

NEW DEMAND SIDE MANAGEMENT OPPORTUNITIES IN THE PRECIOUS METALS INDUSTRY

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ABSTRACT

Title:	**NEW DEMAND SIDE MANAGEMENT OPPORTUNITIES IN THE PRECIOUS METALS INDUSTRY**
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Currently there is an increasing demand for energy across the world. As the human population increases and new technologies find their way to previously difficult to reach areas, this is becoming an increasing problem. Various countries have implemented measures to save energy and provide sustainable development for the future. In South Africa this also holds true, and the state electricity supplier, Eskom, has been involved with energy management for a number of years.

The most prominent energy management initiative is the Demand Side Management (DSM) program. This program was designed to provide measures to reduce electricity usage, as well as implement mechanisms to shift load from the peak electricity periods. These measures are usually implemented with the help of Energy Service Companies (ESCO's).

In South Africa, there are numerous ESCO's, and many successful DSM projects have already been implemented in various industries. Since the precious metals industry is such a large role player in the economy of South Africa, it is natural that a large number of DSM projects comes from this sector. This is true, as can be seen from typical DSM projects on pumps, refrigeration plants, compressed air, and rock winders on South African mines.

Since Eskom has not been able to meet its targets for DSM in the previous two years, a renewed effort has been made to identify and implement new types of DSM projects. In order to find new types of DSM projects, this study focused on the precious metals industry. It was found that DSM has not been implemented on precious metal plants such as platinum concentrators and Carbon in Pulp (CIP) gold plants. Since these plants also have various large pieces of machinery that might be amenable to DSM, this provided a starting point for this research.

An audit was done on a platinum concentrator to investigate new DSM possibilities. It was found that large mills are used on these facilities that might provide large savings. Unfortunately, there are some problems with the current design of these plants, as well as oxidation of the material that seriously hinder implementation of DSM projects.

The attention was focussed to CIP gold plants to the same end. These plants have various sections that have some DSM possibilities. The most prominent savings were shown to be in the milling circuit and the elution boilers. Research has been done to compare the energy cost of using various kinds of fuels to produce steam for the elution columns. It was found that coal is the least expensive fuel for this use. However, various transport and environmental issues preclude the use of these types of boilers. The next best option was the electrode boilers, which can save large amounts of electricity in an environmentally friendly way if controlled correctly.

However, one of the most important results of this research was to prove that the milling circuits on gold plants can be used to provide large amounts of load shift from the peak periods. These findings have been enhanced by the development of a unique simulation model to predict the possibility of load shift on the milling circuit of any gold plant. The viability of load shift on the mills, as well as the accuracy of the simulation has been proven by implementing simulated load shift on an actual gold plant.

Four other gold plants have also been used as case studies on which to implement the new simulation procedures. This produced valuable lessons in terms of load shift on the milling circuits of gold plants. In order to provide a starting point for future research, the simulation model has been expanded to include other industries. It was adapted slightly to be able to simulate load shift on the milling circuits of cement plants and chrome pelletizing plants. This once again proved the value of this research in terms of contributions to the DSM program in South Africa.

SAMEVATTING

Titel:	**NEW DEMAND SIDE MANAGEMENT OPPORTUNITIES IN THE PRECIOUS METALS INDUSTRY**
Outeur:	**Niel Jordaan**
Promotor:	**Dr. J.F. van Rensburg**
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Daar is tans 'n groeiende vraag na energie regoor die wêreld. Hierdie aanvraag groei daagliks soos die menslike bevolking vermeerder en nuwe tegnologie gebruik word in gebiede wat tot onlangs moeilik bereikbaar was. In 'n poging om die groeiende vraag na energie te stuit, het vele lande regoor die wêreld programme daargestel om hulle energie verbruik beter te bestuur en volhoubare ontwikkeling aan te moedig. Soortgelyke programme is ook in Suid-Afrika op die been gebring, waarin die staat se elektrisiteitsverskaffer, Eskom, 'n groot belang het.

Een van die bekendste programme is die nasionale "Demand Side Management" (DSM) - program. Die hoofdoel van die program is om meganismes daar te stel om die elektrisiteitsverbuik in Suid-Afrika beter te reguleer. Van die bekendste meganismes is sekerlik die sogenaamde energie effektiwiteit meganisme wat poog om die gebruik van elektrisiteit te verminder. 'n Ander meganisme staan bekend as lasskuif. Dit poog om die gebruik van elektrisiteit te skuif vanaf piek gebruikstye, na ander tye van die dag waar daar 'n groter opwekkingsreserwe is. Hierdie programme word geïmplimenteer met die hulp van sg. "Energy Service Companies" (ESCO's).

In Suid-Afrika is daar 'n groot aantal ESCO's wat projekte doen in verskeie industrieë. Aangesien die mynbou so 'n groot rol speel in die Suid Afrikaanse ekonomie, is dit net natuurlik dat 'n groot aantal van die projekte uit die sektor kom. Dit kan bewys word as daar gekyk word na die vele lasskuif- en energie-effektiwiteitsprojekte op pompe, verkoelingsaanlegte, druklug en rotshysers in Suid-Afrikaanse myne.

Aangesien Eskom nie sy DSM-teikens vir die afgelope twee jaar kon bereik nie, was daar hernieude pogings om meer projekte te identifiseer en te implementeer. In 'n poging om nuwe DSM-projekte te identifiseer, is hernieude aandag gefokus op die edelmetaal-industrie in Suid-Afrika. Daar is gevind dat daar nog nie DSM-projekte gedoen is op sg. "Carbon in Pulp" (CIP) goudaanlegte en platinum konsentrasie-aanlegte nie.

Dit was eintlik verbasend, aangesien beide hierdie aanlegte groot stukke toerusting het wat moonltik in DSM-projekte gebruik kan word. 'n Studie is gedoen op 'n platinum konsentrasie-aanleg om die moontlikheid van lasskuif te ondersoek. Alhoewel daar groot meulens op hierdie aanlegte is, was daar spesifieke probleme met die ontwerp van die aanleg en oksidasie van die materiaal wat die implimentering van DSM projekte ernstig belemmer.

Die aandag is toe gefokus op die goudaanlegte. Verskeie seksies in die aanlegte het moontlike DSM-potensiaal getoon. Die mees prominente besparings is te vinde in die meulseksie en in die stoomketels wat vir stoomgenerasie gebruik word waarin die energiekostes van verskillende brandstowwe met mekaar vergelyk is om die beste opsie te vind. Daar is gevind dat steenkool die goedkoopste energiekoste het. A.g.v. logistiese- en omgewingsprobleme, is dit gediskwalifiseer as 'n opsie. Die volgende beste opsie is die elektrode stoomketel. Dit het die voordeel dat dit goedkoop en skoon is. Dit kan ook baie energie-effektief gebruik word as dit die regte beheerstelsel het.

Een van die belangrikste bydraes van die navorsing was om te toon dat dit moontlik is om groot hoeveelhede elektrisiteit te skuif uit piektye deur gebruik te maak van die meulseksies op goud-aanlegte. Hierdie bevinding is verder ondersteun deur die ontwikkeling van 'n unieke simulasie-model wat lasskuif op goudaanleg-meulens voorspel. Beide die moontlikheid van lasskuif en die akkuraatheid van die simulasie is bewys deur voorspelde lasskuif toe te pas op 'n werklike aanleg. Die resultate het die simulasie ondersteun. Die simulasie-model is ook toegepas op vier ander goud aanlegte om dit verder te bewys.

'n Verdere bydrae van die navorsing was om die simulasie-model uit te brei om lasskuif te simuleer op sement- en chroomaanlegte. Die resultate was weer eens positief en het die grond voorberei vir verdere navorsing in die gebied.

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TABLE OF CONTENTS

CHAPTER 1 ..... **1**

INTRODUCTION **1**

1.1 WORLDWIDE RISING ENERGY DEMAND 2
1.2 INTERNATIONAL ENERGY MANAGEMENT INITIATIVES 4
1.3 THE ENERGY SITUATION IN SOUTH AFRICA 7
1.4 THE GROWING ELECTRICITY DEMAND IN SOUTH AFRICA 9
1.5 ENERGY MANAGEMENT INITIATIVES IN SOUTH AFRICA 12
1.6 THE ROLE OF THE MINING INDUSTRY 18
1.7 INTRODUCTION TO MINERAL PROCESSING 27
1.8 BASIC BACKGROUND ON PLATINUM CONCENTRATORS 29
1.9 BASIC BACKGROUND ON GOLD PLANTS 33
1.10 POSSIBLE LOAD SHIFT ON CIP PLANTS AND CONCENTRATORS 38
1.11 NEED FOR THE STUDY 39
1.12 CONTRIBUTIONS OF THE STUDY 40
1.13 OVERVIEW OF THE THESIS 41
1.14 REFERENCES 43

CHAPTER 2 ..... **51**

NOVEL DSM SOLUTIONS FOR THE PRECIOUS METALS INDUSTRY **51**

2.1 THE MINERAL PROCESSING MARKET IN SOUTH AFRICA 52
2.2 DSM SCOPE ON PRECIOUS METALS FACILITIES - FOCUS ON PLATINUM AND GOLD PLANTS 54
2.3 POSSIBLE DSM LOAD SHIFT POTENTIAL ON A PLATINUM CONCENTRATOR 66
2.4 EXISTING RESEARCH ON DSM IN GOLD PLANTS 83
2.5 A NEW APPROACH TO IDENTIFY LOAD SHIFT POTENTIAL ON A GOLD PLANT 90
2.6 DISCUSSION OF RESULTS 115
2.7 CONCLUSION 116
2.8 REFERENCES 116

CHAPTER 3 ..... **120**

NEW SIMULATION PROCEDURES TO DETERMINE LOAD SHIFT VIABILITY ON MILLS **120**

3.1 INTRODUCTION 121
3.2 IDENTIFYING CONSTRAINTS FOR THE SIMULATION 121

3.3 GATHERING SYSTEM INFORMATION 122
3.4 DEVELOPING A NEW SIMULATION MODEL 123
3.5 INTERACTIVE USER INTERFACES 126
3.6 REFINING THE SIMULATION 130
3.7 CONCLUSION 133

CHAPTER 4 136

VERIFYING THE NEW SIMULATION MODEL 136

4.1 INTRODUCTION 137
4.2 GATHERING SYSTEM INFORMATION 137
4.3 SIMULATION SETUP 140
4.4 PRELIMINARY SIMULATION RESULTS 142
4.5 VERIFYING THE SIMULATION RESULTS 145
4.6 PROBLEMS ENCOUNTERED 149
4.7 LOAD SHIFT SIMULATION RESULTS 151
4.8 EXPLANATION OF DISCREPANCIES 161
4.9 CONCLUSION 162

CHAPTER 5 163

APPLICATION OF THE NEW METHODOLOGY AND SIMULATION MODEL 163

5.1 INTRODUCTION 164
5.2 GOLD PLANT 1 164
5.3 GOLD PLANT 2 168
5.4 GOLD PLANT 3 172
5.5 GOLD PLANT 4 176
5.6 CONCLUSION 182

CHAPTER 6 184

APPLICATION OF THE NEW METHODOLOGY AND SIMULATION MODEL IN OTHER INDUSTRIES 184

6.1 INTRODUCTION 185
6.2 OTHER INDUSTRIES THAT MIGHT BENEFIT FROM THE SIMULATION MODEL AND PROCEDURES 185
6.3 APPLICATION ON A CEMENT FACTORY 186
6.4 APPLICATION ON A CHROME PELLETIZER 197
6.5 CONCLUSION 205

6.6 REFERENCES 205

CHAPTER 7 208

CONCLUSION 208

7.1 OVERVIEW AND CONCLUSIONS 209
7.2 LIMITATIONS OF PROCEDURES AND SIMULATIONS DEVELOPED 211
7.3 RECOMMENDATIONS FOR FURTHER WORK 212

