6. CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

Chapter 1 mentions the main objective as well as a number of specific objectives to be achieved by this dissertation. This chapter concludes the dissertation by linking these objectives to what has been achieved. It globally focuses on the main objective and also concentrates on details of the specific objectives. The value of the work done in this dissertation is discussed and recommendations are made along with suggestions for future extensions and diversification to this study.

6.2 CONCLUSIONS ON THE OBJECTIVES

The main objective of this study was to develop a means of simulating the cost of electricity associated with the operation of a typical water reticulation system of a deep-level gold mine. Models were to be developed and integrated in such a way that they allow experimentation with scheduling, configuration and tariffs in order to minimise electricity costs associated with water pumping.

This main objective was achieved by employing a structured, systematic approach to identifying and solving all relevant issues. These issues were addressed by the different specific objectives and overall by constant referral back to the main objective. In addition to dealing with issues directly related to the objectives, it was also necessary to include much detail about the environment for which this study is intended to add an appreciation for the importance of what has been achieved.

Much of this dissertation concentrates on the methodology used in generating the models. This is intended to enhance the reader's comprehension of procedures and thought processes used to develop the models. In addition to adding total comprehension by doing this, it is intended that this study can be extended upon in the future to include other components or even a set of models for other systems found within mines. Using the same methodology will ensure compatibility; this will however be discussed later.

The introduction of chapter 1 provides a brief overview of theory and history of energy management as applicable to the mining environment in general. The main point, which is put across in this section, is that energy management in any form is aimed at reducing energy costs to enhance competitiveness. This does not necessarily mean using less energy, but rather reducing the cost of electricity per product.

Chapter 1 continues to deal with the practical environment, for which this study is intended, including global technical and non-technical constraints, which the results would need to adhere to.

6.2.1 Conclusion on extension to Delport's work.

One of the fundamental reasons for conducting this study was for the continuation of research initiated by Delport. Delport's research suggests methodologies and strategies for mine-wide integration of energy management procedures. As mentioned in section 1.3.1, this was to be achieved by modelling all major energy consuming devices within a deep-level mine. Delport however does not develop refined models for all components found within a typical water reticulation system. He proposes energy conversion mathematics for typical pumps, friction losses and efficiency.

This dissertation provides structured models for all common components found within the water reticulation systems of deep-level gold mines. It also makes provision for multiple components and ensures that all models are compatible. Models were verified to ensure that they are valid under typical conditions.

6.2.2 Conclusion on Modelling Methodology

Chapter 2 is solely devoted to explaining the methodology used in the generation, integration and constraints to be considered, when developing energy conversion models. It is important that one realises that modelling is not purely mathematical and academic. In fact the art of proper modelling is diverse and must consider a number influences such as physical, mathematical and financial factors. The use of conceptual models to generate mathematical models is also very important.

Models are in essence bridges between the real world and mathematical world, the methodology presented in this dissertation addresses the importance of providing a proper structured means of building such bridges. This is done by examining types of models and specific criteria of models.

The methodology addresses different contexts which models can fall into. This is important to ensure that different levels of models are compatible. The next part of the methodology presents a modular strategy to develop models to allow separate processes to be individually modelled and integrated into a global system.

The actual model developing process is also dealt with by the methodology, which provides a step-by-step mechanism used to produce each individual model. In addition other factors in the development such as the relevant inputs and outputs of models and system boundaries are addressed. The methodology also makes provision for constraints, which need to be kept in mind in the development process.

The methodology presented in this dissertation proved to be a reliable, robust guideline for model development, while at the same time, being simple enough to avoid confusion.

6.2.3 Conclusion on Separate Modelling

Accurate separate mathematical energy conversion models were developed in chapter 3. A large part of chapter 4 is devoted to verifying that the individual models are valid. Producing models for each common identifiable component of the water reticulation system allows for easy simulation of numerous different systems by simply plugging models for relevant components together.

Due to the mathematical nature of the models at this level, chapter 3 derives the mathematics for the models by starting with basic fluid-dynamic theory. By describing the derivation of the models, it is intended that the reader will be in the position of being able to derive similar models for any specific related components for which models have not been generated in this study.

6.2.4 Conclusion on Model Integration

In order to successfully simulate any water reticulation system, the individual models that have been developed need to be able to be integrated and thus be completely compatible in any configuration. This was achieved by generating models in such a way that the format and units of any inputs and outputs conform to a set standard. The success of the models operating together was evaluated in chapter 4, where it was proved that the models indeed function well together.

The integration of the models working together was verified using two separate sets of case study data. This data was used as an input to a set of models, which represented the configuration of an existing mine. The final simulated cost output of the system of models was compared to the actual cost value supplied by the mine for the cost of pumping at the specific times. The outputs of the system of models proved to be very close to the actual values quoted by the mine.

