2. ENERGY MANAGEMENT AND TELKOM

2.1 INTRODUCTION

It was mentioned that Telkom has no energy management programme in place and thus no formal energy policy implemented by top-management. Without such a policy there can be no responsible management of energy resources and as such, no control measures ensuring that the energy is being used to its maximum potential. This has been the major contributing factor to the high level of inefficiency in the organization's energy utilisation.

Calmeyer [31,p. 16] suggests that the goal of an energy management programme is to reduce energy costs within the context of environmental harmony so as to enhance competitiveness and maximise profits. It is thus clear that with the introduction of such a programme, Telkom will be closer to streamlining the organization and so be capable of competing with other international telecommunication companies destined to enter the South African market.

The chapter is thus focussed on presenting an energy management programme in a telecommunications environment, specifically for Telkom SA. It makes sense to first present a structured methodology for the implementation of energy management before techniques for optimising the energy utilisation are discussed (as those given in chapter 4 and 5). Following this format enables a holistic approach to be taken to optimise the available energy resources.

The chapter begins by presenting important energy management tools that are used in the context of the study. It continues by explaining what an energy management programme is and also the elements needed to implement it. Such a programme is then developed for Telkom that will provide the necessary means for ensuring the efficient usage of the energy resources. As part of the quantification process and hence motivation for the remainder of the study, the chapter ends off by providing a useful tool for establishing whether telephone exchanges (and installed equipment) are operating in the most efficient manner.

2.2   ENERGY MANAGEMENT TOOLBOX

It is the purpose of this section to provide the necessary energy management tools needed for the remainder of the study by explaining billing elements, tariff structures and DSM activities. It is intended to equip the reader with the necessary background needed to understand the applicability of the study. The *billing elements* will provide the necessary tools needed for analysing the electrical performance; *tariff structures* provide the means for analysing the costs associated with energy utilisation, and *DSM activities* are those tools that are used to optimise the energy utilisation. The meaning of each element will become clear as it is used in context of the study.

2.2.1   Billing Elements

Load Profile: The consumption graphically plotted on a time versus power axis (usually kW or kVA) and shows the profile (shape) of the power consumed during a specified period (typically a day, week or month) is known as a load profile. Two essential elements can be obtained from the profile (1) the maximum amount of power consumed (termed *maximum demand*) for the period under consideration and (2) the total amount of energy consumed during the period [31, p. 30]. As an example, consider figure 2.1 showing a typical load profile of the University of Pretoria for a period of one day [34].
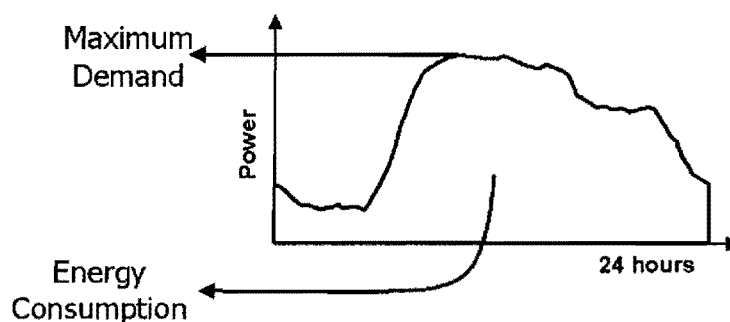

Figure 2.1   Typical load profile of the University of Pretoria

Load Factor: Is the ratio between the actual energy consumed and the energy that could have been consumed had the demand remained at the maximum demand for the particular period [32, p. 13] i.e.

$$L.F_{for\ period} = \frac{Actual\ kWh\ Consumed_{in\ period}}{Maximum\ Demand_{in\ period} \times Number\ of\ Hours_{in\ period}} \qquad [2.1]$$

The factor provides an indication as to how cost effectively the energy is being utilised i.e. the greater the load factor the less it costs per unit of energy [c/kWh] if a two-part tariff is applied (see next paragraph).

Equivalent Cost Per Unit (c/kWh): This provides the average cost of using energy. It is defined as the ratio between the total costs incurred utilising electrical energy (as a result of a particular tariff structure) and the total energy [kWh] used i.e.

$$Average\ Cost = \frac{Total\ Electrical\ Cost}{Total\ Energy\ Consumed} \qquad [2.2]$$

2.2.2 Tariff Structures

Two-Part Tariff: Customers are charged for the maximum demand (MD) and the energy used during a billing period [35, p. 32] i.e. they are billed for the peak rate of consumption [kW or kVA] for that particular month as well as the total energy consumed [kWh]. There is a capacity charge [Rand/kVA] and a constant consumption charge [c/kWh] i.e.

$$R_{Tot} = R_{MD} + R_{Energy} \qquad [2.3]$$

The MD charge [R/kVA] has been included to provide incentive to customers to lower peak consumption. The monetary benefit induced by this motive can be analysed using the load factor concept explained previously – a low load factor implies that the load profile has a large peak (MD) as compared to the rest of the profile. It is this peak that dictates the R/kVA charge in the tariff. This charge has a high prices attached to it, and as a result contributes a large portion to the total electricity bill causing a high average cost per unit of energy [c/kWh]. This provides a powerful incentive to customer to increase their load factors and hence decrease the average c/kWh.