TABLE OF FIGURES

Figure 1: Growing usage of different energy sources [1.2]. 2
Figure 2: Energy usage projections in OECD and non-OECD countries [1.6]. 3
Figure 3: 2004 Spread of electricity supply sales in South Africa [1.65]. 8
Figure 4: Historic overview of the reserve margin [1.35]. 10
Figure 5: Historical overview of rising maximum demand [1.32]. 10
Figure 6: Forecast model showing the rising electricity demand vs the existing capacity [1.36]. .. 11
Figure 7: Demand curve for electricity usage on a typical day in South Africa [1.45]. 12
Figure 8: Illustrating the principle of DSM load management 13
Figure 9: The so-called MegaFlex circle, showing the different demand periods [1.43]. 14
Figure 10: 2006/2007 MegaFlex costs[1.43]. 14
Figure 11: Illustration of the Energy efficiency (EE) principle 15
Figure 12: Historical CFL sales figure [1.44]. 16
Figure 13: Percentages of different energy sources used in Anglo Platinum [1.53]. 20
Figure 14: 2007 Energy usage for Implats [1.54] 20
Figure 15: Distribution of worldwide gold suppliers [1.57]. 21
Figure 16: Gold mining cost comparison for different countries [1.57] 22
Figure 17: Gold mining energy cost comparison [1.57]. 22
Figure 18: Contributors to MD in the industrial, mining and agricultural sectors [1.60]. 24
Figure 19: Contributors to MD in the commercial sector [1.60] 25
Figure 20: Spread of contributors to MD in the residential secto [1.60].r 25
Figure 21: Spread of registered DSM projects [1.60]. 26
Figure 22: Simplified layout of a platinum concentrator 30
Figure 23: Picture of the milling circuit at a platinum concentrator 32
Figure 24: Picture of the flotation cells at a platinum concentrator 33
Figure 25: Simplified layout of a CIP gold plant 34
Figure 26: Typical layout of a system amenable to load shift 56
Figure 27: Overview of the typical motion of material in a SAG mill 57
Figure 28: Basic mill model used in determining the mill power equations 60
Figure 29: Graphic representation of mill running capacities vs installed capacities 62
Figure 30: starting and running torque comparison for a typical SAG mill 63
Figure 31: Torque vs Speed for a typical large ball mill [2.14]. 64
Figure 32: Simplified layout of the crushing and screening section 66

Figure 33: Illustration of the hourly tons on the overland conveyor 67
Figure 34: Hourly representation of ore being fed into the primary mill 68
Figure 35: Illustration of the overtaking capacity of the primary mill 69
Figure 36: Feed silo level reduction in case of crushing section breakdown 69
Figure 37: Crushing and Screening section baseline 71
Figure 38: C&S section Baseline vs Optimised Schedule 72
Figure 39: Simplified layout of the primary milling section 76
Figure 40: Primary mill baseline 77
Figure 41: Simplified layout of the secondary milling section 80
Figure 42: Secondary mill baseline 81
Figure 43: Breakdown of electrical usage on the gold plan in the Den Boef study. 83
Figure 44: Mill energy verification done by Den Boef 84
Figure 45: Thickener level as simulated by Den Boef 85
Figure 46: Desired RD levels compared to the values simulated by Den Boef 86
Figure 47: Elution column energy verification done by Den Boef 87
Figure 48: Thermal model of the kiln developed by Den Boef 88
Figure 49: Temperature verification using the developed mathematical model 89
Figure 50: Picture of an ES range boiler 91
Figure 51: Efficiency curve of an electrode boiler [2.13]. 92
Figure 52: Baselines for the electrode boilers 93
Figure 53: Electricity profile if boiler is switched off. 96
Figure 54: Breakeven analysis if electrode boilers are replaced completely 100
Figure 55: Breakeven analysis for using coal fired boilers in the peak times 101
Figure 56: Layout of the gold plant milling section 102
Figure 57: Mill 1 Baseline 106
Figure 58: Mill 2 Baseline 107
Figure 59: Maximum total load shift for mill 1 109
Figure 60: Maximum total load shift results for mill 2 109
Figure 61: Results of the volumetric percentage simulation 112
Figure 62: Actual thickener underflow tons on different days 113
Figure 63: Effect of the stopped mill on the RD of the thickener 115
Figure 64: Flow sheet of the simulation model developed 125
Figure 65: User interface for the mill tons and storage silo 126
Figure 66: Ore reception user interface 126

Figure 67: Maintenance stops user interface 127
Figure 68: Typical silo simulation result for the simulation model 127
Figure 69: User interface for the load shift hours 128
Figure 70: Interface that shows the tons milled 128
Figure 71: Silo level resulting from the simulation model 129
Figure 72: Trend line of the silo level simulation - showing the slope of the silo level 129
Figure 73: Results of the ENERGY SIMULATOR showing the baseline and optimised milling schedule 130
Figure 74: Results produced by the simulation to show the load shift of the specific application 131
Figure 75: Baselines of the four mills used in the verification of the simulation 140
Figure 76: Input values of the four mills for SIMULATOR 1 141
Figure 77: Tons received per mill as used in the simulation 141
Figure 78: Maintenance schedules of the four mills as used in the simulation 141
Figure 79: Silo level results for Mill 1 142
Figure 80: Silo level results for Mill 2 143
Figure 81: Silo level results for Mill 5 143
Figure 82: Silo level results for Mill 6 144
Figure 83: Comparison between actual and simulated downtime 145
Figure 84: Comparison between actual and simulated mill tons 146
Figure 85: Comparison between actual and simulated mill availability 146
Figure 86: Simulated vs actual silo levels for Mill A 147
Figure 87: Simulated vs actual silo levels for Mill B 148
Figure 88: Simulated vs actual silo levels for Mill C 148
Figure 89: Silo level simulation results for Mill 1 154
Figure 90: Silo level simulation results for Mill 2 154
Figure 91: Silo level simulation results for Mill 5 155
Figure 92: Silo level simulation results for Mill 6 155
Figure 93: Mill 1 Baseline after load shift 156
Figure 94: Mill 2 Baseline after load shift 157
Figure 95: Mill 5 baseline after load shift 157
Figure 96: Mill 6 Baseline after load shift 158
Figure 97: Mill 1 Baseline comparisons 159
Figure 98: Mill 2: Baseline comparisons 159
Figure 99: Mill 5 Baseline comparisons 160

Figure 100: Mill 6 Baseline comparisons 160
Figure 101: Baseline of a typical reef mill at Gold Plant 1. 165
Figure 102: Simulated silo level results 167
Figure 103: Baseline versus Optimised milling schedule for Gold Plant 1. 167
Figure 104: Baseline of a typical reef mill at Gold Plant 2. 169
Figure 105: Simulated silo level results for Gold Plant 2 170
Figure 106: Baseline versus Optimised milling schedule for Gold Plant 2 171
Figure 107: Silo level simulation results for Mill 1at Gold Plant 3 174
Figure 108: Silo level simulation results for Mill 2 at Gold Plant 3 174
Figure 109: Simulated optimised milling schedule for Mill 1 at Gold Plant 3 175
Figure 110: Optimised milling schedule for Mill 2 at Gold Plant 3 176
Figure 111: Baselines of the six mills at Gold Plant 4 178
Figure 112: Silo level simulation results for Mill 1 at Gold Plant 4 180
Figure 113: Baselines vs optimised milling schedules for the six mills at Gold Plant 4 181
Figure 114: The quarry operations of a cement plant 187
Figure 115: Typical raw mill on a cement plant showing the author for relative size 188
Figure 116: Typical silo found on a cement plant 189
Figure 117: The rotary kiln as seen from the exit end 190
Figure 118: Planetary coolers on a rotary kiln 190
Figure 119: Clinker silos on a cement plant 191
Figure 120: Basic differences between the milling circuits of a gold and cement plant 193
Figure 121: Baseline for the cement plant used in the simulation 194
Figure 122: Silo level simulation results for the cement plant 195
Figure 123: Baseline vs optimised milling schedule resulting from the simulation model 196
Figure 124: Placement of Chrome facilities in the bushveld complex 197
Figure 125: Basic layout of the pelletizing plant visited during the research 198
Figure 126: Chrome ore on the stockpile at the pelletizing plant 199
Figure 127: Ball mill at the pelletizing plant 200
Figure 128: Rotary kiln at the pelletizing plant 201
Figure 129: Picture of the chrome pellets as after exiting the kiln 201
Figure 130: Baseline of the mill on the pelletizing plant 202
Figure 131: Silo level simulation results for the pelletizing plant 203
Figure 132: Baseline vs optimised milling schedule resulting from the simulation model 204

LIST OF TABLES

Table 1: List of countries with DSM programs [1.16]. 7
Table 2: 2004 Energy footprint of Anglo Platinum 19
Table 3: Types of interventions on registered DSM projects 26
Table 4: Comparisons between installed and running capacities of SAG mills 62
Table 5: Specifics of the feed silo 68
Table 6: Crushing and Screening section baseline vs Optimised schedule 73
Table 7: Load shift and electricity cost savings fir the C&S section 73
Table 8: Breakdown of equipment electricity usage 84
Table 9: Equipment breakdown in the elution and regeneration section 86
Table 10: Equipment breakdown in the compressor section 90
Table 11: Specifications of the ES 130 boiler 91
Table 12: Annual electricity cost for running an electrode boiler 94
Table 13: Annual electricity cost of running all five electrode boilers 94
Table 14: Cost comparison of using different alternative fuels 95
Table 15: Energy cost for using coal boilers 95
Table 16: Total annual energy cost savings from using coal fired boilers 95
Table 17: Electricity cost savings if boiler is switched off. 97
Table 18: Cost of using alternative fuel boilers for six hours every weekday 98
Table 19: Actual energy cost saving per boiler if coal is used during the evening peak 98
Table 20: Total annual electricity cost for the electrode boilers 98
Table 21: Total annual energy costs per coal boiler 98
Table 22: Total annual energy cost savings 99
Table 23: Payback period calculation results 100
Table 24: Payback period calculation results 100
Table 25: Values used in the savings calculations for mills 1 and 2 110
Table 26: Savings results for mills 1 and 2 110
Table 27: Thickener in and outflows 114
Table 28: Questionnaire used to gather system information 123
Table 29: Values of both the baseline and optimised schedule to show that the results are energy neutral 131
Table 30: Typical results of the MEGAFLEX SIMULATOR, showing the rand savings achieved over a year 132

Table 31: Typical optimised milling schedule calculated by the simulator 133
Table 32: Questionnaire with data gathered from the plant for the simulation 138
Table 33: Comparison of target vs actual production figures on the mills 139
Table 34: Comparison between actual and simulated results on the plant 145
Table 35: Summary of the accuracy of the various simulation results 146
Table 36: Comparison between the total simulated and actual tons milled 149
Table 37: Comparison between actual and simulated average silo levels 149
Table 38: Production details used as input to the simulation 153
Table 39: Optimised milling schedule for the plant as created by the MILLING SCHEDULE SIMULATOR 156
Table 40: Accuracy comparison between actual and simulated load shift 161
Table 41: Electrical capacities of Gold Plant 1 mills 165
Table 42: Gold Plant 1 plant production details. 166
Table 43: Summary of savings for all the mills 168
Table 44: Electrical capacities of Gold Plant 2 mills 169
Table 45: Gold Plant 2 production details 170
Table 46: Electrical capacities of Gold Plant 4 mills 172
Table 47: Production details for Mill 1 at Gold Plant 3 173
Table 48: Production details for Mil 2 at Gold Plant 3 173
Table 49: Installed vs running capacities of the mills at Gold Plant 4 177
Table 50: Production details for Gold Plant 4 179
Table 51: Summary of the savings obtained on the six mills of Gold Plant 4 181
Table 52: Breakdown of ownership of cement companies in South Africa 186
Table 53: Production details for the cement plant 194
Table 54: Summary of savings achieved on the cement plant 196
Table 55: Production details of the pelletizing plant 203
Table 56: Summary of the savings that can be achieved on the pelletizing plant 204

LIST OF EQUATIONS

Equation 1: Elsner equation of gold reacting with cyanide 36
Equation 2: Equation for critical speed of a mill 58
Equation 3: Gross power of a cylindrical mill 59
Equation 4: Power draw of the cylindrical section 60
Equation 5: Power draw of the conical end-sections 60
Equation 6: No-Load power draw 61
Equation 7: Time required to speed up a mill from standstill to design speed 64
Equation 8: Bond total work equation 70
Equation 9: Reduction of Bond total work equation 71
Equation 10: Energy balance equations to simulate the regeneration kiln 88
Equation 11: Equation to calculate the volumetric % of solids in gold slurry 111

LIST OF ABBREVIATIONS

OECD	Organization for Economic Cooperation and Development
Mtoe	Million Tons of Oil Equivalent
US	United States
DSM	Demand Side Management
RTP	Real-Time Pricing
TOU	Time of Use
DG	Distributed Generation
EST	Energy Saving Trust
PV	Photovoltaic
EE	Energy Efficiency
GWh	GigaWatt hour
MWh	MegaWatt hour
GDP	Gross Domestic Product
DME	Department of Minerals and Energy
ISEP	Integrated Strategic Electricity Planning
CFL	Compact Fluorescent Lamps
DMP	Demand Market Participation
SSM	Supply-Side Management
CCGT	Combined Cycle Gas Turbine
OCGT	Open Cycle Gas Turbine
LNG	Liquefied Natural Gas
ESCO	Energy Service Company
M&V	Measurement & Verification
JSE	Johannesburg Stock Exchange
VSD	Variable Speed Drive
MW	Mega Watt
ROM	Run of Mine
DMS	Dense Media Separation
PGM	Platinum Group of Metals
RD	Relative Density
CIP	Carbon in Pulp
HCL	Hydrochloric Acid
CIL	Carbon in Leach
C	Celsius
RPM	Revolutions per Minute
SAG	Semi-Autogenous Grinding
kW	Kilo Watt
µm	Micro meter
SCADA	Supervisory Control and Data Acquisition
NPC	Natal Portland Cement
FeCr	Ferrochrome
PJ	Peta Joule

