Is the project being delayed due to any time constraints such as not being able to install high voltage switchgear during the academic exam period because students need to study? Delays are inevitable and sometimes it might require very thorough planning in order to ensure that all of the materials and resources are available at the specific window of opportunity. Some projects will not be sensitive to the specific time of implementation, as they do not disrupt the normal activity on campus. If there are no delays, then proceed to question 11.

Question 11: If not covered with the previous questions, what are the other reasons for the project not being successful? Included here are items such as poor planning, unrealistic goals or inefficient project implementation.

The benchmark evaluation flowchart should only be used as a guide when attempting to evaluate the energy management projects. Finding fault should not be done on the basis of persecution but rather on improving fault areas and learning from experience. In this way, the probability of success of all of the projects in the energy management programme is increased.

8.2.2 External Evaluation: Inter-Institution Comparison

In the introduction to this section it was said that the comparison of an institution to other local and international institutions was useful. The word useful was used and not necessary because there are a couple of issues that must be considered.

Firstly the value of the comparison to other institutions must be considered. If your performance is better than theirs it does not mean that your programme is successful because it is your electricity costs that are the issue and not theirs.

In the first chapter it is recognised that every institution is unique in terms of its facilities, geographical location, resources, personnel and history or culture. While history or culture does not play a part in terms of energy benchmarks, all of the others (including varying electricity tariff structures and rates) do affect the calculation of benchmarks in terms of energy cost per product or business function. The benchmarks are not only affected by seasonal swing but by climates too where comparison between institutions in different climates will need to consider the difference in the types of load equipment. In this thesis focus is made specifically on electrical energy but the evaluation between various institutions is made difficult when comparing institutions who make use of electricity only and others who use a combination of fuels. Where possible, contact should be made with an institution that has the following characteristics:

- Similar climate to yours
- Similar types of electrical loads e.g. HVAC, lifts, pumps etc.
- Similar facilities e.g. hostels, laboratories, lecture halls, sports facilities.
- Similar percentage mix of fuels
- Same tariff structure
- Similar tariff rates

From this list it becomes evident that the most suitable option would be to evaluate your performance against that of another institution in the same country as you. Unfortunately it is not that simple because the tariff structure needs to also be considered. For example, the Durban campus of the University of Natal is billed according to a time-of-use tariff structure with two demand charges, one for the maximum demand during peak and standard periods and one for the maximum demand for the entire month (these two could occur at the same time) [29]. It becomes difficult when comparing this to the University of Pretoria which is billed according to a demand tariff structure where a charge is levied for the maximum demand in the month as well as the energy consumption.

Using energy alone is not sufficient. For example, during 1998 the University of Bordeaux 1 [57] consumed a total of 7,636,417 kWh. The University of Pretoria, on the other hand, consumed a total of 45,194,648 kWh during the same period. These two values are of no use unless they can be put on the same base. In terms of electrical energy per hostel resident per year, the University of Bordeaux consumes 753 kWh whereas the University of Pretoria consumes approximately 2,584 kWh. Once again these figures are of not much use because the climates of each university are different and the University of Bordeaux makes use of natural gas in their central heating plant to supply heating to all buildings and residences.

In section 4.3.1 it was noted that benchmarks based on the electrical energy unit (kWh) are not satisfactory in an energy management programme where the goal is to reduce the energy cost per product or business function. The focus here is not on the amount of electrical energy but rather on the cost of that energy. For this reason, there can be very little value attached to evaluating your energy benchmarks against other institutions unless both institutions are very similar to each other in respect of the items listed earlier. It does however make for interesting marketing information.

8.3 EVALUATING THE ENERGY POLICY

According to the National Examining Board for Supervision (NEBS) workbook on managing energy efficiency [58], the organisation, in this instance the academic institution, will need to:

- Reaffirm its commitment to energy management
- Reappraise the levels of understanding and co-operation within the institution
- If necessary, revise the energy policy in the light of what has been learned, resetting targets and objectives as required
- Take heed of the comments and criticisms of stakeholders.

For this review to be systematic it should take the form of a management audit. Essentially we want to know how well we are performing with our policies, targets and objectives. In section 2.5 it was recommended that the energy policy be evaluated on an annual basis during which time the points listed above can be evaluated and addressed.

It is advisable to invite commentary from all stakeholders, either through their representation on the energy co-ordination committee or directly themselves, as this will provide ample transparency and representation to the evaluation process. In this instance the stakeholders include the students, personnel members, energy co-ordination committee members, electricity suppliers, government representatives and any other person directly involved with the energy on campus. This evaluation process will be limited if only the input of the energy manager and energy co-ordination committee is considered. Chapter 7 explained how inviting input (both positive and negative) is a good method of encouraging ownership of the energy management programme.

8.4 EVALUATING THE ENERGY MANAGEMENT PROGRAMME

When evaluating the energy management programme some elements might perform better than others. For example the energy strategy as a whole might indicate sufficient progress but the energy policy might be deemed as outdated or ineffective. In this case it is difficult to get an overall feel for the progress of the energy management programme as a whole and the energy management programme matrix in table 8.1 can be used. The table has been slightly amended from its commercial origin [15] in order to be applicable to academic institutions.