Time Of Use (TOU) Tariff: This tariff applies different energy consumption charges during different periods of the day, and seasons of the year [31, p. 38]. The energy charges during each interval closely tracks the cost to supply the energy (from the utility side). There are usually three billing periods in a day: peak, off-peak and standard. TOU tariffs also usually incorporate demand charges for MD. As with the consumption charge, the demand rates are also differential with time.

2.2.3 DSM Activities

According to Gellings and Chamberlin [36], DSM are those activities which involve action on the demand- or customer-side of the electricity meter resulting in a reconfiguration and/or change in magnitude of the load inducing energy expenditure savings, such as:

Peak Clipping: This is the process of reducing the system peak load (MD) and has most applicability when considering tariff charges for maximum demand.

Valley Filling: Entails building load during off-peak periods so as to increase the system load factor and thus decrease average cost of energy [c/kWh].

Load Shifting: Involves shifting load from peak to off-peak and thus has major monetary benefits when use in conjunction with tariffs structures.
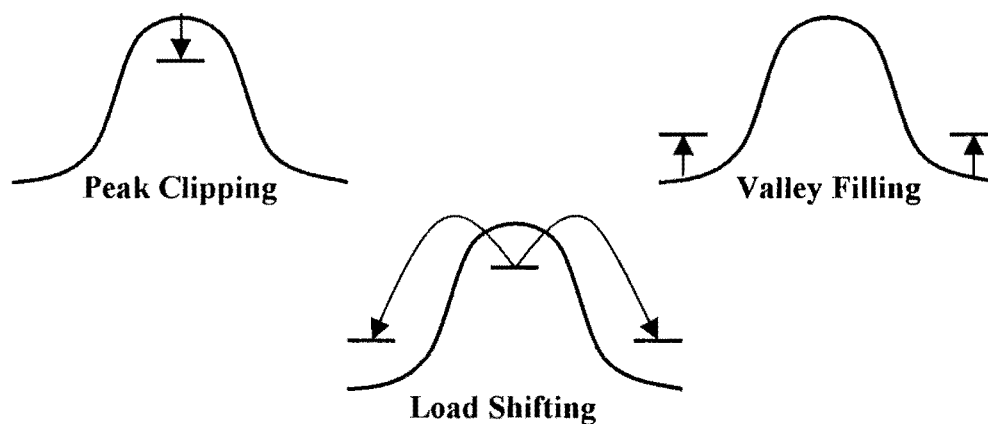

Figure 2.2   DSM activities

2.3   THE ENERGY MANAGEMENT PROGRAM

Delport [2, p. 2] suggests that the basic philosophy followed in generating an Energy Management Programme for an organization consists of 4 closely linked building blocks; they are (1) Energy Policy, (2) Energy Policy Strategy, (3) Energy Audit Policy, and (4) Energy Audit Strategy. The interaction of these with each other is depicted in figure 2.3 below.
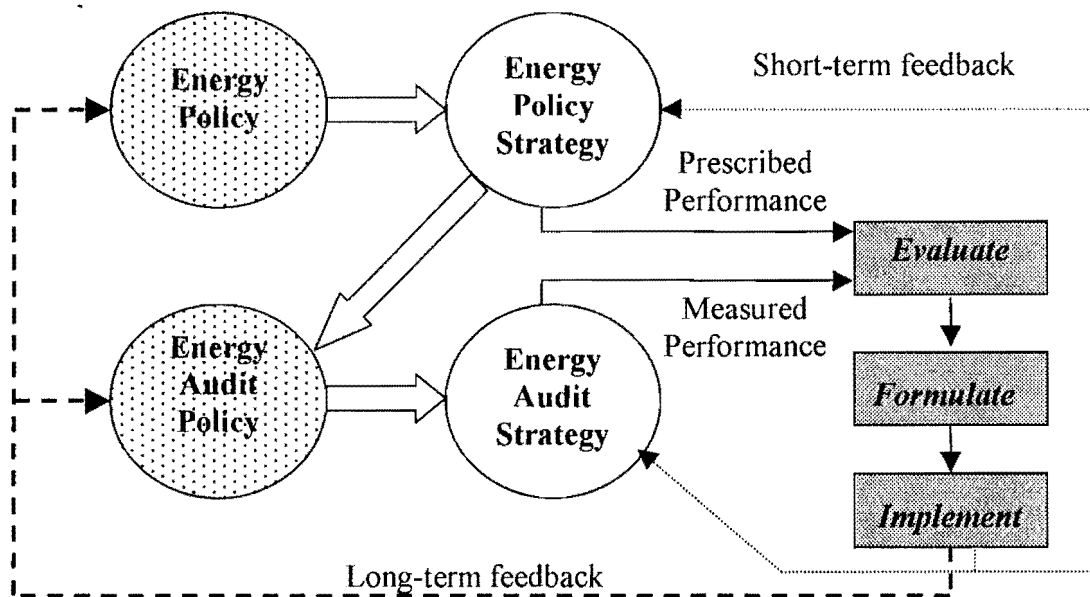

