6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS ON OBJECTIVES

6.1.1 Conducting This Study

From the studied literature it was determined that there is certainly large scope for the development of Energy Management in the telecommunication environment. It was observed that most telecom companies have implemented *energy conservation* with the objective of lowering energy costs, however it was noted the conservation techniques do not necessarily translate into savings. This study thus focused on implementing *energy management* in its truest form i.e. "the process of optimising the energy consumption to reduce the energy costs".

Further studies revealed that there was a lack of information relating telecommunications, HVAC, and energy costs. In addition, case studies presented supporting data to suggest that investigation into this relationship was necessary. As such, the technical portion of the dissertation concentrated on developing energy conversion models relating the cooling of telephone exchanges to energy costs. Due to the scope of the study, these models were developed with a strong emphasis placed on the "energy management" concept.

As a whole, the study was strongly motivated by the lack of necessary information, which is essential to Telkom if it wishes to streamline its operation and hopefully be strong competition to other prospective companies wishing to enter the country in the near future. As such, the study will have a substantial impact on the company's strive to become an efficient operator, and hence provide its customers with the best quality of service possible.

6.1.2 The Energy Management Programme

The foundation for the study was the construction of an *Energy Management Programme*. Although this programme is, as of yet, not an official policy of the company, it did provide the pivotal drive for the continuation of the study. The programme was developed using the energy policies of the University of Pretoria and AT&T, which provided the intricacy, and specification for the development of "Telkom's Energy Policy".

It was discovered that if such a programme were not presented, the study would have been ambiguous and unfocussed. As such, it formed the basis, providing direction and scope for the research. In addition to this, the programme (and hence the work conducted in this dissertation as a result) was not merely presented for the purpose of the study, but was, and is intended to be an official policy for the implementation of energy management in the company. That is, the research conducted here within is not merely yet another hypothetical and/or theoretical study, but has definite practical (real-world) applicability.

The programme was developed with a holistic view of the company taken into account i.e. in context of the organisational hierarchy, the primary objective of the policy was focussed on implementing energy management on an *organisational level* (see figure 3.1). From this, more specific, narrowed down objectives can be drawn up, from which more specialised implementation of energy management can be carried out. Thus, the programme presented is intended to be the starting point to the introduction of the management of energy in the company.

Concluding the specific objective: An *energy policy* was presented that will provide the structure needed to implement energy management in Telkom. An *energy policy strategy* was also presented to provide a method of fulfilling the objectives of the policy. To obtain a better understanding of the energy utilisation and hence implementation of the management of energy in the company, *energy audits* were conducted at selected exchanges, which enabled a *diagnosis* of the utilisation.

6.1.3 Energy Efficiency

Following the guidelines of the programme, an investigation into the energy efficiency of the company was conducted. The results showed that telephone exchanges were operating in an extremely inefficient manner, especially when compared to other telecommunication companies around the world. This prompted the development of an *Energy Efficiency Evaluation Tool* in the form of energy norms.

Although not explicitly stated, it was illustrated that the tool has four inherent functions: (1) it is used as an energy efficiency evaluator – indicating whether an exchange and/or the various energy end-users are operating in an efficient manner, (2) it enables inefficiency to be pinpointed i.e. equipment causing an energy wasteful environment can now be located, (3) benchmarks can be established form which standards for the equipment, and the exchanges themselves can be determined, and (4) exchanges can be classified according to energy utilisation e.g. manned or unmanned exchanges; small, medium or large installation etc.

The investigation into the energy efficiency also provided important information related to the energy distribution in an exchange i.e. it was discovered that three major electricity end-users could be identified: HVAC, rectifiers (supplying the telecommunication equipment), and logistical equipment. From measurement audits conducted, it was determined that the HVAC equipment tends to consume the bulk of the energy i.e. 55% of the total building load (see table 2.1). It was also reported that, as compared to other telecom companies, this is an exorbitant amount of energy to be used merely for space cooling. From this, and the fact that HVAC generally tends to present the most energy saving opportunities, it was deduced that the remainder of the study should focus on this process.