CHAPTER 1

INTRODUCTION

1.1 WORLDWIDE RISING ENERGY DEMAND

Over the past few decades, energy has become a much talked about topic. The reason for this is that the demand for natural resources continues to climb, even as these resources are being depleted by over usage. According to Price Waterhouse Coopers the world's energy demand is expected to rise by two-thirds between 2003 and 2030 [1.1]. By then, global electricity sector investments are expected to reach US$10 trillion – three times higher than the investment in the electricity sector during the past 30 years [1.1]

This presents an annual growth rate of 1.6%. By 2030, the world will be consuming 16.3 billion tonnes of oil (Mtoe) equivalent [1.2]. This growth is shown in the following figure, highlighting the contribution of different energy sources:

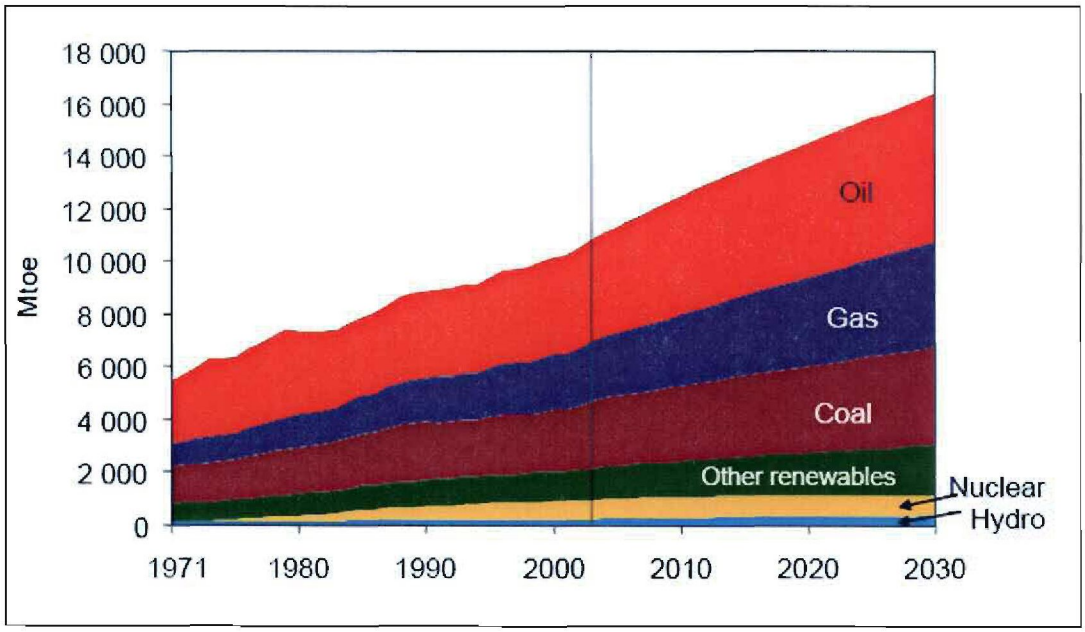


Figure 1: Growing usage of different energy sources [1.2].

Fossil fuels will continue to dominate energy supplies, meeting more than 80% of the projected increase in energy demand. Oil remains the single most important fuel, with two thirds of the increase in oil use coming from the transport sector [1.2]. The vertical line in Figure 1 is indicative of the year the figure was published, circa 2003.

A large portion of the world's energy demand is from developed countries. A good example is the United States that is home to 4% of the world's population, but uses 25% of the world's energy [1.3].

The rising energy demand is not only a problem typical of first world countries. Various other developing countries are also starting to make a marked impact on the energy situation of the world. The increased demand for energy is a natural consequence of economic growth and higher standards of living in these countries [1.4]. In the IEO2006 mid-term outlook, countries outside the Organization for Economic Cooperation and Development (non-OECD countries), account for 70% of the increase in world energy use [1.5].

The non-OECD countries with the largest impact on the rising energy demand are mostly found in Asia, the Middle East, Africa and Central and South America. Previously people used to burn wood for domestic purposes, but the influx of electric appliances has created a situation where even relatively poor people are moving towards electricity for domestic use. Even though expanding use of home appliances also results in increased demand for electricity in developed countries, their more mature infrastructures and slower rates of population expansion, result in slower growth of total net electricity consumption [1.5].

As such, the non-OECD countries are expected to overtake the OECD countries in the developed world regions like North America and Europe in terms of energy use by 2010 [1.6] . This energy demand is expected to continue climbing in the future, as shown in the figure below:

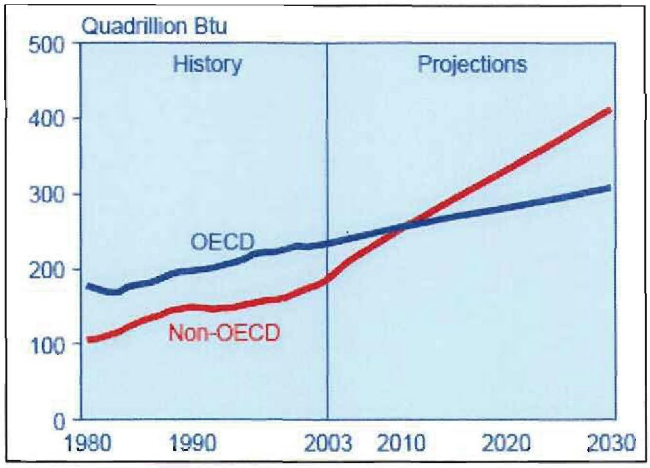


Figure 2: Energy usage projections in OECD and non-OECD countries [1.6].

The vertical line in the figure is indicative of the year the figure was published, namely 2003.
This enormous increase in energy demand has led to attempts by various countries, to control their energy usage in order to ensure sustainable development. The following sections describe some of the initiatives that have been launched in various parts of the world.

1.2 INTERNATIONAL ENERGY MANAGEMENT INITIATIVES

1.2.1 INITIATIVES IN THE UNITED STATES

Energy management is not new in the world, and has enjoyed attention for at least 40 years. For example, Energy Efficiency first appeared as a policy in the United States during the 1970's. This was sparked by rising electricity demand, prices and capital costs [1.7]. As a result, the US has adopted various mechanisms to reduce energy consumption and reach efficiency targets. These include the following on the demand side:

ENERGY EFFICIENCY STANDARDS

Energy Efficiency standards for major appliances and equipment have been successfully implemented, and have shown significant demand reduction over the long term [1.7].

DEMAND SIDE MANAGEMENT

Demand Side Management (DSM) strategies were commonly pursued in the 1980's and 1990's. There were often state-sponsored incentives to encourage their adoption. In the mid-1990's, many companies cut back on DSM spending due to the restructuring of the electricity industry [1.8]. Currently, however, the deregulation of the electricity industry enables the return of previously successful DSM strategies into industry.

TIME-OF-USE (TOU) AND REAL-TIME PRICING (RTP)

One way to improve reliability in electricity markets is to expose customers to Time-of-Use (TOU) or Real-Time Pricing (RTP). This will motivate customers to decide how much electricity to consume and when. This is due to the higher price of electricity during peak times, which will most likely result in consumers adjusting their electricity consumption to the lower priced times, also known as off-peak times [1.7].

INTERRUPTABLE LOADS AND LOAD BIDDING

This has been confined mostly to large industrial customers who pay a reduced rate in exchange for agreeing to have their electricity supply shut off in times of high demand and low capacity [1.7]. This is not yet viable for small end users because of the higher electricity tariffs they have to pay. It has been suggested that these users will also participate in interruptible load programs, if a

lower tariff incentive program is offered to them [1.9].Various initiatives have also been undertaken on the supply side. These are the following:

DISTRIBUTED ENERGY GENERATION AND RENEWABLE ENERGY

Distributed Generation (DG), is defined as electricity generation close to the point of consumption. A typical example of this is generators installed by companies to cope with increased demand or power cuts from normal utilities. There is great interest in DG technologies in areas where demand is already high [1.10].

Another initiative is the non-polluting renewable energy sources that can help to offset peak loads. Examples of this can be found in the 1996 power outages in California, where solar photovoltaic (PV) cells were used to offset outages caused by air conditioner-driven loads during the heat wave [1.11].

IMPORTS

A current trend in the US is to interconnect with neighbouring utilities. This permits the sharing of resources, which reduces the amount of extra generating capacity each utility has to maintain. For Example, the states of California and New York, are importing electricity as their demand exceeds the available supply [1.7] [1.12].

BENCHMARKING

Benchmarking was developed as an analytical method of comparing indicators of one electricity supplier with another. Key indicators are developed for the industry, therefore allowing different utilities to have a better understanding of their own cost structures. This indicates where the specific company might improve on efficiency, thereby moving towards the greater goal of energy saving [1.7].

MAINTENANCE

Traditionally, maintenance has played a key role in increasing the efficiency of power suppliers. The role of adequate maintenance cannot be underestimated, since nearly 30% of all transmission system disturbances in the US since 1984, can be attributed to equipment failure of some sort [1.13]. It is also important to coordinate maintenance schedules with demand forecasts in order to ensure adequate generation when most needed.

1.2.2 INITIATIVES IN THE EUROPEAN UNION

Currently, the council of the European Union is in the process of drafting a "*Directive on Energy Efficiency - Demand Side Management*". The purpose of this document is to get all the members of the union to achieve a certain level of energy efficiency improvements through Energy Efficiency – Demand Side Management programs. It would remain the choice of the member state as to which mechanisms to adopt to achieve these goals.

The target cited in this document is a minimum year-on-year reduction in energy use of one percent (1%). There is also a minimum required investment by each member state in various EE-DSM initiatives as a percentage of net revenue gained from sales of electricity and natural gas [1.14].

1.2.3 INITIATIVES IN THE UNITED KINGDOM

In 1992, the United Kingdom established an independent, non-profit Energy Saving Trust (EST). The purpose of the EST is to design and oversee various DSM programs. The primary mandate was to reduce carbon dioxide emissions through DSM and Energy Efficiency.

From 1992 to 1995, the UK power sector invested in more than 500 energy efficiency projects. This produced an estimated saving of 6,800 GWh. The total cost of these projects was in the order of US$ 165 million. The UK also implemented an Utilities Act in 2000, which requires from gas and electricity suppliers to meet specific energy efficiency targets. This is monitored by the government regulator [1.15].

CONCLUSION

The examples cited in this section were included to inform on some of the DSM achievements in some of the larger countries of the world. However, there are many countries that have successfully implemented DSM strategies. The following list names but a few [1.16]:

LIST OF COUNTRIES WITH DSM PROGRAMS			
Argentina	Hong Kong	Netherlands	Spain
Australia	India	New Zealand	Sri Lanka
Belgium	Indonesia	Norway	Sweden
Brazil	Ireland	Peru	Taiwan
China	Italy	Philippines	Thailand
Denmark	Japan	Singapore	United Kingdom
France	Malaysia	South Africa	USA
Greece	Mexico	South Korea	Vietnam

Table 1: List of countries with DSM programs [1.16].

1.3 THE ENERGY SITUATION IN SOUTH AFRICA

Even though South Africa is seen as a developing country [1.17], its energy consumption as measured against output (GDP) is very high compared to its global competitors. The industrial sector is the largest user of energy and electricity in South Africa, with a total of 68%, while the rest of the usage is made up by the residential, mining, transport, agricultural and commercial sectors [1.1] .

This distribution of energy usage is caused by the energy intensive economy of South Africa that requires a large amount of energy for every Rand of value added [1.18]. Most of South Africa's energy is obtained from coal, which contributes about 70% of primary energy [1.19]. Local coal is abundant and cheap, resulting in low energy costs, particularly for electricity, which is the cheapest in the world [1.17].

Some energy is also obtained form biomass, nuclear power, hydropower, natural gas and wind. [1.20]. Most of the primary energy is turned into final energy, such as electricity and liquid fuels. In 2005, the country's final energy demand was estimated to be 2400 PJ [1.21]. This is in the process of changing as the renewable energy white paper of 2002 sets a target of 10,000GWh of renewable energy sources by 2013 [1.22]. The use of this low cost energy has provided South Africa with a competitive advantage, which encouraged the growth of energy-intensive industries such as aluminium smelting and mining [1.23][1.24].