Figure 2.3   Interaction of the four elements needed for an energy management program

According to the Oxford Advanced Learners Dictionary [38] the following definitions apply:

- ❑ **Policy**:   "A plan of action, statement of ideals, etc proposed or adopted by a government, political party, or business".

- ❑ **Strategy**: "A plan designed for a particular purpose; the process of planning or carrying out a plan in a skilful way".

2.3.1   The Energy Policy

From the definition above, an energy policy is the starting point for any government, party or person wishing to address the responsible management of their energy resources. It is

the formal statement through which the course that is being adopted with respect to energy is defined. The policy provides vision, and directs the energy management programme in the right direction. Calmeyer [31, p. 18] states that "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". He extends upon this by mentioning that there are three essential components needed to completely formulate an energy policy:

- **Declaration of commitment**: A written declaration from top management ensuring that the programme of managing energy will be sustained and has their full co-operation.
- **Mission Statement**: extends on the declaration by defining the focus of the energy management program.
- **Program Goals**: determine the specific objectives in order to achieve the mission statement.

Examples of energy policies are presented in addendum A which have been drawn up by:
1. the Centre for New Electricity Studies (CNES) for the University of Pretoria [39, pp. 1 to 4].
2. the American telecommunications provider, AT&T [40].

2.3.2 The Energy Policy Strategy

It is however not enough to merely generate yet another policy for an organization without formulating a method of implementing or achieving the objectives. An energy policy strategy, or a way in which the policy can be achieved needs to be generated [21]. According to Delport [2,p. 2] a strategy is dynamic in the sense that it is regularly adapted and updated in synergy with changes in the energy management of organizations. As such there needs to be short-term and long-term feedback.

Calmeyer [31,p. 21] suggests that there are four "areas of activities" that need to be followed in a systematic way so as to optimise the energy utilisation of available resources.

These, and the interrelationships are depicted in figure 2.4 and make up the energy policy strategy.
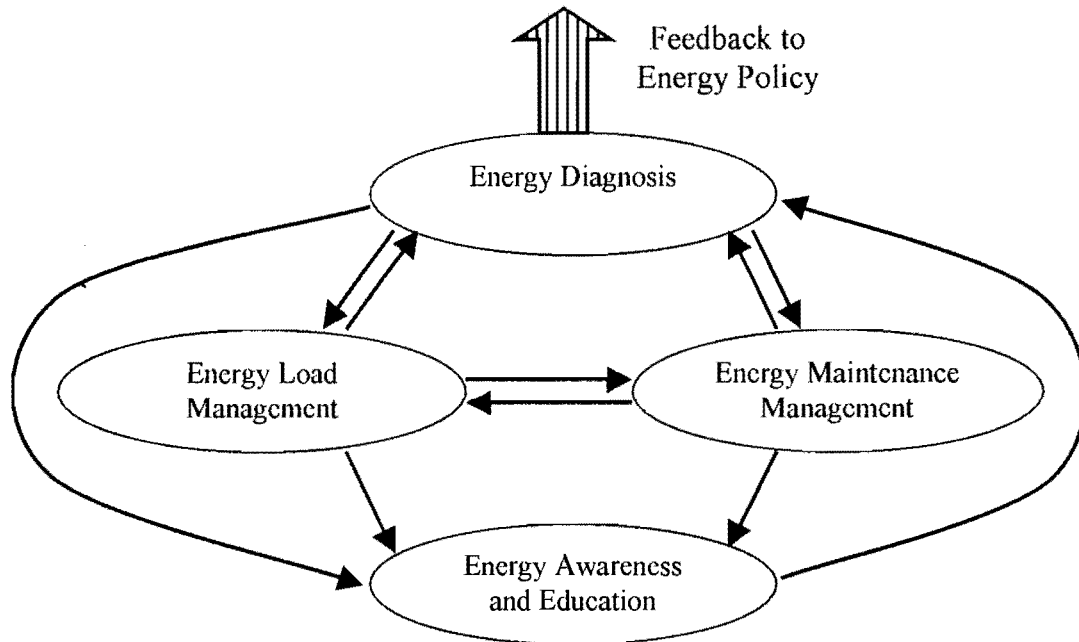