Table 8.1: The Energy Management Programme Matrix [15]

Level	Energy Policy	Organising	Relating to Users	Measurement Systems	Marketing	Investment
4	Energy policy, action plan and regular review have commitment of top management.	Energy management fully integrated into management structure. Clear delegation of responsibility for energy costs.	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, monitors costs, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the institution and outside it.	Positive discrimination with detailed investment analysis in order to exploit all potential projects.
3	Formal energy policy but no active commitment from top management.	Energy manager accountable to energy committee representing all users, chaired by a member of the governing body.	Energy committee used as a main channel together with direct contact with majority of users.	Reports for individual premises based on sub-metering, but savings not reported effectively to users.	Programme of awareness on campus and regular publicity campaigns.	Some payback criteria employed as for all other investment.
2	Unadopted energy policy set by energy manager or senior departmental manager.	Energy manager in post, reporting to *ad hoc* committee, but line management and authority are unclear.	Contact with majority of users through *ad hoc* committee chaired by senior departmental manager.	Reports based on supply meter data. Energy unit has *ad hoc* involvement in budget setting.	Some *ad hoc* awareness training on campus.	Investment using short-term payback criteria only.
1	An unwritten set of guidelines.	Energy management the part-time responsibility of someone with only limited authority or influence.	Informal contacts between maintenance personnel and a few users.	Cost reporting based on invoice data. Reports compiled for internal use within facilities department.	Informal contacts used to promote energy efficiency.	Only low-cost measures taken.
0	No explicit policy.	No energy management or any formal delegation of responsibility for energy costs.	No contact with users.	No information system. No accounting for energy costs.	No promotion of energy efficiency.	No investment.

Table 8.1 can be used to evaluate the performance of individual aspects of the energy management programme and when applied to the energy management programme at the University of Pretoria, delivers the following results:

- *Energy Policy*

Researchers in energy management have drawn up a draft version of the energy policy. This policy has not been formally adopted and as such has not yet received the full commitment of the top management. In terms of energy policy, the University of Pretoria is at level 2.

- *Organising*

An energy co-ordination committee has been established and an existing manager has been targeted to assume the role of energy manager. The line management and authority of the energy manager have not been finalised and at present this manager is also being utilised for other functions. The organisational structure therefore finds itself somewhere between levels 2 and 3 but also with some aspects of level 1 present. Appointing the energy manager in a formal post will boost this performance into levels 3 and 4.

- *Relating to Users*

The communication channels to end-users are not yet fully functional with the main communication flowing from the energy co-ordination committee but only to a few end-users on campus. The relationship with end-users finds itself more established than level 2 in terms of the energy co-ordination committee acting as the main channel but needs to be expanded to include the majority of users in order to remove the remnants of level 1.

- *Measurement Systems*

The University of Pretoria has a fully functional energy monitoring system and supervisory control and data acquisition (SCADA) system in place capable of performing all measurement and costing functions in real-time. Therefore, in terms of measurement systems, the University of Pretoria is at level 4.

- *Marketing*

With a comprehensive measurement system comes the availability of ample marketing material. This material in harnessed into regular monthly reports to the energy co-ordination committee and to the University community. Chapter 7 included some of the marketing material presently used at the University of Pretoria. The programme has not, however, reached its full potential partially due to its infancy. For this reason the marketing aspect of the energy management programme is at level 3.

- *Investment*

Very little investment has taken place into energy management projects. To date most funds have been used for the acquisition of the measurement system. This too can be ascribed to the infancy of the programme where it was decided to first get all the measurement tools in place before commencing with specific energy management projects. In terms of investment, the University of Pretoria is at level 1.

From the analysis of all of these elements, it by no means implies that the energy management programme at the University of Pretoria is incomplete. The programme is indeed complete because it has the correct structure and addresses all of the areas-of-activity. This analysis simply helps to identify areas where more attention should be paid. At present the energy management programme at the University of Pretoria is not fully effective. The fact that it is not on the lowest level (level 0) for any of the elements implies that it is on the right track. It does however require more work.

8.5 ACQUIRING FUNDING

Acquiring the funds with which to invest into the energy management programme are difficult to come by. Unfortunately very little can be done without the investment of capital for equipment and material.

Funding should be procured both from within and from outside the institution. If the top management truly supports the energy manager then they will make some dedicated funds available for the energy management programme. All avenues must be exploited and other sources of funding include:

- Loans from financial institutions
- Grants from government departments (including foreign aid)
- Obtaining sponsorship from commercial companies for individual projects
- Obtaining sponsorship from various segments within the institution (for example encouraging academic departments to sponsor and adopt a real-time energy meter)

The benefit of the energy management programme is that the returns are not only fairly easy to measure but that they are almost guaranteed. Following the selection process of chapter 6, on the Energy Load Management activity area, will ensure that only the feasible projects are implemented.

A process of separate metering and billing (as discussed in chapter 7) should be employed to proportionally recover the total electricity costs of the institution from the sectors responsible for this cost.

8.6 THE EMPLOYMENT OF SAVINGS

In chapter 5 the term "savings" was quantified. In the energy management context, a financial saving is not an income but rather a reduction in the financial accountability of the institution. In other words, achieving an energy saving simply means that you are giving out less money for energy each month. It is important that only the measurable savings be considered. The measurable savings are those savings that can be calculated from the difference between the financial accountability of energy consumption after a preventive action was taken and the financial accountability if no such action were taken.