South Africa also owns various mineral deposits such as gold and platinum. Due to the presence of these resources in South Africa, the economic development of the country has focused, to a great extent, on the extraction and processing of these resources. These industries, by their very nature, are very energy intensive [1.25]. This has created the need for extensive energy supply

infrastructure, the main form of which is the electricity supply network provided by ESKOM [1.26].

By the early 1990's, Eskom supplied 98% of the electricity in South Africa, with a nominal generating capacity of 39154 Megawatts from 20 power stations [1.27]. The other 2% was provided by a few mines and other industries that had their own generation capabilities. By 1999 Eskom accounted for 95.7% of generating capacity in South Africa, while some municipalities provided 1.5 %. The remaining 2.7 % was filled by private generators [1.28]. By 2004, the sales from this network had the spread shown in the following figure [1.65]:

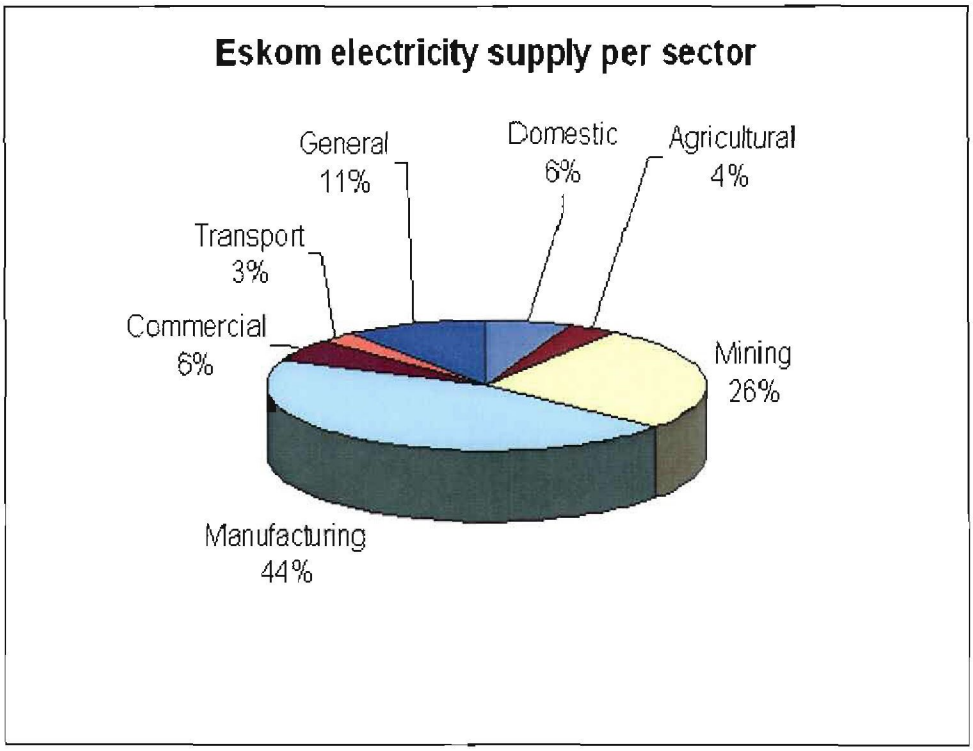


Figure 3: 2004 Spread of electricity supply sales in South Africa [1.65].

The mining, manufacturing and domestic sectors constitute almost 81 % of South Africa's total electricity sales. According to a 2001 estimate of electricity generators in South Africa, the generation capacity in this country was still mainly supported by coal at that stage, followed by nuclear and hydro/pumped storage. Gas, as a source of generation, is very absent in South Africa when compared to the rest of the world [1.29].

1.4 THE GROWING ELECTRICITY DEMAND IN SOUTH AFRICA

1.4.1 INTRODUCTION

As part of the reconstruction and development program started by the South African government in 1994, the national electrification programme is currently receiving much attention. This programme is implemented in terms of the White Paper on Energy Policy [1.30] [1.31]. The goal of this policy is to provide every household in the country with at least basic electrification.

The practical implementation of this has proven to be successful, as there has been an overall increase in electrified households from 50% in 1995, to 69% in 2003 [1.29]. During 2006, Eskom has exceeded their electrification targets by connecting 106,968 new customers [1.32]. The largest proportion of this increase has been focused in rural areas, where the increase was from 21% in 1995, to 54% in 2003.

In urban areas, a smaller growth was experienced, with 76% electrification in 1995, compared to 79% in 2003 [1.29]. Even though the goal of total electrification is a noble one, there have been some concerns regarding the increasing demand it creates on existing electricity supply infrastructure. According to Nortje [1.33], electricity consumption in South Africa is currently growing at approximately 1000 MW per annum. In the past, electricity demand increase in South Africa was addressed by the erection of large (3000 – 3600 MW) pulverised coal-fired power stations [1.34].

Investment in these power stations ensured an adequate reserve margin of electricity in the country. This was especially true in 1993, when the reserve margin was approximately 40% due to over-investment in this area. After the electrification program was started in 1994, the reserve margin began decreasing due to increased demand. As such, the margin was approximately 20% by 1999 [1.35]. The historic overview of the reserve margin is shown in the following figure:

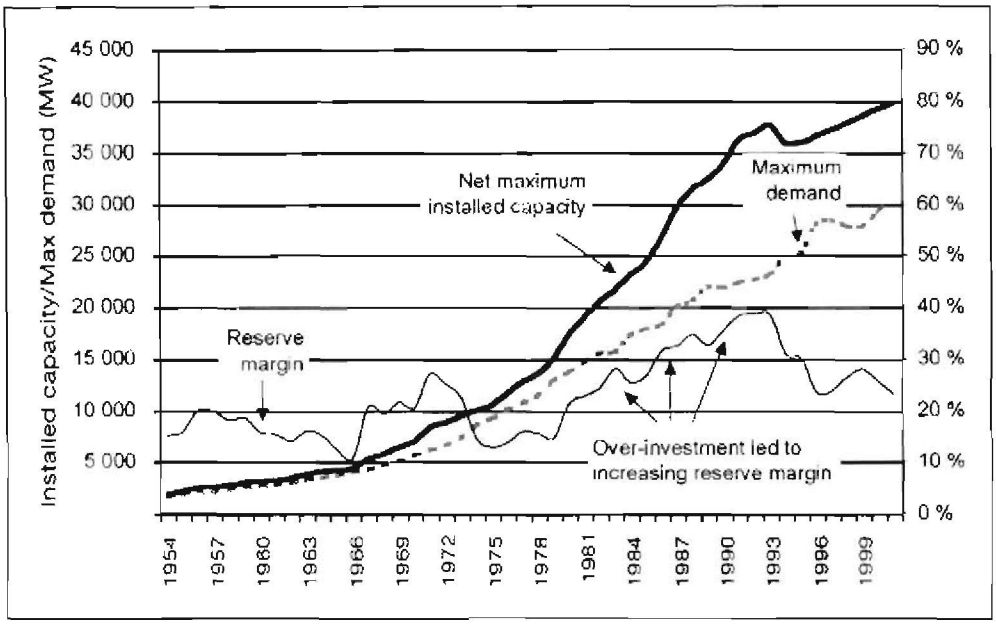


Figure 4: Historic overview of the reserve margin [1.35].

In the figure, the left-hand vertical scale is the installed capacity/maximum demand, while the right-hand vertical scale is the reserve margin available. Unfortunately, no new power stations have been erected in the past few years to cope with the growing demand for electricity. ESKOM has been aware of this problem for quite some time, and various studies have been done to predict the future demand for electricity. By studying the historic demand overview, it can be seen that it was expected that the peak demand will get very close to the operational capacity by 2005 and 2006[1.32]. This is shown in the following figure:

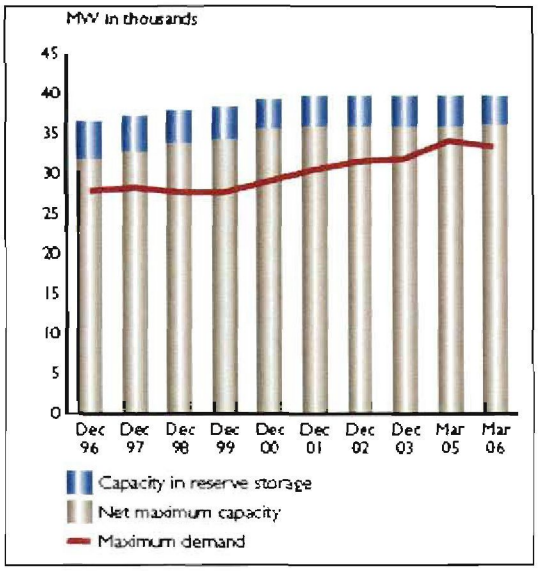


Figure 5: Historical overview of rising maximum demand [1.32].

Another such study has been done by R.M. Surtees [1.36]. The results of this study predict that the demand will actually start to overtake the demand in the winter of 2007. The result of this model is shown in the following figure:

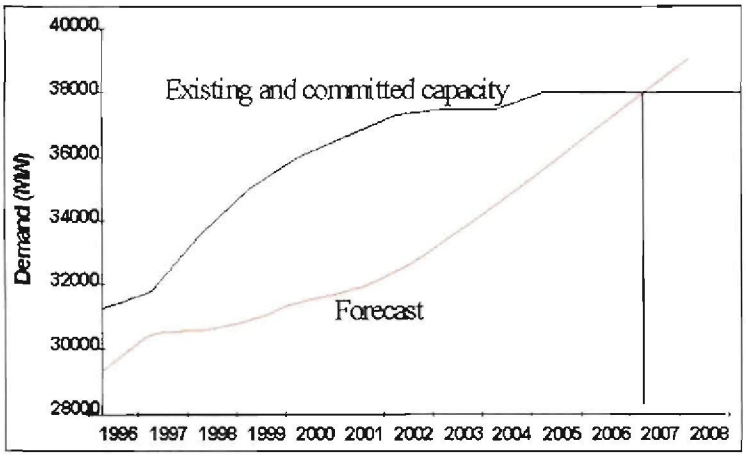


Figure 6: Forecast model showing the rising electricity demand vs the existing capacity [1.36].

This situation has been driven home quite unexpectedly by the power supply interruptions in the Western Cape Province during 2006. These interruptions occurred because of damage to the rotor and stator of unit 1 of Koeberg nuclear power station. Unfortunately this occurred almost at the same time as a refuelling outage of unit 2 of Koeberg [1.37].

This has shown how precariously close the balance between supply and demand has become in South Africa. This is especially true in the Western Cape, since Koeberg is the only base load power station in the province. This creates a greater vulnerability to network incidents in this province [1.37]. In spite of these problems, the Department of Minerals and Energy (DME), is still confident that it will reach the following savings goals in different industries by 2015 [1.31] [1.38]:

- Industry and Mining – 15% final energy demand reduction
- Power Generation – 15% reduction in parasitic electrical usage
- Commercial and Public Sector Buildings – 15% final energy demand reduction
- Residential Sector – 10% final energy demand reduction
- Transport Sector – 9% final energy demand reduction

1.4.2 PEAKS IN THE ELECTRICITY DEMAND CURVE

As a result of the increase in electricity supply to domestic users, there has necessarily been an increase in the amount of electrical appliances used in these areas [1.39]. The most common users are electric stoves, lights and geysers. These appliances are mostly used in the mornings when

people are getting ready for to work, and in the evenings when people are at home, preparing food, taking baths or showers, or watching television.

As a result of this type of usage, two prominent peaks are formed in the daily demand curve – one in the morning between 07:00 and 10:00, and one in the evening between 18:00 and 20:00. A graphic presentation of the demand curve of a typical day is shown in the following figure:

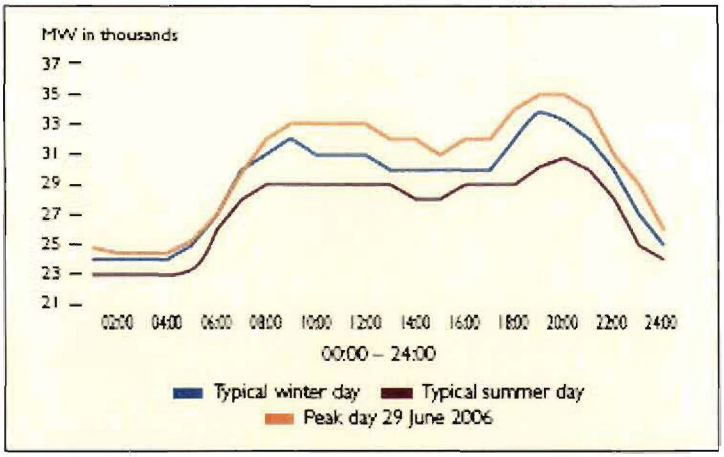


Figure 7: Demand curve for electricity usage on a typical day in South Africa [1.45].