Figure 2.4   The interaction between the "areas of activities" for an energy policy strategy

- **Energy diagnosis**: Acquisition and analysis of the energy utilisation through the activities of auditing, load metering and measurement.

- **Energy load management**: This focuses on optimising the energy utilisation so as to reduce the energy cost per product or process through load control. Delport [32, p. 15 & 16] mentions that this can be done with a number of Demand-Side Management activities as those discussed in chapter 2.2.3.

- **Energy maintenance management**: This aims to improve system efficiency and ensure sustainability through proper maintenance of system components.

- **Energy awareness and education**: It is essential to promote energy awareness to all employees. Without the co-operation of these people the management of energy cannot be done in an effective manner.

See energy policy strategy examples presented in Addendum A.

2.4   ENERGY MANAGEMENT PROGRAMME FOR TELKOM

Using the energy policy examples of the University of Pretoria and AT&T presented in Addendum A, a policy for Telkom has been constructed. The policy of the University is used as a template, whereas the information provided in AT&T's policy is used for its content.

It is important to mention that the energy policy presented on the following pages is not an official policy of Telkom, but is rather a recommendation for the further development of energy management in the company. As such it provides the basis for the remainder of the study and presents a methodology for the implementation of energy management.

AN ENERGY POLICY FOR TELKOM

Mission Statement

Manage the energy resources available to Telkom with the purpose of optimising operation and hence provide the best possible services to its customers.

Primary Objectives

Manage the supply and demand of the energy resources available to the organization. Ensure the optimal usage of these resources so as to reduce the energy expenditure through promotion and energy awareness to all users. An accurate account of energy consumption is to be made with the purpose of reducing energy expenditure, while still enabling customers to telecommunicate when, where and how they want to.

Specific Objectives

Manage the supply and demand of energy resources

This involves the controlling and manipulation of all the electrical and/or energy sources, resources and consumables available to the organization through processes such as Demand-Side Management. In so doing optimise the energy consumption with the objective of minimising energy expenditure and thus maximise profits. Areas of primary importance are building design, standby equipment, HVAC, rectifiers and tariff selection, all of which have a significant effect on the energy utilisation.

Energy measurement

This involves the complete energy auditing of all energy sources, resources and consumables available to the organization. This includes all major energy consuming equipment installed and implemented in buildings and exchanges; and involves the buildings and exchanges themselves. A complete, and accurate account of all energy usage is to be made according to an audit plan.

Setting energy norms and benchmarking

This involves the setting of applicable norms and standards according to measurable benchmarks. Through the use of these norms, management of all major energy sources,

resources and consumables can be carried out in an optimal manner. The norms are to be set up in such a way as to provide guidance to present and future energy-users, technical personnel and would-be contractors.

Promote energy awareness to all energy users

This is the transfer of information to all energy-users, technical personnel and would be contractors in the organization, in which a message of conserving and saving energy is conveyed and carried out. A direct consequence of energy awareness is the promotion of efficient usage of energy by all users.

ENERGY POLICY STRATEGY

Manage the Supply and Demand of Available Energy Resources

Long-term Strategies

- *Have the capabilities of controlling and manipulating the energy consumption of the buildings and exchanges through automated load control. Although the organization is a long way away from this it is important to include it here to present an optimal and aggressive energy management strategy.*
- *Set up clear and defined management procedures for the controlling and manipulation of energy sources, resources and consumables within the organization.*
- *Draw up strict procedures for the purchasing and implementation of energy consuming equipment.*
- *Review existing energy end-users and assess energy efficiency performances.*

Short-term Strategies

- *Appoint a dedicated Energy Manager to assess the energy "needs" and implement viable long-term solutions for the organization as a whole.*
- *Compile and implement an audit plan to investigate the supply and demand of electrical energy within buildings and exchanges.*
- *Investigate currently employed technologies such as HVAC, lighting and telecommunications equipment for inefficiencies.*
- *Investigate and implement alternative tariff structures to suit individual buildings and exchanges.*

