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.

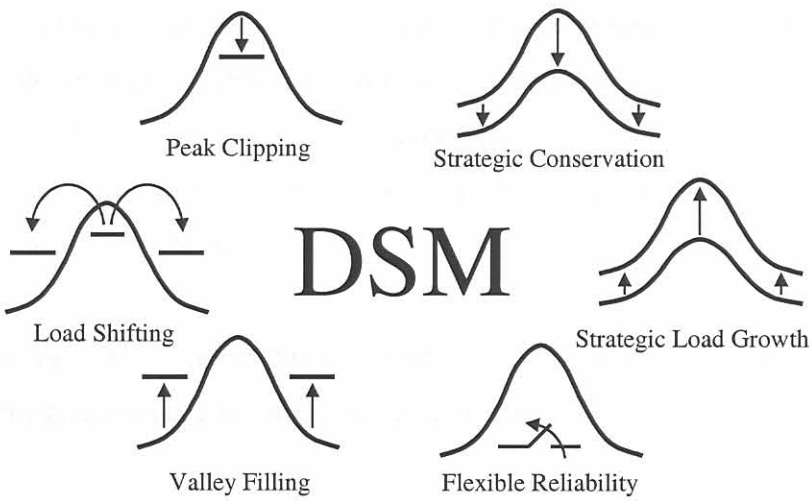

Figure 1.1: Demand-Side Management Activities

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.

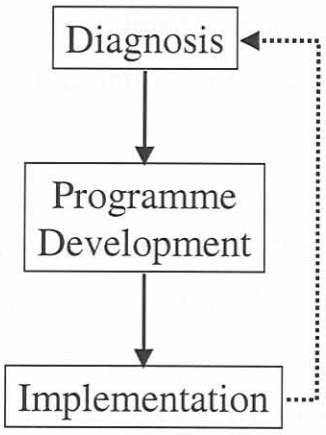

Figure 1.2: Structure of the Energy Management Workbook

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.

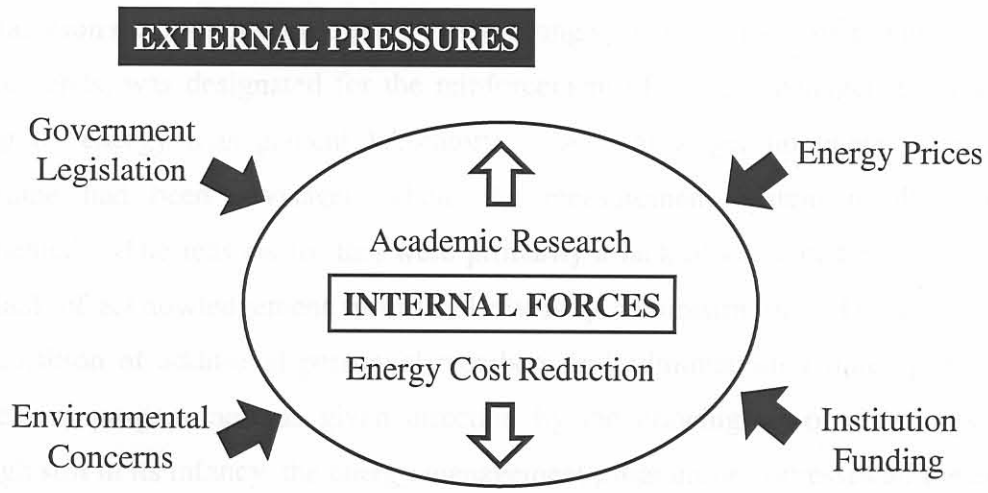

Figure 1.3: Energy Management Pressures and Forces acting on an Academic Institution

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.