Typically the gross savings that are realised from an energy management project will be required to firstly pay back the initial investment capital outlay of that project. Thereafter the net savings amount can be employed in a multitude of ways. Ideally these should be reinvested in the resources that were responsible for creating this saving and can be used:

- To extend and maintain the tools of the energy management programme such as the measurement and control system
- As the investment capital for new equipment and other material required for the programme
- To maintain and upgrade the existing electricity reticulation systems
- To make available bursaries for the extended and specialist training of the energy management staff in order for them to acquire the necessary knowledge to create more savings
- To make available performance bonuses for the energy manager and the members of the Energy Action Team

Naturally not all of the savings need to be utilised for some or other purpose and a percentage can be apportioned to the academic institution itself.

The process of reinvesting a portion of the savings back into the energy management programme is a very powerful method of acquiring investment capital. Unfortunately, if the first suggestion is used, the reinvestment capital will only become available once all of the initial capital outlay for the project has been recovered. Based on the case studies in sections 5.4, 5.5 and 5.6, this could be any length of time from a couple of months to 5 years. In some cases, such as staff incentive bonuses or student bursaries, it may be preferred to split the savings right from the beginning of the project and not to wait until all the capital has been repaid.

If this is indeed so, then the amount that must be earmarked for capital investment recovery should preferably be determined first and the rest apportioned according to set percentages. The crucial factor is determining the length of the period of consideration. In other words, when is a saving not a saving anymore? In all honesty only the single initial difference between the old and new benchmarks is quantified as the saving and this cannot reoccur because the new improved benchmark is now the value that has to be beaten in order to realise a new saving. Financially speaking, however, this would mean that no energy management projects would be viable and as a result a certain project period is considered in order to calculate the returns and payback periods. The longer the period of consideration, the smaller the contribution of the savings that must be made to the recovery of the initial investment capital and the larger the amount that can be distributed. This concept is illustrated in figure 8.2.

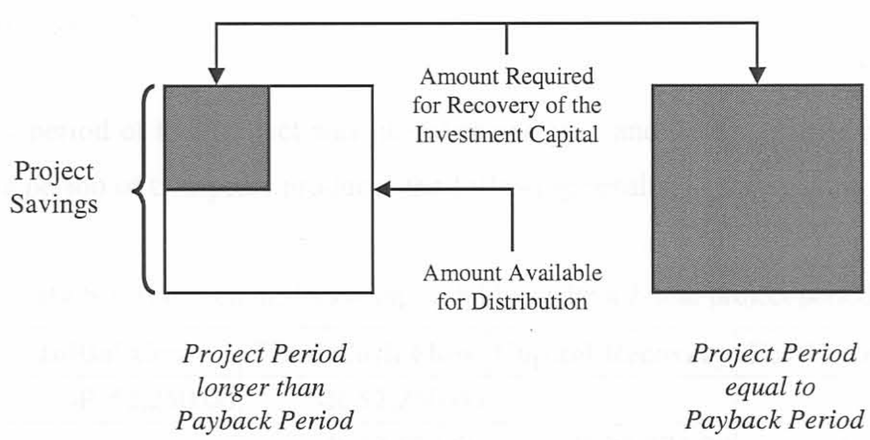

Figure 8.2: The Effect of Project Savings Period on the Employment of the Savings

Considering a project period shorter than or equal to the payback period is not logical if the distribution of the savings is being pursued, as there are no savings to distribute once the initial investment capital has been recovered.

The amount that must be repaid in order to recover the cost of the initial investment capital can be calculated with equation 3.7 where the project period is substituted for n and the MARR is substituted for i. Consider the power factor correction project in section 5.6. The initial investment amount was R 52,250.00 and the project was considered over 5 years. After 5 years, the amount of capital that must be repaid or allocated for the recovery of the initial investment capital is equal to R 92,082.35 based on a MARR of 12%. Spreading this over the 5-year project period will require an annual "reservation" of R 18,416.47. Applying this to the cost summary table of this project (table 5.12) produces the resultant cash flow presented in table 8.2.

Table 8.2: Resultant Cash Flow – Power Factor Correction Case Study

Year	Initial Cost	Total Cash Flow	Capital Recovery	For Distribution
0	-R 52,250.00	-R 52,250.00		
1		R 42,537.59	R 18,416.47	R 24,121.12
2		R 45,371.22	R 18,416.47	R 26,954.75
3		R 48,388.81	R 18,416.47	R 29,972.33
4		R 51,601.78	R 18,416.47	R 33,185.31
5		R 55,022.24	R 18,416.47	R 36,605.77

Using this method, the initial capital amount has been recovered (with interest based on the MARR of the institution) and the remaining R 150,839.29 can be distributed as required. Note that the running costs were automatically taken into account by considering the total cash flow from table 5.12.

The payback period of this project was just over one year and reducing the savings period to consider a period of two years produces the following results:

Table 8.3: Effect on the Resultant Cash Flow with a 2-year project period

Year	Initial Cost	Total Cash Flow	Capital Recovery	For Distribution
0	-R 52,250.00	-R 52,250.00		
1		R 42,537.59	R 32,771.20	R 9,766.39
2		R 45,371.22	R 32,771.20	R 12,600.02

In this case the amount of capital that must be repaid or allocated for the recovery of the initial investment capital is equal to R 65,542.40 and the remaining R 22,366.41 can be distributed as required. In this instance the entire initial investment amount has been recovered but less money is being earmarked for distribution and re-investment.