□ *Also investigate alternative technologies, and set guidelines and specifications (i.e. norms and benchmarks) for the purchasing of energy consuming equipment.*

Energy Measurement

Long-term Strategies

□ *Install dedicated measuring equipment at all buildings and exchanges so that progressive and continual monitoring of the energy load can be conducted.*

□ *Have a central control centre capable of controlling and monitoring the energy consumption of all buildings and exchanges within the organization. This concept is linked to the automated load control, and is added to present an aggressive and ambitious view of the future.*

Short-term Strategies

□ *Develop an audit policy that will enable and authorise the complete load measurement of buildings and exchanges within the organization.*

□ *Conduct an energy audit to assess the current state of energy utilisation.*

□ *Install automated measuring equipment to measure the various energy end-users, such as HVAC, lighting and telecommunications equipment.*

□ *Analyse acquired data to draw up conclusions and recommendations.*

Set Energy Norms and Benchmarks

Long-term Strategies

□ *Implement managerial procedures for the utilisation and implementation of energy norms and benchmarks.*

□ *Formulate benchmarks for buildings and exchanges, and installed equipment.*

□ *Revise norms and benchmarks continually (feedback) to avoid stagnation.*

Short-term Strategies

□ *Set up energy norms and standards compatible for all buildings and exchanges with reference to building dimension, HVAC, lighting and telecommunication equipment.*

Promote Energy Awareness to All Users

Long-term Strategies

- *Have a workforce that is energy efficient.*
- *Have clear and defined communication channels for feedback of energy users.*

Short-term Strategies

- *Educate management on the efficient use of energy.*
- *Educate employees on how to use energy efficiently and the benefits thereof.*
- *Set up a working procedure that describes the exact process for employees to provide feedback to management.*

2.5   AN ENERGY ACCOUNT OF TELKOM

Paragraph 2.4 provided a methodology for the implementation of energy management in the form of an energy policy. Included were the specific objectives needed to define the outcomes of the programme, and incorporated in the objectives was the complete energy measurement (auditing) of all energy sources, resources and consumables. By providing a detailed diagnosis of the energy utilisation, a reference point is established from which the remainder of the study can be conducted.

As such, extensive energy audits were conducted at various exchanges so that a comprehensive analysis of the energy utilisation could be compiled. The measurements were conducted on exchanges selected on the basis of their respective functions. That is, from the walk audits it was observed that exchanges could be classified into two broad categories: *manned* and *unmanned*. It was noticed that while some buildings were exclusively used for the purpose of telecommunicating, others were also used for office work and thus contained office space. This prompted an investigation into the effects thereof.

2.5.1   Electrical Layout of a Typical Exchange

Figure 1.1 illustrated the energy requirements for a typical telecommunication site; figure 2.5 on the next page on the other hand, presents a simplified one-line diagram of the electrical layout of a typical exchange. This provides a clear understanding of the energy requirements and interconnections, and as such forms the basis for the implementation of energy management.