Concluding the specific objective: *Energy norms* related to the processes involved in telecommunication exchanges, and the exchanges themselves were presented in an evaluation tool. This then enabled exchanges to be classified as either *manned* or *unmanned* i.e. where the former contains telecommunication equipment and office space with human activity, and the latter only has telecommunication equipment and no office space.

6.1.4 HVAC Model Development Methodology

It was discovered that in order to explain the context in which the models, relating the process of HVAC to energy costs were to be developed, an appropriate modelling methodology had to be formulated. For this reason figure 3.1 was constructed to provide insight into the "global" framework for the development of the models. As such, it illustrated that the organisational hierarchy, and hence managerial aspects have a direct influence on the modelling to be done. This was then zoomed in on, and showed that *operational performances* (elements affecting the HVAC process) have a definite influence on the energy costs – see figure 3.2.

With the above in mind, a flow diagram (figure 3.3) was developed to incorporate all aspects affecting the energy utilisation, and hence energy cost of the air-conditioning equipment. From this, it can be concluded that both managerial and operational aspects have a direct influence on the minimisation of energy costs. That is, Demand-Side Management (DSM), tariff selection, as well as the operational performances all have an effect on the electricity bill at the end of the month.

An analysis of various modelling strategies revealed that the "Building Block" approach would be the most appropriate methodology for the development of the models. For the modelling at hand, it was discovered that using this methodology provided ease of construction but most importantly, retained model versatility, which is important when developing a tool that is to be used in energy management.

As the name suggests the models were to be developed using "building blocks", the output of one block being the input to another. Construction of the models in this manner proved to have a number of benefits: (1) it enables experts in a particular field to use a "block" (model) relevant to his/her field of study, (2) the models themselves are not complex, and enabled quick calculation, and (3) integrity of the models are maintained i.e. they can be integrated into other model sets and hence be used in conjunction with other studies.

Concluding the specific objective: Not only was a *modelling methodology* selected for the development of the energy conversion models, but the context in which they were to be developed was also explained. The "building block" approach, as mentioned above, proved to be very efficient for the purpose for which it was intended.

6.1.5 HVAC Model Development

Following the methodology, the construction of the models proved to be relatively simple. In all, three "building blocks" were constructed. Combined, these "blocks" enable the elements that affect the heat load (i.e. Btu/hr) to be translated into electrical energy utilised by the air-conditioning equipment (i.e. kWh and kVA); hence the term, "energy conversion model". The three models enable the calculation of (1) the *total building heat load*, which is the total heat gained by an exchange, (2) the *required cooling capacity* an air-conditioner needs when installed in a particular exchange, and (3) the *energy and power* utilised by the equipment (i.e. kWh and kVA) to maintain a constant temperature set point.

From the model set it is determined that the total heat load to a typical exchange is dependent on six *heat gain elements*: (1) temperature difference between outdoor (ambient) temperature and the indoor (set point) temperature, (2) conduction through walls and ceiling, and hence also thermal resistances of these structures, (3) heat gained due to infiltration of air, (4) heat gained due to lights, (5) heat gained due to people and their respective "degree of activity", and (6) heat gained due to the telecommunication equipment itself. Since there is direct proportional relationship between the total building heat load and the required cooling capacity (equation 4.16), it is also noted that the air-conditioning equipment's "size" is also dependent on these same six elements.

Being able to calculate the air-conditioner's required cooling capacity as a function of these elements, provides an extremely useful tool – it can be used for (1) checking if presently installed equipment is adequately sized for a particular exchange, (2) sizing equipment (for newly built exchange), (3) retrofitting, and (4) forecast equipment "size" (e.g. what capacity air-conditioner will be needed if an additional 5 000 lines are installed?)

The final " building block" (model) was developed using *equipment specific* information (i.e. C.O.P and power factor) to relate the required cooling capacity to the energy utilisation. The model was constructed in such a way that these could also be used as variables, and hence also occur as inputs to the model set. This enhances the applicability of the models since there is now greater versatility, and as such provides a very powerful tool for implementing energy management.