For projects that require no initial capital outlay, all the savings can be distributed. In this instance a savings period will need to be considered that is mutually beneficial to the institution and the energy management programme. It is recommend that a period not shorter than one year is considered in order to gain the full benefit, if any, from the variations in the electricity cost due to the factors included in section 4.3.2 such as seasonal swing.

The length of time that has been considered here must not be confused with the analysis period used to determine the viability of projects. The latter was discussed in chapter 5. Instead the period being used here is the length of time that the savings from a specific energy management project must be considered in order for them to be reinvested into the energy management programme. Irrespective of the length of the period, the institution will still recover all of the initial capital because all of the funds essentially remain within the institution and the longer the period of consideration, the greater the funds that are recovered at the MARR. As an alternative solution to determining the length of time for which the savings should be considered, a fixed amount of capital can be earmarked for reinvestment into the energy management programme and this paid off first. Thereafter all savings are not reinvested and no longer of significance.

8.7 CONCLUSION

This chapter has focussed on the evaluation of the energy management programme by firstly evaluating the activities of the energy strategy, evaluating the energy policy and finally evaluating the energy management programme in its entirety.

The evaluation process ensures that the energy management programme is complete because the correct feedback is obtained in order to ensure that the programme remains focussed on the electricity cost in an environment where constant pricing fluctuations are experienced and technical improvements are continually introduced.

The regular and complete evaluation of the energy management programme will help to ensure that the optimal use is made of financial and human resources and taking a critical look at the energy management projects on campus will provide invaluable experience leading to a dynamic and highly successful programme.

The next and final chapter will refer back to the objectives of this thesis and provide some recommendations regarding the management of electricity cost within an academic institution.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

"My sole collateral was my own faith in my ideas"
John H. Patterson

9.1 INTRODUCTION

In chapter 1, the main objective of this dissertation, along with a subset of specific objectives, was listed. In this chapter referral will be made to these objectives and the content of this dissertation in general. The value of this work will be discussed and the chapter will conclude with recommendations regarding areas of future work based on this dissertation.

9.2 CONCLUSIONS ON THE OBJECTIVES

The main objective of this study was to present a systematic and structured approach for the management of electricity cost within an academic institution.

A structured energy management programme utilises the financial and human resources available on campus better. Adopting a systematic approach helps to ensure that all energy management projects add their full effect to the energy management programme in general and each is implemented at the most beneficial time. The energy management programme has to fit into the other activities on campus and should compliment the output of these activities.

In chapter 1 the theory and history behind energy management was covered and a complete energy management programme was outlined as having to look at reducing the energy cost within the context of environmental harmony in order to enhance competitiveness and maximise profits. In other words, the goal of the energy management programme is to reduce the electricity cost per product (students and personnel) or business process (faculties, departments etc.) and not simply to reduce the electricity cost. The title of this dissertation is focussed on the management of the electricity cost and not the reduction of the electricity cost.

In this dissertation the complete energy management programme was given structure by firstly creating an energy policy on campus and then linking this to an energy strategy comprising four areas-of-activity, namely Energy Diagnosis, Energy Load Management, Energy Maintenance Management and Energy Awareness and Education. The four activity areas provide the energy management programme with its content and ensure that the often-neglected areas of maintenance, and awareness and education are not overlooked. The main objective was achieved by addressing a series of specific objectives.

- *Conclusion on the Energy Management Programme Model*

  In chapter 2 the goal of energy management programme was graphically represented through figure 2.1. This figure, when combined with the activities of an energy management programme in figure 2.2 provided the complete energy management programme presented in figure 2.5. This model is well structured with the energy strategy receiving direction from the energy policy and then providing feedback to the energy policy in order for it to remain focussed. This highlights the sentiments in chapter 1 regarding the ongoing activities of an energy management programme whereby energy is a continual issue on campus and not a temporary one. Energy deserves constant attention because it is a recurring business expense of sizeable proportions.

- *Conclusion on an Energy Policy*

  An energy policy was introduced in section 2.3 that comprises three parts, namely a declaration of commitment from the top management of the institution, a mission statement that defines the focus of the programme and finally a set of programme goals to be worked towards. The energy policy determines the destination of the energy management programme.

- *Conclusion on an Energy Strategy*

  An energy strategy was introduced in section 2.4 as being made up of the four areas-of-activity. The energy strategy determines the route that must be taken in order to arrive at the destination that was focussed on in the energy policy. In other words, the energy strategy is the plan that deals directly with the activities and projects of the energy management programme. The activities of the energy management programme are grouped under 4 areas-of-activity within the energy strategy.

- *Conclusion on the Areas-of-Activity*

  The interaction between the areas-of-activity is covered in section 2.6. By defining specific activity areas, all the projects and activities in the energy management programme are systematically implemented ensuring the optimal use of financial and human resources as well as ensuring that there is no loss of information. This is achieved through increased communication levels and meticulous attention to documentation.

- *Conclusion on the Interaction between an Energy Policy and Strategy*
  The interaction between the energy strategy and policy is covered in section 2.5. This interaction is usually misunderstood and the terms "policy" and "strategy" are used fairly loosely without understanding their correct place and contribution towards the energy management programme. This dissertation has made the link very understandable and this will help to clear all misconceptions regarding these two vital elements of the energy management programme.