An 11kV, 3-phase line supplied by the utility forms the primary energy source. This is then stepped down to the standard 380V by a transformer, usually the property of Telkom. In the event of a power failure or interruption, a backup diesel generator is on stand-by. In some cases the entire exchange can be supplied by the backup, while in others only the vital equipment such as the rectifiers, telecommunication equipment, HVAC, and control systems are connected.
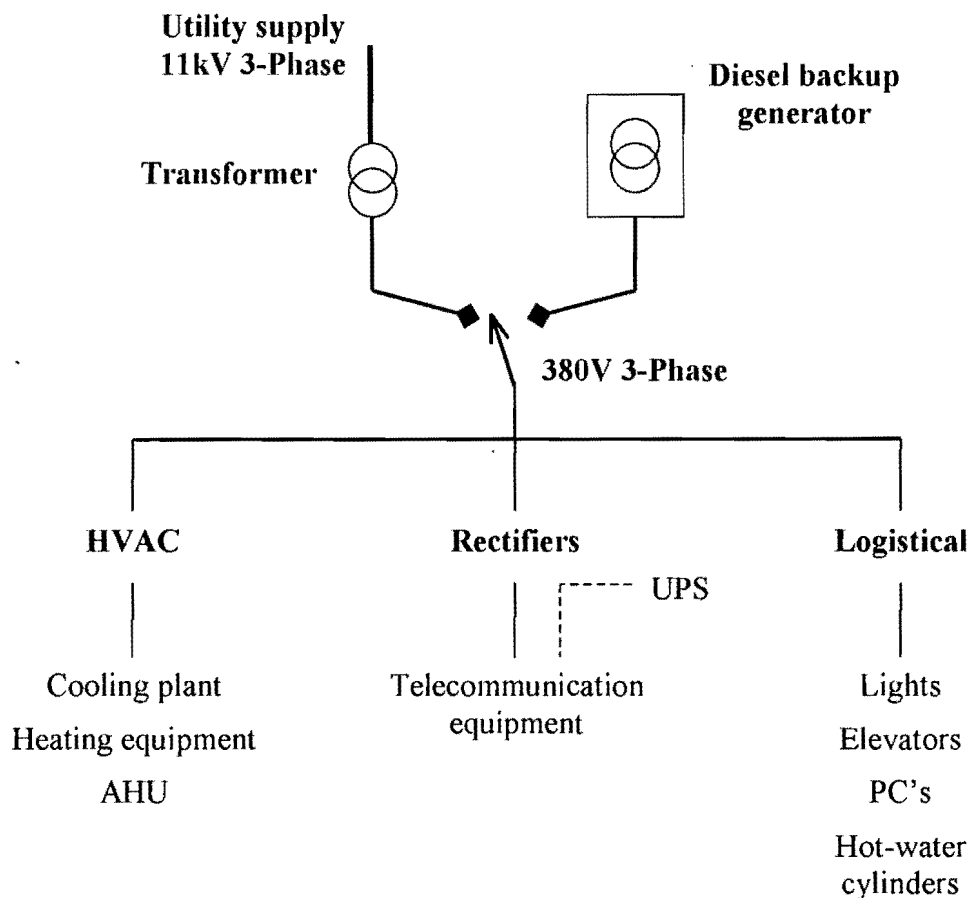
Figure 2.5   One-line diagram of a typical telecommunications exchange

A 380V, 3-phase bus supplies the necessary energy to the equipment (end-users), which can be divided into two broad categories: AC and DC. The DC end-users, which operate at a constant 48V, are the rectifiers, batteries, and telecommunication equipment. HVAC and logistical equipment (lights, elevators, alarms, Computers, hot-water cylinders etc.) make up the AC components which require the standard 380V (AC).

According to Parsons [17], exceeding the temperature specifications (specified by the ETSI 300-019 series mentioned in chapter 1) can affects the telecommunication equipment's reliability and even result is system failure. Most of the energy used by the telecommunication equipment is converted directly to heat [15], thus to avoid temperatures drifting beyond the specified limits, the indoor temperature has to be controlled using an appropriate HVAC system.

The telecommunication equipment requires a constant 48V supply, generated by the rectifiers. A UPS (Uninterruptible Power Supply) is present in case of power failures. Typically, exchanges also require logistical equipment, if not for the purpose of telecommunicating, then for human activity (maintenance, office work etc.).

2.5.2   Measurement Audit

Extensive measurement audits were conducted to analyse the energy utilisation and to establish efficiency levels. This paragraph summarises the results of the audits and draws conclusions from them, thereby providing the motivation for the continuation of the study.

Energy Consumptions

Table 2.1 below shows the various loads depicted in figure 2.5 as a percentage of the total building load. Confirming the differences between manned and unmanned exchanges, it is noted that manned exchanges consume more energy as a result of additional logistical equipment such as lights, personal computers, alarms, hot-water cylinders etc.
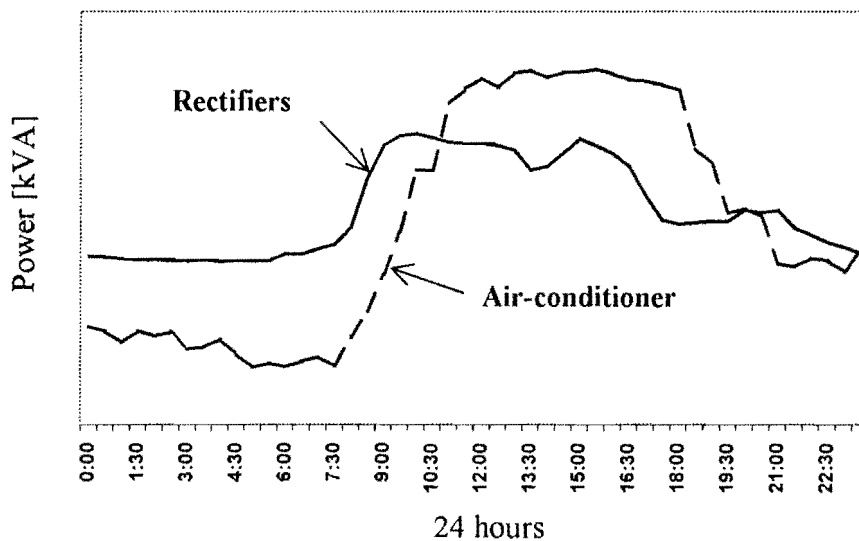
	% Of Total Building Load	
End-User	*Unmanned*	*Manned*
Rectifiers	44	33
HVAC	55	55
Logistical	1	12