Concluding the specific objective: Energy conversion models were developed that enable redesigning, retrofitting and implementation of air-conditioning equipment in telephone exchanges. They also aid with understanding the effects of manipulating the elements that contribute to the heat load. In addition the models proved that they could be used to set up cost-effective energy configurations, schedules and tariffs.

6.1.6 Model Verification

In retrospect, the context in which the models were developed, as well as the construction of the models using the methodology, proved to be viable options. This conclusion is drawn from the fact that the data obtained from case studies compared closely to the theoretical results obtained from the models i.e. the simulated power and energy values (calculated by the models), for both manned and unmanned exchanges, was in the order of 5% of the actual measured values (95% accuracy). As such the models are a true representation of the real-world process and can be used to closely predict the energy and power utilised.

6.1.7 Applicability of Model Set

It was discovered that the models presented a number of useful functions – not only do they provide reliable information for which they were intended, they also offer insightful information into the process of cooling exchanges. As such, it is noted here that the models have immense applicability, not only for energy management (for which they were intended) but also for fields other than this. That is, the methodology used to construct the models, enables them to be used in applications such as management, financial analysis, building design, HVAC equipment design, and also in future research fields such as TES (Thermal Energy Storage).

As a reminder, it is noted that the models were intended for three specific objectives: to calculate (1) the *total building heat load* of a specific exchange, (2) the air-conditioning equipments' *required cooling capacity* to maintain a specified temperature set point, and (3) the *energy utilisation* (active, reactive and apparent power/energy) of the equipment.

Models 4.12 and 4.13 are used to calculate the total building heat load for a manned and unmanned exchange respectively. The results obtained using specifications of the two case studies (Hillcrest and Bronberg exchange) revealed that the building heat load has a cycling period of one day, and thus has a repetitive profile. From this and model 4.16, the cooling capacity required by the equipment to maintain a fixed temperature set point can be calculated (see figure 5.2). Being able to simulate graphs such as this has enormous implications – cooling capacities (and thus equipment size) can be anticipated for exchanges that already exist, and that still need to be built. This enables management to do forecasting, and can thus project budget costs, capital outlays and payback periods.

The last model, model 4.23, is the pivotal link between the cooling of exchanges and energy management. That is, it places an extra dimension to the context for which the models were intended – being able to calculate the energy utilisation as a function of the *total building heat load*, and hence elements that supply heat, the management of energy can be carried out rather effectively. It is now possible to determine the effects of manipulating aspects such as temperature differences, wall and ceiling types, lighting, personnel, and telephone lines on the energy utilisation. In addition the model incorporates two *equipment specific* elements, which also have a pronounced effect on the energy utilisation. In all, the models provide a complete package for projecting, forecasting and calculating energy usage of air-conditioning equipment as a function of the elements that necessitate the need for the equipment.

With energy and power values available, cost analysis of the equipment can be conducted through the introduction of tariffs. This completed the "energy management tool" that was a subsidiary of the primary objective of this study. The Rand amount it would costs to alter a particular element affecting the cooling of an exchange can now be calculated. As such it enables a diversity of energy cost reduction techniques in the form of (1) altering operational performances, (2) improving equipment specific performances, (3) selecting the correct tariff, and (4) imposing an optimal operating schedule.

It is noted that from the examples and illustrations presented in the previous chapter that definite energy cost savings can be realised if certain alterations to the operational performances are made, such as increasing the temperature set point or decreasing the number of lights. Energy costs can also be drastically lowered if the power factor and C.O.P are increased. In addition, it was also illustrated that different tariffs result in different energy costs; thus by selecting the appropriate tariff, energy costs can also be lowered.

In conclusion, the models developed do indeed provide a useful "energy management tool", and as such present an alternative method for lowering energy costs of air-conditioning equipment. In all, the model-set goes a long way to improving the efficiency of telephone exchanges and the company as a whole.

Concluding the specific objective: A simulation package implementing the models was constructed to illustrate the effects of altering certain operating conditions. As such this enables cost effective energy configurations to be set up for specific scenarios. The models proved to have great applicability in lowering energy costs of the air-conditioning equipment.