- *Conclusion on the Key Energy Management Tools and Concepts*
  Many of the common energy management terms have been explained in chapter 3 as well as the areas of electricity tariffs and financial analysis tools. Other items that have been addressed include energy auditing (chapter 4), maintenance management (chapter 6) and energy awareness and education (chapter 7). All of these terms and concepts have been put into their correct place within the energy management programme which makes it easier to understand them because the reader can now see where they should be used and how they contribute to the overall programme structure.

- *Conclusion on Project Selection and Prioritisation Methods*
  A method to select between alternatives for the same project was presented in section 5.3 and this applied to the case studies of chapter 5. Section 5.7 presented a method of prioritising the energy management projects based on their Net Present Value (NPV), Internal Rate of Return (IRR) and capital investment requirements. This ensures that the best combination of projects is implemented with respect to the amount of capital that is made available for investment by the institution.

- *Conclusion regarding Project Examples*
  Key projects as examples of both the equipment and people components of the energy management programme were included in the case studies in chapter 5 and 7 respectively. Chapter 7 and the appendix provide some examples of energy awareness material and the projects where this material was used. Chapter 5

included case studies involving the electrical equipment and focus was made on projects involving direct load control, the upgrading of existing equipment and installation of new equipment. Other than these projects, many case studies and experiences from the University of Pretoria have been included to emphasize certain sections in all of the chapters. The projects and activities that have been included as examples have been selected to provide emphasis to the theories.

- *Conclusion on the Methods of Programme Evaluation*
  Chapter 8 was dedicated towards methods of evaluating the energy management programme. The evaluation process starts at individual project level and then expands this to the energy strategy and eventually to the energy policy. The evaluation process ensures that the energy management programme remains focussed by addressing the topical issues. The evaluation process also strengthens the abilities of the energy management team by expanding their experience.

Addressing all of the specific objectives has ensured that all of the material necessary to meet the main objective has been covered. This dissertation has essentially taken the enigmatic process of energy management and simply provided a logical and systematic structure to this process in order for it to be applied to academic institutions. This does not mean that the existing energy management programmes of institutions that do not follow the structure included here are failures. On the contrary, these institutions should be praised for taking the initiative in addressing their electricity costs. However, adapting their present programmes to adopt this systematic structure will ensure that their programmes produce greater results through addressing all the relevant energy issues on campus. As a final conclusion it must be said that, with the aid of this dissertation, any academic institution is capable of initiating and running an energy management programme and all institutions should be addressing their electricity costs. The case studies in this dissertation have proved that the benefits outstrip the pitfalls.

9.3 RECOMMENDATIONS AND FUTURE WORK

This section includes both recommendations regarding the management of electricity cost within an academic institution as well as defining the scope of future work based on this material.

9.3.1 Recommendations Regarding Energy Management on Campus

- *Recommendations on Starting an Energy Management Programme on Campus*

  The starting point when looking at energy management on campus must be to determine the extent of the existing programme. If no programme is presently running then the facilities department should initiate the process by setting up an energy co-ordination committee and selecting a manager within the facilities department of the institution who should be tasked with the duties of the energy manager. Naturally a dedicated post is preferable but a joint post will suffice as an interim measure. The line functions and reporting structure should be determined and formalised. The top management of the institution must take ownership for the establishment and continual support of the energy management programme.

  The next step is to draw up a plan for the energy management programme in the form of an energy policy and strategy. During this planning phase a budget should be drawn up with which to commence the energy management activities. Typically at this level the energy manager will require some funds with which to undertake the Energy Diagnosis activity area as explained in chapter 4. However, much of the diagnosis activity can be performed without requiring equipment for electrical load measurement. In other words, the energy manager can commence his or her tasks while waiting for some funds. If no funds are made available, the energy manager can attempt to arrange the loan of measurement equipment from other institutions or commercial companies. All that is required is the first breakthrough project that will not only produce savings but gain credibility for the programme. The following areas should be looked at:

  - Frequent verification of the electricity costs and negotiating for an improvement in the tariff structure and rates. This requires little effort and will help to create a working relationship with the electricity supplier. Included here is the installation of power factor correction (see section 5.6) or obtaining the benefit of diversity (section 3.2.6).
  - If the campus constitutes mainly commercial buildings, then the heating, ventilation and air-conditioning (HVAC) equipment should be looked at first. This equipment not only uses a large amount of power but adversely affects the power factor. Thereafter office equipment such as personal computers, printers, facsimile machines and photocopiers should be targeted by ensuring

that their energy efficient (or low power) settings have been set and by encouraging the users to pay attention to the way in which they use these machines. This was also covered in the case studies in chapter 7. Next the lighting should be targeted and more efficient lamps should be investigated (as in section 5.4). Finally, the direct load control of the hot water equipment should also be considered.

- If there are student residential hostels on campus then the water heating systems should be targeted first followed by HVAC equipment and finally the multitude of appliances that the students keep in their dormitories and rooms. If hot water is going to be addressed in the residences and hostels, then similar equipment in the commercial office buildings on campus may as well be addressed in the same project.