Table 2.1   Percentage energy consumed by the various end-users in an exchange

Load Profiles

Typical load profiles of the rectifiers and HVAC equipment are plotted in figure 2.6 below. Knowledge of these profiles aid in the implementation of demand-side management and is therefore used in this context in chapter 5. For the moment however, the profiles are presented so that the processes involved can be visualised and understood.

At 07h30 the rectifier's power consumption starts to increase as a result of Telkom clients making use of telephonic services as they arrive at their place of work; consumption continuously increases as more customers make use of the services; at 09h30 the profile levels-off. As lunchtime approaches at approximately 13h00 the consumption decreases slightly, and then increases again as lunch ends. There is then a decrease in consumption as the clients end the day and go home. A base-load exists after office hours due to residential phone calls, and remembering the rectifiers also supply certain control equipment, also for system operation. Interestingly, it is noticed that after 19h00 the consumption rises slightly as a result of "call-more-time" when Telkom's tariff rates are lowered.

2.6 Typical load profiles of the cooling equipment and rectifiers for a period of one day

The profile describing the air-conditioning equipment can be explained as follows: many sources of heat exist in an exchange, of which the telecommunication equipment and outdoor conditions are the most prominent. Note that as the rectifier's consumption begins to increase, so does the air-conditioner's. At approximately the same time, the sun's radiation begins to take effect and the outdoor temperature rises; this has a pronounced effect on the cooling load and hence the air-conditioner's load increases. Similarly, as the rectifier's consumption decreases and the outdoor temperature drops, so does the air-conditioner's profile.

From the descriptions it is noted that the rectifier's profile is primarily dictated by the customers use of the telephonic services. Thus, in terms of demand-side management there is very little that can be done to improve efficiency of this end-user i.e. according to the energy policy, customers must still be able to "telecommunicate when, where and how they what to". On the other hand however, the cooling equipment's profile is strongly dependant on operational, and hence managerial constraints (operating times, set points, building design, installed equipment etc.) all of which allow DSM activities to be carried out. The importance of this becomes clear in the following paragraph.

2.6   AN ENERGY EFFICIENCY EVALUATION TOOL

The energy policy states that *energy norms* need to be developed in order to establish measurable benchmarks with which to compare performances, and thus provide reference points from which to analyse efficiencies. According to Delport [42, p. 1], an energy norm is a performance level that links elements of production to the energy consumption. As such it is an excellent tool for the management of energy.

The development of measurable benchmarks is an integral part of an energy policy. Referring to figure 2.3 it is noted that there needs to be controlled feedback (long-term and short-term) if there is to be successful management of energy; this however only has relevance if there are reference points with which to compare results i.e. if there are no set standards, how is it possible to determine if performance is optimal or not?

Table 2.2 presents the energy norms for the processes taking place in exchanges. In addition to streamlining, the norms also provide an efficient way of distinguishing between manned and unmanned exchanges. For the purpose of illustrating this, actual values obtained from energy audits are listed in the table – note the differences between the two types of exchanges!

Norm	Description	Units	Unmanned Exchanges	Manned Exchanges
$\dfrac{Q_{TOT}}{FloorArea}$	This is the most general of all the norms and determines the total energy consumed per month, per square meter of floor area. It is used to establish if a problem exists with the energy utilisation and also as a measure of efficiency, and hence if further investigation is necessary. *Many European companies define the benchmark to be 16 kWh/m²* [1].	$[kWh/m^2]$	163.78	92.15
$\dfrac{Q_{HVAC}}{FloorArea}$	The norm is defined as the ratio of the energy consumed by HVAC for a period of one month to the total floor area. Once a problem with the energy utilisation has been detected, the cause of the problem can be narrowed down using this norm. That is, if it is determined that the value for this norm deviates far from a specified benchmark, the fault lies with HVAC, if not then further investigation is necessary. Since this norm provides a value for the amount of energy to be consumed per square meter of floor area, it is very useful when predicting HVAC energy consumptions (and hence tariff selection) for a particular building.	$[kWh/m^2]$	89.63	51.32
$\dfrac{Q_{REC}}{FloorArea}$	This is very similar to the norm above, except that it determines if the problem lies with the rectifiers (which supply the telecommunication equipment)	$[kWh/m^2]$	73.90	30.18
$\dfrac{MD_{TOT}}{FloorArea}$	Defined as the ratio of the maximum demand (MD) for a particular month to the total floor area, the norm has applicability when considering tariff structures (especially when a MD charge is incurred). It is thus used for DSM.	$[kW/m^2]$	0.268	0.141
$\dfrac{MD_{HVAC}}{FloorArea}$	Normally, the installation of HVAC equipment is sized on the basis of the floor area e.g. the cooling capacity must be 0.2 kW/m². Thus finding the correct benchmark for this process is critical. In addition to this, the norm provides a tool for predicting power consumptions and thus aids in tariff selection and scheduling.	$[kW/m^2]$	0.165	0.074