Even though the values on the above figure were current for 2006, it still serves to illustrate the typical daily demand profile for South Africa. The peaks are also higher in winter, because of an extra load due to domestic heating requirements [1.29] [1.40]. The peaks are also higher during weekdays than during weekends [1.39].

1.5 ENERGY MANAGEMENT INITIATIVES IN SOUTH AFRICA

1.5.1 THE ENERGY PLAN

The White Paper on the Energy Policy of the Republic of South Africa has been instrumental in providing a plan for the intelligent use of energy resources in the country. The paper has been used as a guideline for the Integrated Strategic Electricity Planning (ISEP) process [1.36]. This process is intended to provide the strategic framework for projections of supply-side and demand-side options that will need to be implemented to meet future energy needs [1.41].

1.5.2 ENERGY MANAGEMENT INITIATIVES – SHORT TERM

LOAD MANAGEMENT

As part of the ISEP process, Demand Side Management (DSM), is seen as a short to medium term solution to the energy crisis in South Africa. DSM is described as the scheduling and implementation of different activities to influence the time, pattern and amount of electricity consumption in such a way that it produces a change in the load profile of the industry, while still maintaining customer satisfaction [1.42].

Typical examples are load management programmes within the industrial and commercial sectors of South Africa. The different concepts can perhaps be better illustrated in graphical form. The first figure illustrates the load management principle:

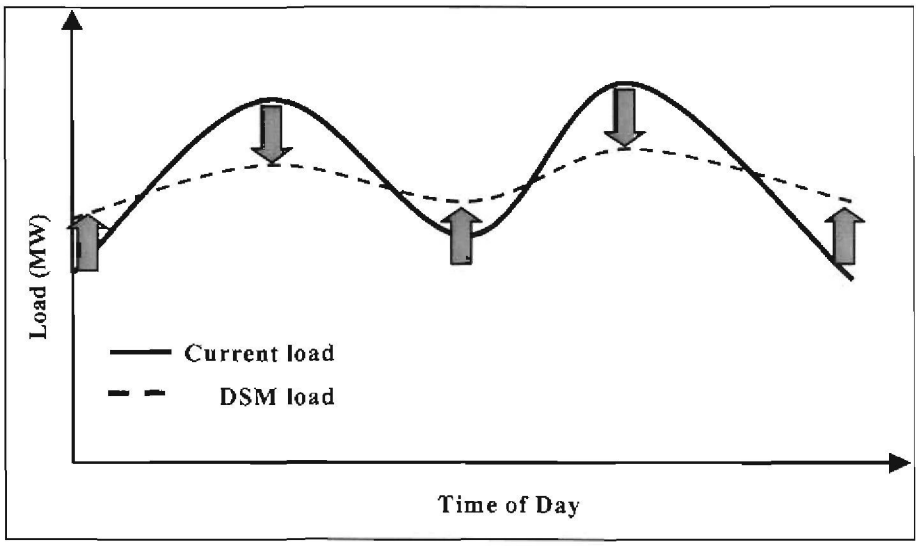


Figure 8: Illustrating the principle of DSM load management

As can be seen from the figure, the purpose of load management is to shift electricity usage from the morning and evening peaks, to other times of the day. This has the effect of flattening the daily demand curve and preserving a greater reserve margin in the supply grid. There are various ways in which Eskom tries to encourage its large customers to adapt this kind of initiative. The most common way probably is introducing Time-of-Use (TOU) tariff structures like MegaFlex.

This tariff structure is divided into three periods namely: peak, off-peak and standard. All of these occur on the typical weekday, while the peak times are dropped on Saturdays and Sundays. There also are no standard times on Sundays. The different periods are also priced accordingly, with peak time in the winter being the most expensive time for electricity use, and off-peak in the summer being the cheapest. Industries on the MegaFlex tariff then has the option to save significant

amounts on their monthly electricity bill, by simply adhering to the fixed off-peak and standard times. The following figure shows the MegaFlex periods for a typical week:

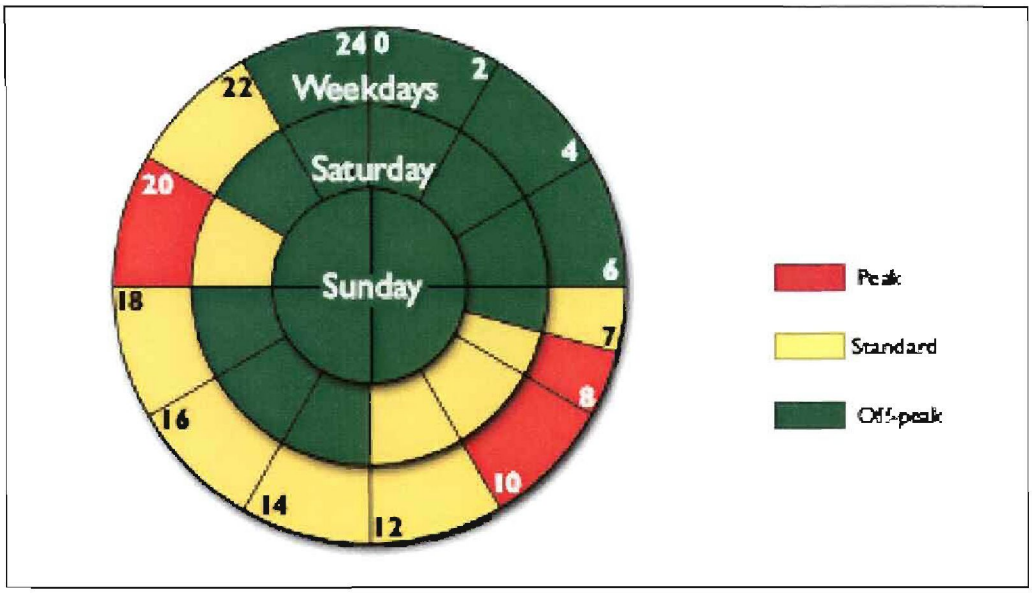


Figure 9: The so-called MegaFlex circle, showing the different demand periods [1.43].

For the period from 1 April 2006 to 31 March 2007, the active energy charge for the MegaFlex Structure was the following [1.43]:

High-demand season (June – August)		Low-demand season (September – May)
52,22c + VAT = **59,53c/kWh**	Peak	14,82c + VAT = **16,89c/kWh**
13,81c + VAT = **15,74c/kWh**	Standard	9,20c + VAT = **10,49c/kWh**
7,51c + VAT = **8,56c/kWh**	Off-peak	6,52c + VAT = **7,43c/kWh**

Figure 10: 2006/2007 MegaFlex costs[1.43].

As part of the DSM programme, Eskom has made available funds to increase the viability of supporting this programme. From these funds, industrial and commercial customers are incentivised to participate in DSM by funding the capital required to do the necessary conversions to equipment and/or buildings. For load management, Eskom funds all the capital expenditure [1.37].

ENERGY EFFICIENCY

Energy efficiency (EE), on the other hand, designed to improve overall efficiency and reduce consumption, only receives 50% of the funding for a project [1.37]. The following figure shows the typical reducing result of implementing an energy efficiency project:

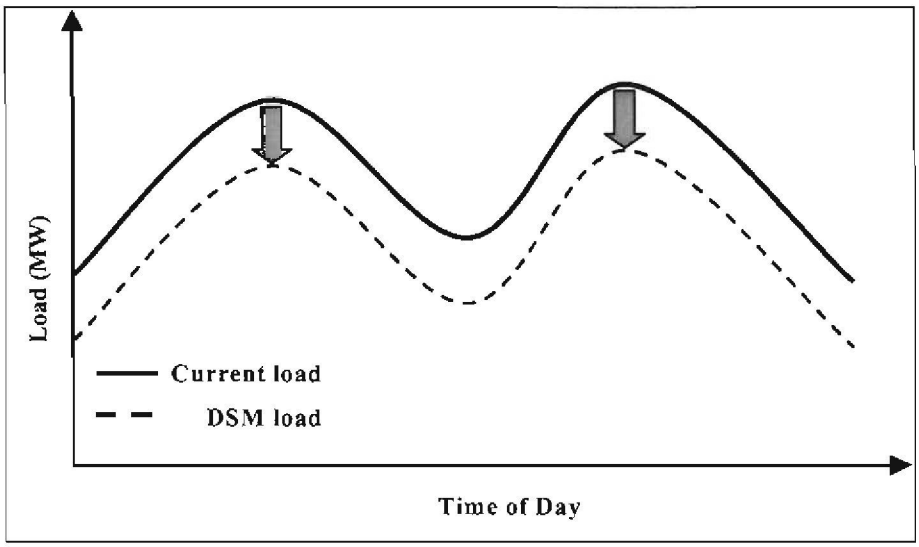


Figure 11: Illustration of the Energy efficiency (EE) principle

As can be seen, the entire load is dropped, therefore reducing the total demand profile of the specific installation. A typical EE success story in South Africa includes a major project of 2005 in the residential sector. This project focused on the distribution of approximately 3 million compact fluorescent lamps (CFL's) in order to reduce peak electricity demand [1.37].

Research done by Venter and Van Der Walt showed that the sale of CFL's in South Africa has increased considerably over the past decade. Savings calculated from the usage of these CFL's were calculated to be approximately 18.6 MW by mid 2005 [1.44]. The following figure shows the historical sales figures for the CFL's in terms of units sold per year:

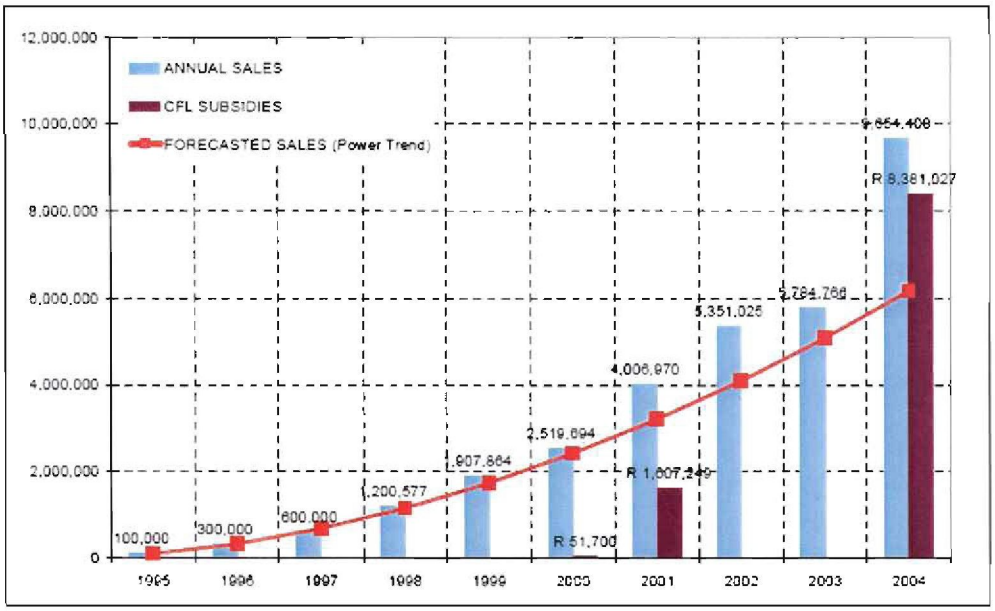


Figure 12: Historical CFL sales figure [1.44].

DEMAND MARKET PARTICIPATION

Another short term plan implemented by Eskom is known as the Demand Market Participation (DMP) programme. This programme allows industrial clients to effectively become a virtual power station by offering their load reduction to the power pool. Compensation is calculated in terms of scheduled hours and MWh reduction [1.37].

1.5.3 MEDIUM TERM PLANS

OPEN CYCLE GAS TURBINES (OCGT)

At the time of writing, there were two liquid fuel (OCGT) plants being built in Atlantis and Mosselbay. These plants will be used primarily for peaking capacity and will have a capacity of approximately 500 MW each.[1.37]. Four units were already in commercial operation by 31 March 2007 [1.45].

MEDIUM TERM DSM

These are mostly additional measures implemented to compliment the existing short term DSM programme. These measures include solar water heating, cogeneration and residential TOU tariffs to allow dynamic control of residential power loads [1.37] [1.1].

1.5.4 LONG TERM PLANS

BASE LOAD

According to the ISEP, Supply Side Management includes the activities required to identify, evaluate, optimally select, implement and monitor the different options for the future generation of electricity to meet customer demand [1.41].

These are not simple goals, as it includes the building of new base load power stations, an exercise which can easily cost in the order of R40 billion for an extra 4000 MW in the grid. It is also a very lengthy process [1.46]. As an alternative or possibly as an addition to this, Eskom has commissioned the return to service of three mothballed power stations. These are the following: Camden (1600 MW), Grootvlei (1200 MW), and Komati (1000 MW).