At the University of Pretoria the hot water systems in the hostels were targeted above the HVAC equipment because the energy management staff were familiar with this type of equipment. It is planned to obtain assistance from engineering specialists on campus to target the large HVAC load next.

- *Recommendation on the Adaptation of an existing Energy Management Programme*
  If an energy management programme is already in operation on campus, it can easily be ammended in order to follow the systematic structure presented in this dissertation. The methods and tools that are included here are very novel and they will help to make these established programmes more successful.

In section 1.6 it was mentioned that the institutions with energy management programmes in South Africa fall into two categories. Firstly, those that use energy management on campus to both reinforce their energy management teaching as well as reducing costs and secondly, those that pursue energy management purely as a management function aimed at cost management.

- *Recommendation for Institutions focused on Electricity Cost Management only*
  This dissertation has included all the material necessary to create an energy management programme orientated towards the management of electricity cost. Although some historical and background information has been included, this material is important as it helps to place an energy management programme within

an academic institution in the context of energy management as an activity previously focussed on the industrial, commercial and residential sectors.

- *Recommendation for Institutions focused on Energy Management Research and Lecturing as well as Electricity Cost Management*
  All the information in this dissertation is relevant but perhaps more benefit can be extracted from the energy management programme model presented in chapter 2. This model will help students to understand the purpose and function of an energy policy and strategy. The energy management tools in chapter 3 will also benefit students in energy management as well as the case studies from other institutions presented in chapter 1.

- *Recommendation regarding the Energy Manager*
  Finally it is recommended that a person with all the necessary management traits be selected for the position of energy manager. Naturally a good knowledge of electrical energy (and other energy sources) is preferred. The energy manager must have the necessary authority to take action in the best interest of the programme and under no circumstances should the leadership be shared. Multiple authority will not allow for the energy manager to take ownership of the task of reducing the electricity cost per product or business process and this will lead to the failure of the programme. All elements of management will be required from budgeting through to marketing and this should be borne in mind during the selection process.

9.3.2 Future Work

Ideally the energy manager at an academic institution should have written this dissertation. However, all the necessary experiences of commencing with an energy management programme have been acquired and therefor solid advice in this regard can be supplied.

If this dissertation had to be rewritten based on existing knowledge and experience, nothing would be left out. The length of this dissertation may be longer than normal but none of the information should be sacrificed as it will all be of use to an energy manager at an academic institution. The purpose of the dissertation is to provide a structured and systematic approach. Naturally there are many examples of energy management projects that have not been included. The reason for this is that those examples and case studies that have been included have been done so only to emphasize the theories that have been presented. This dissertation is not a collection of "do-it-yourself" style energy management projects.

This dissertation has built the structured skeleton for the management of electricity cost within an academic institution. There exists a great deal of scope for future work by students working towards lower degrees in the sense of specific energy management projects. In other words the solutions to specific energy management projects should be investigated and these, with the aid of this dissertation, should be used in the energy management programme as and when the time is suitable. Students working towards equivalent or higher degrees can look at expanding and adapting the energy management programme methodology presented in this dissertation to national and global levels.

One area that should be expanded upon is a method for determining the ideal ratio between the amount of capital that is made available for investment into energy management projects and the return on those projects. This may not necessarily fall within the scope of electrical engineering and could possibly be considered under engineering management. Finding the ideal investment ratio will assist the energy manager in procuring the funding while ensuring that the institution is not badly financially leveraged.

In closing it must be said that any academic institution is capable of addressing their electricity costs on campus irrespective of their geographical or political climate. Occasionally consultants will be appointed to address the management of the facilities on campus and this will include the management of the electricity cost. In this instance the methodology presented in this dissertation is still applicable irrespective of whoever is tasked with the responsibility of managing the energy management programme. Academic institutions, through their energy management programmes, can have a significant impact on the social and financial well being of the population simply because they are in the position to provide the leaders of tomorrow with energy management skills today. In this way an energy efficient, environmentally focused population is created.

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APPENDIX A: MONTHLY ENERGYWISE REPORT

University of Pretoria

Energywise Report
July 1999

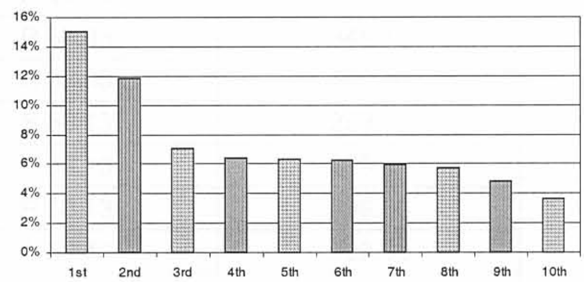
The EMSup says that during this month on Main Campus and Lynnwood Campus...

The Maximum Demand was	10 269 kVA
The Total Energy Consumed was	4 779 631 kWh

THE TOP 10 CONTRIBUTORS TO THE COST OF ELECTRICITY WERE.....

Rating	Group	Cost Contribution
1st	Women's Hostels	R 132,197.73
2nd	Men's Hostels	R 104,349.18
3rd	Merensky Library	R 62,518.89
4th	Chancellor's Building	R 56,113.54
5th	Human Sciences Building	R 55,443.18
6th	Nature Sciences I Building	R 55,175.23
7th	Engineering Tower	R 52,261.19
8th	Education and Law Building	R 50,692.32
9th	Agricultural Sciences Building	R 42,756.05
10th	Heavy Machine Laboratory	R 32,367.62

% Contribution to the overall Electricity Account



The Pretoria City Council says that during this month...