$\dfrac{Q_{HVAC}}{Q_{TOT}}$	This is one of the most important benchmarks to set; it defines how much of the total energy consumed by the exchange is due to HVAC. As such it determines if the air-conditioning plant is consuming too much or too little energy, and hence if it is optimal for that particular exchange.	[%]	55	55
$\dfrac{Q_{REC}}{Q_{TOT}}$	The norm is similar to the one above, except that it determines what percentage of the total energy utilisation is due to the rectifiers (and hence telecommunication equipment). If the value of a particular exchange is far from the benchmark, then either there is a problem with the rectifiers, or the other equipment (e.g. HVAC) is consuming too much or too little. *Many European companies define this benchmark to be 70%* [1].	[%]	44	33
$L.F_{TOT}$	The norm defines the load factor of the total energy utilisation of an exchange. This has applicability when considering tariff structures (especially when MD charges are applicable) and thus is used to optimise energy costs.	[%]	80	89
$L.F_{HVAC}$	Aids in setting operating schedules for the HVAC equipment e.g. a load factor of unity implies that the air-conditioner is operating 24 hours a day (never switching off) – for obvious reasons this is undesirable.	[%]	75	96
$L.F_{REC}$	The norm is very similar to the one above, except that it calculates the load factor of the rectifiers (and hence telecommunication equipment).	[%]	85	77

Table 2.2   Energy Norms for telephone exchanges

European standards stipulate that the energy consumed per floor area should not exceed 16 kWh/m^2 (see first norm), however with manned exchanges consuming 92 kWh/m^2 and unmanned exchanges consuming 164 kWh/m^2, it is clear that there is large scope for improvement in Telkom's energy utilisation. Granted, there are vast differences in weather conditions (i.e. temperature levels are typically a lot lower in Europe than they are locally), and in addition, the thermal quality of buildings are much higher in Europe (due to more stringent building codes) than in South Africa, enabling the European countries to use a lot less energy for space cooling. Nonetheless, it still illustrates the fact that Telkom is extremely inefficient with its energy.

Magnus [41] mentions that the process of HVAC in Bell Communications (USA) only constitutes 21% of the total energy consumption, and Bengtsson [19] stipulates that in Swedish based Telia this process only consumes 30%. Thus, it is clear that while Telkom consumes 55% for this process (see table 2.1) drastic improvements are necessary!

Fortunately, from the explanations presented in paragraph 2.5.2, it was mentioned that while little can be done in terms of DSM to optimise the energy utilisation of the rectifiers, the process of HVAC offers the widest selection of energy management opportunities. Confirming this, Grobler [23, p. ii] states that the "biggest energy-saving potential lies in the retrofitting of HVAC systems".

2.7   SUMMARY

The chapter formed the basis of the study by presenting a holistic methodology for the implementation of the management of energy. As such, an energy policy was formulated enabling the responsible management of energy sources, resources and consumables; in so doing setting up control measures ensuring that energy is being used to its maximum potential.

This then led to energy audits being conducted to establish efficiency in the organization. It was then concluded that a distinction between manned and unmanned exchanges could be made, prompting an investigation into the effects thereof. This resulted in development of an energy efficiency evaluation tool in the form of energy norms, which highlighted the differences between the two types of exchanges.

Typical load profiles of the rectifiers and HVAC equipment were also obtained from the audits. From these, it was concluded that not much in terms of demand-side management could be done to lower the energy expenses of the rectifiers, but that the process of HVAC offered a vast selection of DSM activities.

This fact was welcomed since it was determined that in both manned and unmanned exchanges 55% of the total load was as a result of HVAC, and because literature showed that European standards dictate this value to be less than 30%, it presented great incentive to investigate optimising this process through DSM. This has formed the basis for the remainder of the study i.e. to concentrate primarily on optimising the process of HVAC through demand-side management.