The cost of this refurbishment was estimated at approximately R12 billion for a total of 3800 MW of power [1.46] [1.47]. At the end of 2006, only about 190 MW has been commissioned on these three plants. By the middle of 2007, this figure has risen to 772 MW [1.45].

Longer term (2007-2010) plans include the construction of new base load (1800 MW) and/or mid-merit (2400 MW) plants. Possible projects include the Coega combined cycle gas turbine (CCGT), and possibly a CCGT plant at Saldanha. These plants will operate on liquefied natural gas (LNG) [1.37].

1.5.5 THE ROLE OF ESCO'S

Energy Service Companies (ESCO's), are a large part of the emerging energy market in South Africa. These are companies who make it their business to sell energy services, usually energy management activities. The goal is to achieve energy savings for the client [1.31].

In order to implement a DSM project, an ESCO normally works in partnership with the electricity supplier or regulatory body, and the consumer [1.48]. For a typical project, the ESCO will introduce the prospective client to the DSM process. If the client is interested, the ESCO will continue with the following steps for a successful DSM project [1.49]:

- Perform a Site Audit on the facility of the client
- A detailed project proposal of potential successful projects is submitted to Eskom DSM

- The proposal is evaluated by Eskom DSM
- Funding is approved for the project implementation
- Metering and Verification (M&V) investigates the potential savings of the project
- Implementation and commissioning of the project by the ESCO
- Measurement of realised savings after commissioning
- Feedback of realised MW savings to Eskom DSM

These projects can either be load management or energy efficiency projects, depending on the type of facility and funding required by the specific project. In South Africa, ESCO progress is monitored by a body called Measurement & Verification (M&V). The purpose of this body is to ensure that the ESCO has followed proper procedures in calculating possible DSM potential at different consumers.

M&V will also keep a performance assessment record of each DSM project after commissioning in order to ensure that the projected results are met by the ESCO. This DSM process has proven itself over the past few years in South Africa and the world, and will most likely continue to play an important role in the future of energy management.

1.6 THE ROLE OF THE MINING INDUSTRY

1.6.1 ENERGY USAGE IN THE SOUTH AFRICAN MINING INDUSTRY

INTRODUCTION

As shown earlier in this document, South Africa is a country with an intense involvement in the mining industry. Because the economy is so dependant on heavy industry and mining, South Africa has one of the largest energy intensities in the world. In fact, there are only 10 other countries that have higher commercial primary energy intensities [1.50].

The mining industry accounts for approximately 6% of South Africa's total energy usage. On average, electricity supplies 67% of the mining industry's total energy demand, with coal at 19% and petroleum products at 13% [1.51]. If historical figures are quoted, it is found that the industry purchased 33,372 GWh of electricity from Eskom in 2003. By 2005, this electricity consumption by the industry has increased by nearly 22% to 40,557 GWh [1.51].

The industry is a key player and the various impacts it has on the economy as a whole should not be underestimated. From 1995 to 2004, the following figures can be quoted for the mining industry [1.52]:

- 9.5% of all fixed investments and 40% of market capitalization on the JSE.
- 6.8% of the GDP
- 34% of merchandise exports
- 7% of non-agricultural formal employment

This research was focused primarily on the precious metals industry in South African mining. Even though this encompasses various types of metals, the research was focussed on gold and platinum mining in particular. As such, the following sections are dedicated to the use of energy, and especially electricity, in these facilities.

ENERGY USAGE IN PLATINUM MINING

The mining of the Platinum Group of Metals (PGM's) is a complicated and involved series of processes. These processes include mining, concentration, smelting and refining. A study was done by Anglo Platinum in 2004 to determine the energy footprints of their operations. The following table summarizes the results of this study [1.53]:

Facility	Typical Equipment	Electricity	Liquid Fuel	Coal	Gas
Mines	Compressed air, ventilation fans, winders, fridge plants, pumps	8.25 PJ	2.03 PJ		
Concentrators	Milling, Flotation, Tailings. Crushing	4.87 PJ			
Smelters	Furnaces, Flash Dryers, ACP	3.97 PJ		1.46 PJ	0.23 PJ
Refineries	Liquid Pumping, Tank house, Compressors, Boilers	0.91 PJ	0.10 PJ	1.32 PJ	0.04 PJ
TOTAL		**18 PJ**	**2.13 PJ**	**2.78 PJ**	**0.27 PJ**

Table 2: 2004 Energy footprint of Anglo Platinum

By extracting the above results into a more usable form, the following graph was drawn to indicate the percentages of the different types of energy used at Anglo Platinum facilities:

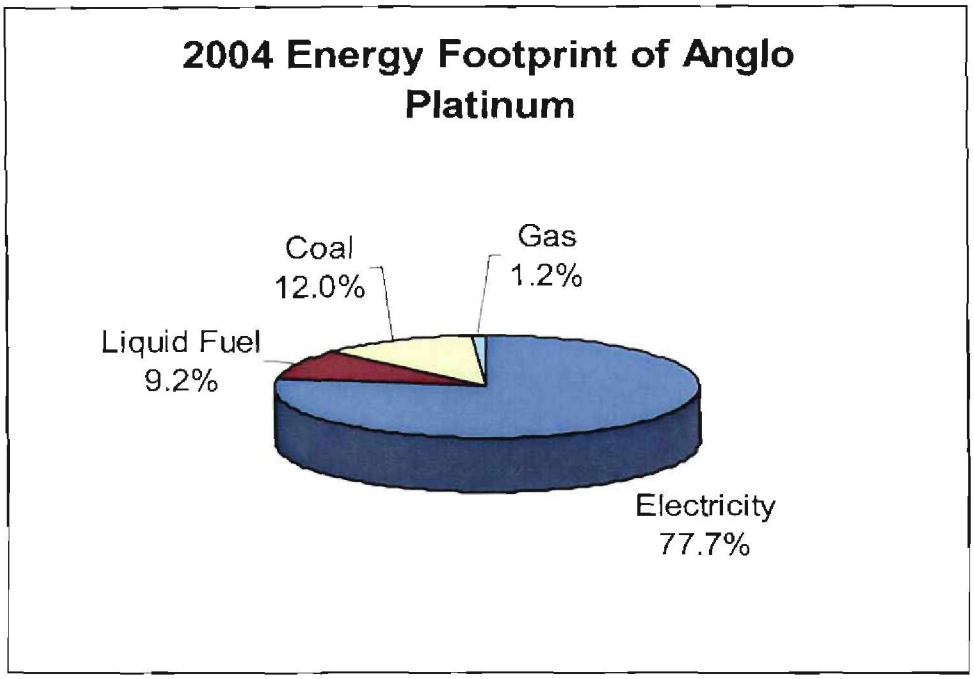


Figure 13: Percentages of different energy sources used in Anglo Platinum [1.53].

It can be clearly seen that electricity is the largest contributor of energy by a wide margin. Similar results can be found for Implats in the Annual Report for 2007. This report indicates that the total energy usage for the Implats group was 157 PJ in the 2007 financial year [1.54]. The following graph provides a summary of the percentages that different fuel types contributed to the total energy usage:

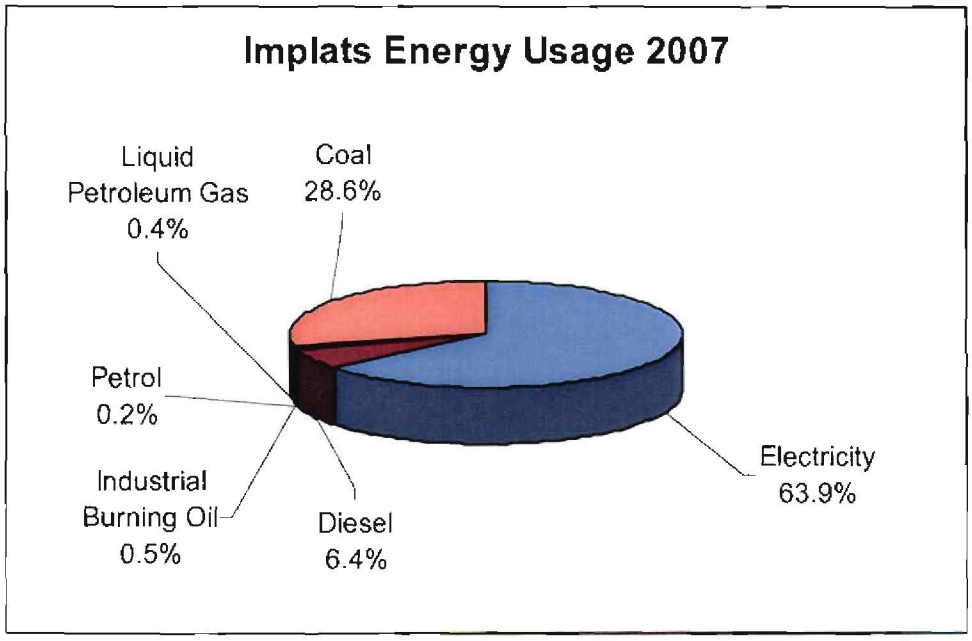


Figure 14: 2007 Energy usage for Implats [1.54]

If the results for Anglo Platinum and Implats are compared, it can be seen that electricity is the major supplier of energy in both companies. Platinum mining currently has one of the highest demands for growth in electricity consumption. According to Howells [1.55], the demand is expected to increase by 115% from 2003 to 2020. As such, it can be expected that platinum mining will play an important part in the energy future of South Africa.

ENERGY USAGE IN GOLD MINING

Between 1970 and 2001, the energy required to run a South African gold mine efficiently has increased considerably. The main reason for this is because the ore grade has been decreasing steadily over this time. This required that mines be made deeper in search of new gold. This declining grade also means that more ore needs to be processed in order to obtain a ton of gold. In South Africa in particular, gold mines are the single greatest users of electricity across all sectors - 90% of the energy used on a gold mine is electricity [1.56] .

Traditional involvement includes mining houses like AngloGold Ashanti, Harmony Gold and Goldfields, with new players entering the field in recent years. According to a 1998 study done by the Mining Association of Canada, South Africa contributed approximately 19% of the world's gold [1.57] which is the largest portion of any single country; this is shown in the following figure:

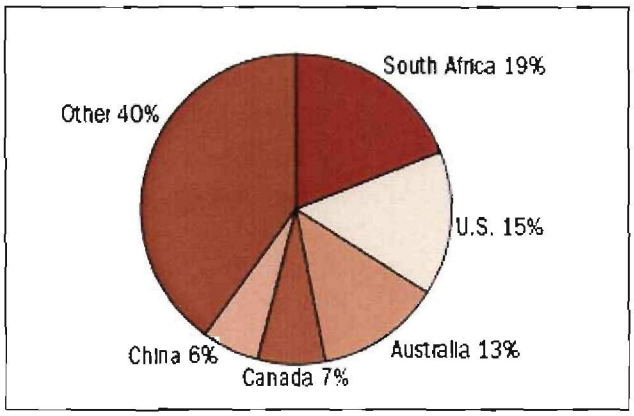


Figure 15: Distribution of worldwide gold suppliers [1.57].

A cost comparison was also done in 1998 between the energy costs of mining gold in South Africa, the US, Canada and Australia. It was found that South Africa had the highest mining energy cost of all these countries [1.58]. The comparison shown was made in 1999 US dollars, comparing the average $/tonne hoisted by the different countries:

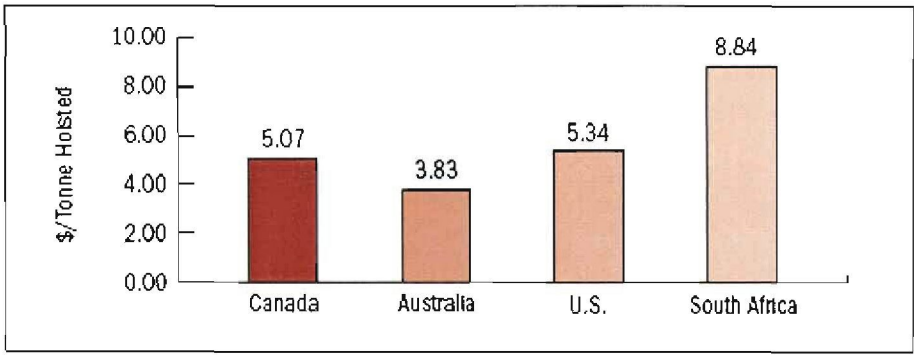


Figure 16: Gold mining cost comparison for different countries [1.57].