ON MAIN CAMPUS

The Maximum Demand was	8 120 kVA
The Total Energy Consumed was	3 690 566 kWh

ON LYNNWOOD CAMPUS

The Maximum Demand was	2 770 kVA
The Total Energy Consumed was	1 088 850 kWh

THE COMBINED ACCOUNT OF MAIN CAMPUS AND LYNNWOOD CAMPUS

The Maximum Demand was	10 270 kVA	@ R44.95/kVA = R 461,636.50
The Total Energy Consumed was	4 779 416 kWh	@ 8.76 c/kWh = R 418,676.84
		R 880,313.34

THE SAVINGS DUE TO DIVERSITY

620 kVA @ R44.95/kVA = R 27,869.00

THIS REPORT WAS PREPARED BY THE CENTRE FOR NEW ELECTRICITY STUDIES

.....home of the EMSup System

VISIT OUR WEBSITE FOR MORE INFORMATION

http://snesweb.ee.up.ac.za

APPENDIX B: MONTHLY HOSTELWISE REPORT

University of Pretoria

Hostelwise Report
July 1999

The Separate Hostel benchmarks for this month are...

Hostel	Cost per Student per Month (R/Student/Month)	Energy per Student per Month (kWh/Student/Month)
Katjiepiering	R 61.73	357.31
Maroela	R 61.73	357.31
Mopanie	R 61.73	357.31
Kollege	R 58.16	347.13
Taaibos	R 58.16	347.13
Boekenhout	R 63.03	345.10
Olienhout	R 63.03	345.10
Klaradyn	R 58.13	299.65
Jasmyn	R 58.13	299.65
Erika	R 58.13	299.65
Asterhof	R 58.13	299.65
Madelief	R 58.13	299.65
Nerina	R 58.13	299.65
Magrietjie	R 58.13	299.65
Tuksdorp	R 58.13	299.65

These benchmarks are based on the energy consumption and contribution to the system maximum demand for each hostel at sub-station level (hence the duplicate values in the table above). The security lighting and kitchens are also taken into account in the calculation of these benchmarks and the actual occupancy for the month is used.

The Average Hostel benchmarks for this month are...

Tukkies Hostel Average	R 59.72	323.07

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.....home of the EMSup System

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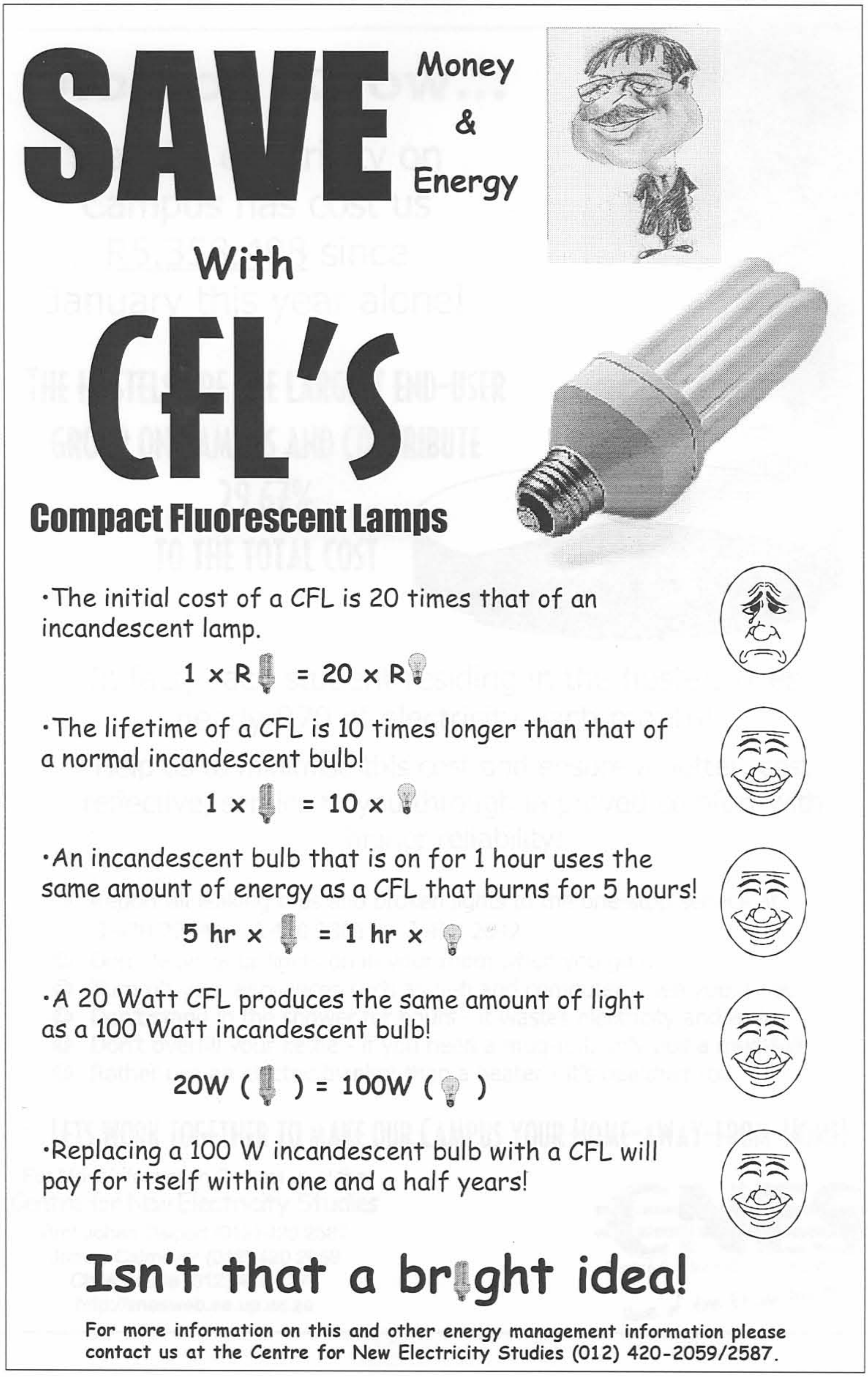
APPENDIX C: COMPACT FLUORESCENT LAMP POSTER