6.2.5 Conclusion on External Compatibility

Developing models that conform to a set of pre-determined standards ensured proper model integration. This integration strategy was however not limited to only ensuring integration of models with each other. In order to produce models that can be applied to any general water reticulation system, the models were developed using input and output variable formats and units that are commonly used in the mining environment.

An important part of ensuring external compatibility is also covered in the methodology. It is very necessary to adhere closely to the various system boundaries as described in chapter 2 to avoid stray influences.

6.2.6 Conclusion on Experimentation

The models and their applications in systems of models as described in this dissertation are of such a nature that their final output value are energy values. This means that if profiles of flow rates and other inputs for a pre-determined time are used, the output of the system of models will be an energy profile which allows one to examine the cost of electricity using different tariffs. It is thus also possible to vary the input profiles to observe the effect energy usage profiles and so also the cost associated with each set of input conditions.

6.2.7 Conclusion on Future Systems

Using the 'building block' approach described in the methodology of this dissertation, it is possible to simulate any general configuration of a water reticulation system. This naturally does not imply that the system must exist. In fact one of the benefits of this study is that it is now possible to create a number of different water reticulation systems which could be used in a proposed installation and evaluate the energy usage of each. This allows experimentation with a number of different energy recovery configurations.

Proposed installations could now for example determine the energy costs of a system using a three chamber pipe feeder system versus turbines or no recovery at all. The reduction of energy costs can then be weighed up against the capital outlay required for a three chamber pipe feeder system of the cost of turbines using a number of present value of money techniques as mentioned in section 1.4.4.

6.3 EXTENDED VALUE OF THIS STUDY

In addition to the obvious financial savings to individual mining business units, studies such as this may have much further reaching benefits. The national department of minerals and energy [43] is continuously evaluating ways and means of environmental pollution reduction. Using the models developed in this study to manage the energy demand of the water reticulation systems in a number of mines will ultimately mean the capacity of the supplier will not need to be as great, thereby having a positive influence on the environment.

In 1999 Eskom sold 31,505 GWh of energy to the mining sector of South Africa [10, p. 96]. This represents 18.2% of the country's total energy consumption. Section 1.2.1 mentions that water pumping in typical mining operation in South Africa is responsible for about 17.6% of the total energy costs. This means that the water pumping in South African mines uses in the order of 3.2% of the country's total energy supply. If one considers the typical potential saving of up to 51% of the energy and 59% of the maximum demand as shown in table 5.2, it becomes clear that if energy-aware decisions are taken, especially when deciding on energy recovery systems in prospective mines, it can have a significant influence on the South African environment in the future. It must be noted that if only scheduling changes are brought about, only the maximum demand can be changed. A certain amount of water needs to be pumped in any cycle and this will require a specific amount of energy. This means that if no energy recovery changes are made by a particular mining shaft, reduction of maximum demand will be the only way that they can contribute to the environment.

In current installations, decisions may need to be taken about energy recovery system installations. Reducing the energy requirements of the water reticulation system, especially the maximum demand will be of benefit to the environment.

6.4 RECOMMENDATIONS AND FUTURE WORK

6.4.1 Implementation Recommendations

The models presented in this dissertation are robust and simple to use. They provide a way of simulating changes to existing water reticulation systems and the way they are operated with reasonable ease. It is thus highly recommended that all deep-level gold mining operations make use of the models presented and integrate them into their overall energy management policies and procedures. It is also highly recommended that these models be used to evaluate the prospective systems.

A great benefit of modelling the water reticulation system of deep-level gold mines as suggested is that there is no need for capital expenditure to be able to do this. Models can easily be implemented in spreadsheet applications commonly found on personal computers. It is however suggested that this dissertation be read in its entirety before any attempt at modelling is made. This is to ensure that the reader is aware of all factors and influences that must be kept in mind such as contexts, system boundaries, buffers and other constraints.

6.4.2 Future Work

The next step in the entire quantified energy management approach at deep-level mines would be to model all other systems and processes found within a mine in a similar way to this study. This includes the compressed air system, fridge plant, vertical transport system, ventilation system and all other essential and support systems.

Once complete modelling of all the systems found within a deep-level mine has been done, it will be possible to prioritise systems in schedule generation and be able to simulate schedules of the entire mine. Once the entire mine can be simulated, a number of different tariffs can be experimented with and the entire mine's scheduling can be geared towards specific tariffs. Evaluation using Real Time Pricing (RTP), should also form an integral part of such a study.

Following the extension to this work just mentioned, a further study should be undertaken into the development of customised tariffs. These tariffs should be developed for internal billing purposes. By billing each energy consuming system found within a mine in a fashion relevant to that system's operation will ensure that personnel responsible for each section make an effort to reduce electricity costs.