This comparison was also taken further, by comparing the energy cost of obtaining a troy ounce of gold in each of these countries, as shown in the following figure:

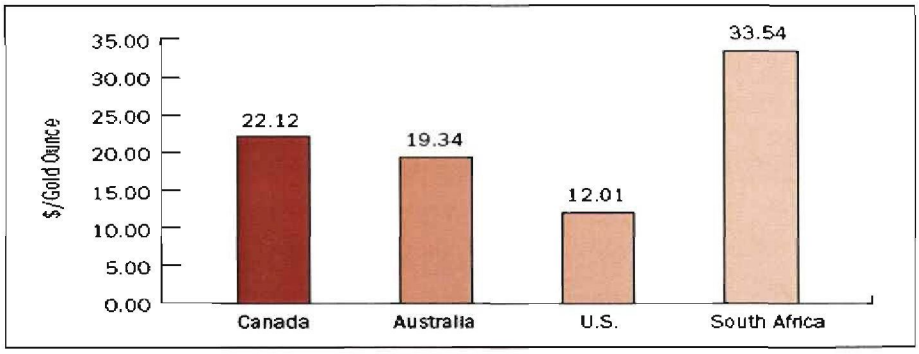


Figure 17: Gold mining energy cost comparison [1.57].

Once again, South Africa came out at the top, with the highest energy cost to produce a troy ounce of gold.

ENERGY BREAKDOWN OF A TYPICAL GOLD MINE

Various studies have been done in order to determine the energy breakdown in gold mines. The following approximate figures have been calculated for gold mines in South Africa [1.51]:

- Compressed air: 21.3 %
- Underground mining systems and activities: 18.9 %
- Underground pumping stations: 17.7 %
- Winding systems: 14.2 %
- Smelting plants and mineral processing equipment: 13.7 %
- Ventilation and cooling: 7.9 %
- Buildings, hostels and essential services: 6.3 %

These figures must only be taken as approximate, as they can vary depending on the setup of a specific mine.

1.4.2 ENERGY MANAGEMENT IN THE SOUTH AFRICAN PLATINUM AND GOLD MINING INDUSTRY

Various studies have been done with regards to energy management in the mining industry. One such study was done at the University of Cape Town [1.59]. In this study, the authors, Hughes, Howells, Trikam, Kenny and Van Es, looked at the potential for Demand Side Management (DSM), in various industries. The mining industry was a large part of this study and the results for this industry is described in this section.

The study took the form of audits undertaken at different sites. The audits included site tours to gain insight into production processes and energy usage. Conversations were also held with key personnel at the different sites. Meters were also installed at the different sites to determine the load profiles for the different equipment. Types of mining that were included in the study were Gold and Platinum mining. The following sections describe the equipment on these two types of mines that might have DSM potential.

ENERGY AUDITS ON A PLATINUM MINE

On the platinum mine included in the above audit, the following equipment was identified as large electricity users: Cooling, ventilation, ore transport, rock winders, man winders and milling. The only load shift procedures that could be found were the shutting off of the pumps and rock winders on the shafts during peak times. Energy efficiency measures identified included the replacement of incandescent bulbs with CFL's, and by installing VSD drives and high efficiency motors. It was also estimated that improvements to the compressed air system could possibly improve efficiency by 10% [1.59].

ENERGY AUDITS ON A GOLD MINE

A gold mine was audited and the following sections were identified as the main electrical energy users: Compressed air fans, pumps, gold plant, rock winders, fridge plant and hostels. Current DSM measures at the mine included load shifting on the pumps. It was estimated that this could be improved upon, while the addition of an ice plant could provide load shift in the fridge plant. The rock winders were also mentioned as possible areas for load shifting.

On the energy efficiency side, it was recommended that incandescent light bulbs be replaced by CFL's. Another option was the installation of VSD drives and V-belts on fans and motors, as well as using the compressor intercoolers to preheat water for the hostels [1.59].

1.4.3 NEW DSM POSSIBILITIES IN THE PRECIOUS METALS INDUSTRY

INTRODUCTION

Since the energy usage in South African gold mines is so high compared to other countries, it has become a prime target for DSM projects in this country. Various ESCO's have already implemented DSM projects in this industry.

In order to show just how extensive these projects are in South Africa, an attempt was made to obtain a list from Eskom showing all the DSM projects completed in South Africa. Since the information on these projects is considered confidential by Eskom and the various ESCO's involved, such a list could not be obtained. However, some documentation published by Eskom on the subject was obtained and the results are discussed in this section. The documentation [1.60], provided a summary of the contributors to the maximum demand in the various sectors. The following figure shows the contributors in the industrial, mining and agriculture sections:

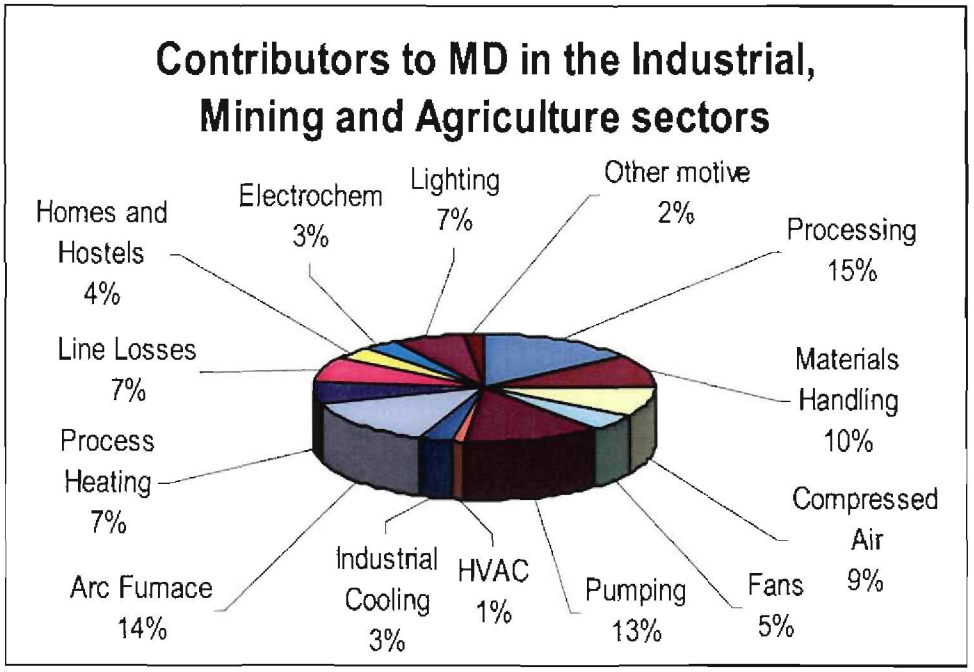


Figure 18: Contributors to MD in the industrial, mining and agricultural sectors [1.60].

In the commercial sector, the maximum demand is mostly a result of lighting and HVAC related end uses. The spread is shown in the following figure:

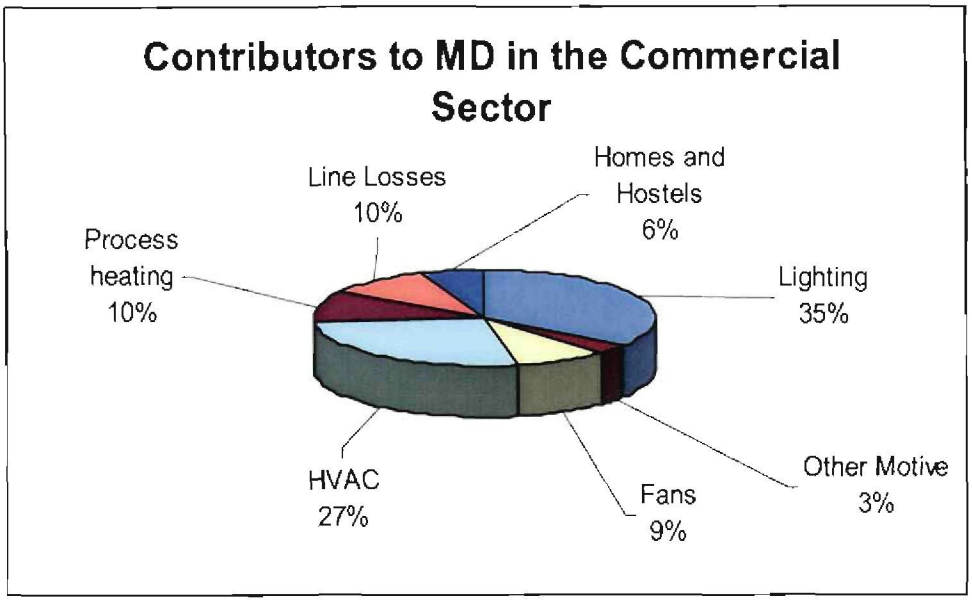


Figure 19: Contributors to MD in the commercial sector [1.60].

In the residential sector, the largest usage comes from uncontrolled water heating, incandescent and space heating applications. The spread of contributors are shown in the following figure:

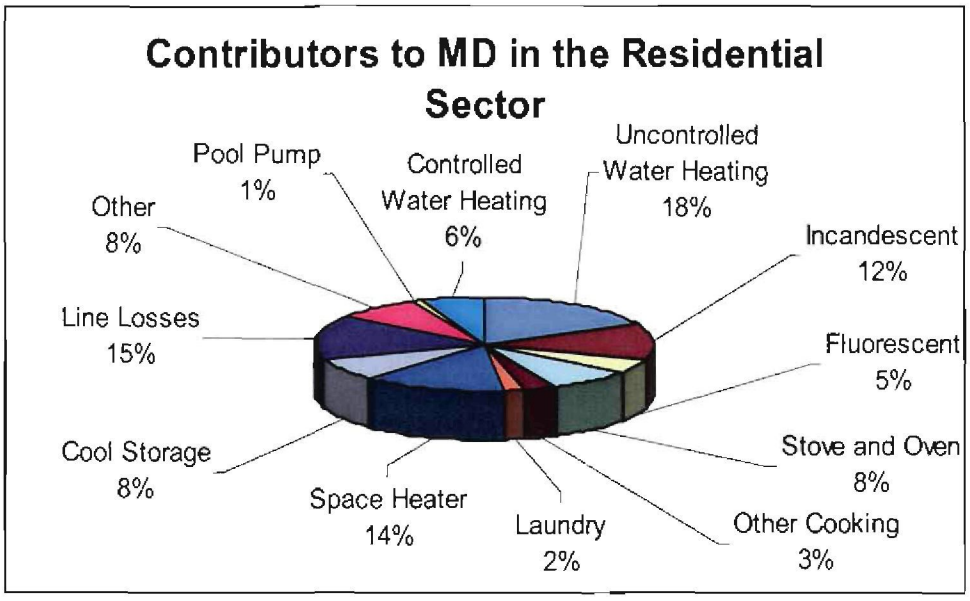


Figure 20: Spread of contributors to MD in the residential secto [1.60].r

If these graphs are examined, it can be seen that even though there are a large number of contributors to the maximum demand, there are only a few that stand out as large role players. Most of the current DSM projects were focussed on these large contributors. According to Eskom, the most registered DSM projects were done in the commercial sectors, followed closely by the

residential and agricultural sectors. The mining sector only features in the fourth place, with 15% of registered DSM projects. A comparison can be made from the following figure:

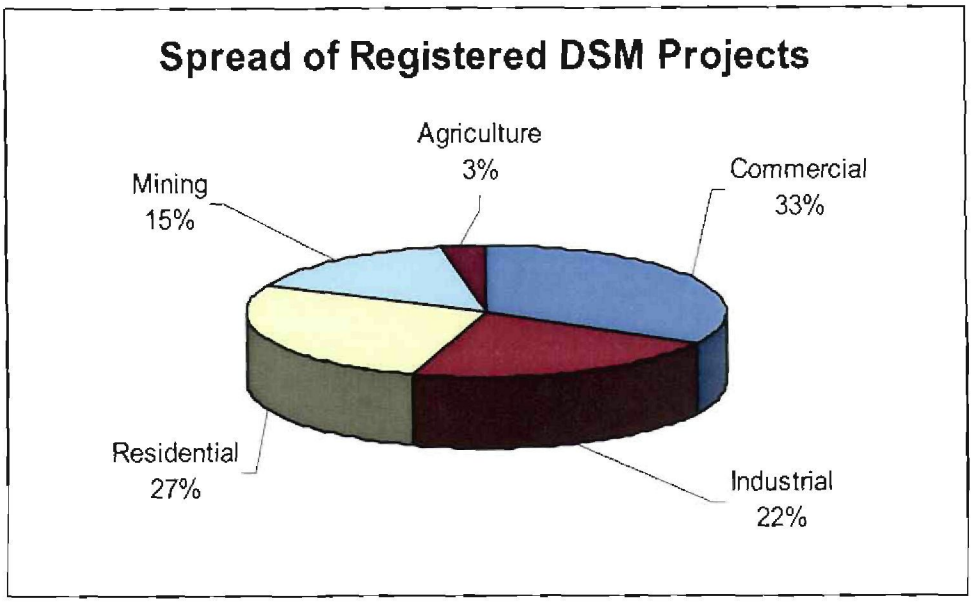


Figure 21: Spread of registered DSM projects [1.60].