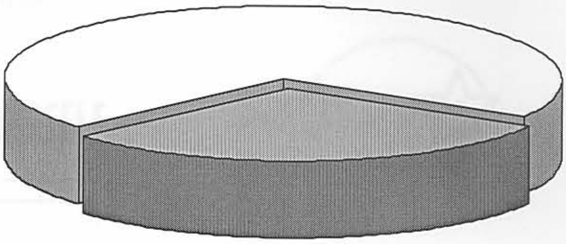


APPENDIX D: HOSTEL INFORMATION POSTER

DID YOU KNOW...

that the electricity on Campus has cost us R5,358,498 since January this year alone!

THE HOSTELS ARE THE LARGEST END-USER GROUP ON CAMPUS AND CONTRIBUTE 29.67% TO THE TOTAL COST



In fact, each student residing in the hostels uses nearly R70 of electricity each month!

Help us to minimise this cost and ensure a better, cost reflective, service to you through improved comfort with higher reliability!

- ☺ Report all leaking taps and broken lights to the one-stop service at ✆420 2244 or ✆420 2301 or ✆420 2042
- ☺ Don't leave your lights on in your room when you go out
- ☺ Turn off your appliances such as hi-fi and computer when you go out
- ☺ Don't stand in the shower for hours - it wastes electricity and water
- ☺ Don't overfill your kettle - if you need a mug-full, only boil a mug-full
- ☺ Rather use an electric blanket than a heater - it's healthier too

LETS WORK TOGETHER TO MAKE OUR CAMPUS YOUR HOME-AWAY-FROM-HOME!

For More Information Contact us at the
Centre for New Electricity Studies
Prof Johan Delport (012) 420 2587
James Calmeyer (012) 420 2059
Chris Fourie (012) 420 2274
http://snesweb.ee.up.ac.za

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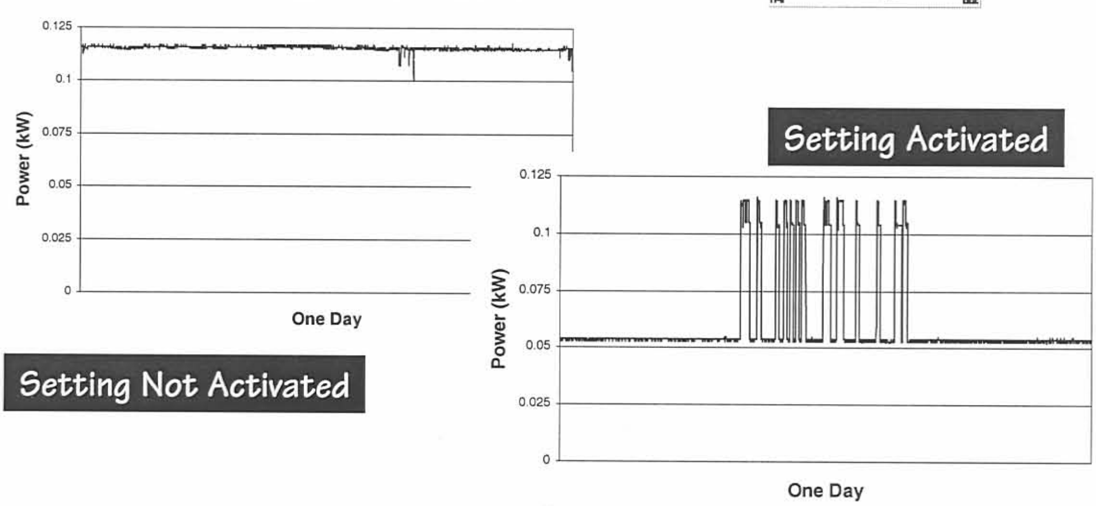
APPENDIX E: COMPUTER EFFICIENCY POSTER

DID YOU KNOW...

that activating the "low power standby" setting on your computer could reduce the energy consumption by

49%

SEE THE RESULTS FOR YOURSELF...



In this specific case the electricity cost for the month was reduced by nearly R4.00. This may not seem much... but when multiplied by the number of computers on Campus the saving potential is awesome!

LETS WORK TOGETHER TO MAKE OUR CAMPUS ENERGY EFFICIENT!

For More Information Contact us at the
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