6.2 RECOMMENDATIONS ON SPECIFIC OBJECTIVES

6.2.1 The Energy Management Programme

First and foremost, for Telkom to manage its energy effectively it will be necessary for the company to draw up an official energy policy, in which the Energy Management

Programme is laid out. Only once this has been done, can the organization begin to make use of its energy sources and resources responsibly.

6.2.2 Energy Efficiency

Making use of the *Energy Efficiency Evaluation Tool*, it is recommended that every exchange (of which there are approximately 3600) be evaluated so that an overall picture can be obtained. Utilising the norms presented in the tool, statistical data can be retrieved, from which the energy efficiency of the various end-users and the exchanges themselves can be analysed. This will indicate, as a whole, where primary attention should be paid and where improvements are to be implemented. These could be managerial and/or operational amendments.

Further studies are to be made into calculating actual benchmarks for the norms presented in the tool. The statistical data obtained from a complete audit (as mentioned above) will provide valuable data with regards to this; however further more in-depth studies are required to come to an explicit solution. Once such benchmarks have been determined, currently utilised exchanges, and exchanges still to be built can be optimised using these figures, going a long way to improving the energy efficiency of exchanges as a whole.

6.2.3 HVAC Model Development

Although the models conclusively describe the relationship between the cooling of exchanges to energy costs, there is one concept that was not explicitly covered. Thermal Energy Storage is slowly starting to gain interest, promising to be a viable method of minimising the energy consumption and demand. Since this is a relatively new topic, there is certainly vast scope for research in the field.

There are essentially two variations of TES – thermal storage of the building, and thermal storage of the air-conditioning plant itself. The former method involves lowering the temperature of the building structures (e.g. walls, floors, doors, equipment etc.) below the usual operating temperature, so that at peak-demand times the air-conditioner can be switched off, and hence lower energy cost. The latter process involves utilising storage tanks (e.g. water tanks) to store energy – water is cooled during the low-demand periods of the day, which is then used to cool the building interior during peak-periods.

Combining this process to the models developed in chapter 4 has two aspects which have to be considered. Firstly, the air-conditioner's cooling capacity has to be revised – obviously to lower the building structures below normal operating temperature, a system with a larger cooling capacity is necessary. The question is, what is the optimal required cooling capacity? Secondly the correct operating schedule has to be determined i.e. with various billing periods, an optimal operating schedule exists.

6.2.4 Applicability Of Model Set

In the chapter covering the applicability of the model, a number of examples and illustrations were presented. These illustrated how the energy utilisation was affected as the operational performance and equipment specific inputs were manipulated. This was then combined with two tariff structures, namely Nightsave and Miniflex. The examples presented, showed that for different conditions, one of the tariffs resulted in a lower cost than the other. As such, it is recommended that the models be applied to all exchanges so that the most cost-effective tariff can be selected for a particular exchange.

In addition to this, the models are also to be applied to exchanges so that the best operational performance for a particular exchange can be achieved. For example, removing unnecessary lights, ensuring doors are left closed so as to reduce infiltration, place insulating material on walls to increase thermal resistances etc. The models are also to be used when designing new exchanges e.g. wall and ceiling area, wall and ceiling insulation, lighting etc.

The models are also to be used when drawing up policies and regulations e.g. they can be used to motivate a temperature set point change from the present 20 °C, to 35 °C or even higher, which will result in massive cost savings; or they can be used to motive the implementation of a policy stating that no office work is to be done in exchanges – separately built office blocks are to be constructed for this, which also drastically reduce energy costs.

6.3 SUMMARY

The study proved to be very successful in that it provides a practical means of improving energy efficiency in telecommunication exchanges. The work contained in this dissertation was laid out is such as manner that it provides information that can be adapted to other fields of study, and as such provides a versatile tool for any industry wishing to improve its efficiency.

In all, the study provides Telkom with an extremely useful tool for ensuring the efficient use of its energy. As such it truly fulfils its primary objective, "to implement energy management in a telecommunications environment and in so doing provide useful energy optimisation tools"