A list of the typical DSM applications in different sectors is summarised in the following table:

Sectors	DSM Contributors	Typical Projects
Industrial, Mining and Agriculture	Processing	Motor and VSD
	Materials Handling	Motor and VSD
	Compressed Air	Compressed Air
	Pumping	Pumping optimization
	Arc Furnace	Load Management
Commercial	Lighting	Efficient Lighting
	Fans	Motor and VSD
	HVAC	Motor and VSD
	Process Heating	Load Management
Residential	Uncontrolled Water Heating	Ripple Control
	Incandescent	Efficient Lighting
	Stove and Oven	Appliance Labelling Awareness
	Space Heater	Appliance Labelling Awareness
	Cool Storage	Appliance Labelling Awareness

Table 3: Types of interventions on registered DSM projects

Since the mining sector contributes to such a large extent to the energy usage of South Africa, it should be considered as a prime candidate for the DSM program. However, this section has shown that only 15% of DSM projects were done in mining. The above table shows that most of the DSM projects performed in the mining sector were done with VSD drives and efficient motors. Load management was performed on arc furnaces, as well as some other projects like pumping.

A typical example of such a project is from a case study published by Measurement and Verification (M&V). This project was implemented by an ESCO that rescheduled the mine's underground water pumping system to run according to an optimised profile that switches off the pumps during peak times. The intended load shift was 3 MW, while the actual load shift achieved was approximately 3.87MW [1.61].

It has been shown earlier in this chapter that the largest users of electricity in the mining sectors are the processing facilities. However, the only DSM projects that could be found on these facilities were done with VSD drives and more efficient lighting, as done by Voltex on Amandelbult [1.53].

Since the purpose of this research is to identify new DSM opportunities in the precious metals industry, especially gold and platinum, it is proposed that load shift opportunities be sought out in precious metals facilities. The focus is shifted to two types of facilities in particular, namely Carbon in Pulp (CIP) gold plants, and platinum concentrators.

Even though these facilities may be used for different purposes, they both use similar equipment and processes with the purpose of extracting minerals from reef. Before moving into the specific details of each type of plant, some explanation of the general terms and processes used in mineral processing would be in order.

1.7 INTRODUCTION TO MINERAL PROCESSING

Mineral processing has the primary function of beneficiating valuable minerals from their ores. A large portion of these plants make use of hydrometallurgical or pyrometallurgical processes as part of larger extractive metallurgical operations. There are four general types of processes involved in mineral processing, these include the following:

- Comminution, or particle size reduction
- Sizing, or separation by means of screening or classification
- Concentration by using physical or chemical properties of the material
- Dewatering, or solid/liquid separation.

The general processes provided above are described in more detail in the following sections:

1.7.1 COMMINUTION

This entails the reduction of particle size of different materials. It can either be done on dry materials or slurries, depending on the process. The easiest ways to implement this are either by crushing, grinding or both. Crushing is normally used in the case of run of mine (ROM) material. A typical example of this is found on a gold plant [1.68].

1.7.2 SIZING

This is a general term that is used for the separation of particles according to size. The most common way of achieving this is by making use of different screens. Another way of separating particles is by using the physical properties of the material. This is known as classification. In this process, the equipment uses the difference in settling velocities exhibited by particles of different sizes. Hydro cyclones are typical classification equipment found on mineral processing plants [1.69].

Another method of separation is known as froth flotation. This is most often used in platinum concentrator plants. It is achieved when particles are separated based on their surface potential, which can either be hydrophobic or hydrophilic. Hydrophobic particles are recovered from the froth, while hydrophilic particles are discharged as tailings [1.66].

1.7.3 CONCENTRATION

Gravity concentration is based on the idea that particles can be classified based on their specific gravity. There are various processes that use this principle; the following are examples [1.68]:

- Sluice Boxes
- Rocker Boxes
- Shaking Tables
- Jig concentrators
- Centrifugal Concentrators

- Dry Washers

1.7.4 DEWATERING

Since most of the precious minerals are in slurry form at some stage during the extraction process, dewatering is a very important part of the process. This can be accomplished in many different ways, but the most common include filter presses, Larox Filters or rollers. The water removed here is usually returned as process water to be used again in a closed circuit.

From the short introduction it was gathered that mineral processing encompasses wide areas of expertise and engineering disciplines. It can be found in almost all areas of the mining industry in South Africa, making it a key contributor to the economy, as well as the energy usage profile of the country

1.8 BASIC BACKGROUND ON PLATINUM CONCENTRATORS

The role of a platinum concentrator is mainly the cost effective grinding of ore to the size required for mineral extraction. After milling, the optimum separation of valuable particles from particles of no value is performed [1.62]. The following figure shows a simplified layout of a typical platinum concentrator, showing the different parts and the process flow:

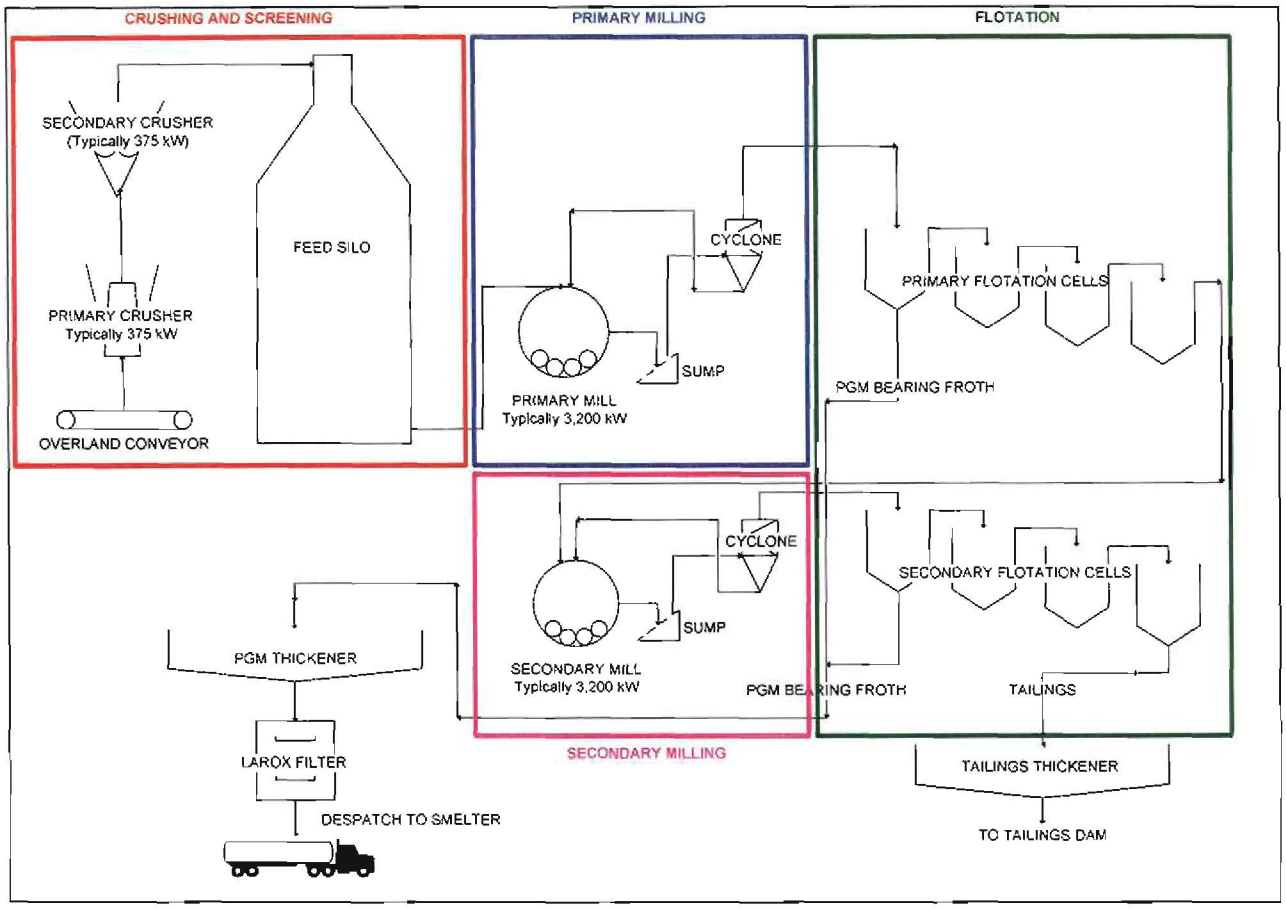


Figure 22: Simplified layout of a platinum concentrator

The different processes found on a platinum concentrator are described in the following sections:

CRUSHING AND SCREENING

The first process encountered is known as the primary crushing and screening. The purpose of this is to crush the platinum group of metal (PGM) ore from the shafts to a certain size in the order of -100mm diameter. Typical equipment found here includes gyratory crushers a well as wet and dry screens.

From primary, the crushed rocks go to the secondary crushing section, where they are crushed to even smaller sizes. The typical equipment used here includes cone crushers. There might also be a tertiary crushing section similar to the secondary one, depending on the plant. There is also a dust filtration section used to extract dust away from the crushing operations. Normally these types of crushers are not used continuously, but only on demand from the rest of the plant.

MILLING

As expected, the mills used on a concentrator are the greatest users of electricity. Typical values include installed motor capacities of 3200 kW per motor. Sometimes there are more than one motor attached to a mill, thereby doubling the electrical capacity. In a concentrator, ore crushed in the crushing and screening sections are stored in storage silos used to keep the mills supplied in case one or more of the crushers has to be taken offline.

From this silo, the ore is fed into the primary mill, usually of the Run-Of Mine (ROM) type found in various other industries such as gold and cement. The milling process is a wet process and the milling is aided by adding steel balls to the mill, known as grinding media. This mill has a twofold purpose: First, it produces the final crushing of the ore, and second, it exposes the surfaces of the ore particles to the surface. This is important for the chemical reaction in the flotation cells.

After the material has been crushed in the mill, it is fed through a trommel screen at the discharge end of the mill in order to remove any waste rocks known as pebbles.

The slurry being discharged from the mills moves through a small discharge bin to a hydro cyclone. In the cyclone, the heavy and light materials are separated according to their weight. The heavier material moves down and is pumped back to the feed end of the mill for further milling. This material is known as cyclone underflow. The lighter material, which has been milled to the correct size, is known as cyclone overflow and is pumped to the primary float section.

From the primary float, the material is sent through a secondary mill. The main purpose of this mill is to expose the surfaces of the PGM particles that were covered by a layer of erosion during the first floatation. This is important since the oxidation prevents the chemicals added in the flotation process to react with the PGMs. This means that the flotation will not be as effective and the yield will be much lower than normal. The following picture shows the primary and secondary mills installed on a concentrator:



Figure 23: Picture of the milling circuit at a platinum concentrator

FLOTATION

Flotation cells are used to extract the PGMs from the rest of the non-valuable materials. The typical concentrator plant has a large number of flotation cells constructed in a cascading fashion. There are pipes leading from one cell to the next, allowing the slurry to move down the cascade, thereby increasing reaction time and leading to a higher yield.

Flotation works by pumping the slurry with the PGMs into the flotation cells. Air is then blown in from the bottom of the cells to agitate the slurry. Various chemicals are also added to assist in the process. As the air agitates the slurry, froth is formed on top of the mixture. The PGMs cling to this froth and are removed from the cells by means of an overflow, leaving the non –valuable materials in solution inside the cells.

In order for the flotation process to work properly, the level of the slurry in the cells should be carefully regulated. If the level should drop, the froth bearing the PGM will not be able to flow away, since the level will be below the overflow channels. This will result in an immediate loss of production. The constant level will also ensure a constant relative density (RD) in the flotation cells.

In the flotation section, the only significant electricity users are the pump motors used to pump the slurry between tanks. These motors have typical installed capacities of 100-110 kW, and are utilised continuously when the flotation section is in operation.The following figure shows a typical layout of flotation cells in a concentrator:



Figure 24: Picture of the flotation cells at a platinum concentrator

CONCENTRATION

All the non-valuable material or tailings left in the flotation cells are pumped away to a thickener section. In the thickeners, the tailings are concentrated and sink to the bottom. These are then pumped away as thickener underflow to the tailings dam.

The PGM concentrate removed earlier from the flotation cells are pumped to another thickener. In this thickener, the PGM material is concentrated by allowing it to sink to the bottom of the thickener tank. From here it is pumped to a Larox pressure filter that squeezes out the water from the slurry, leaving a cake of PGM concentrate ready to be transported to the smelter.

1.9 BASIC BACKGROUND ON GOLD PLANTS

In South Africa, the most common type of gold extraction process is known as the Carbon in Pulp (CIP) process, and was pioneered in South Africa during the 1970's [1.63]. The first plant of this type was ERGO, on the east rand, which came into production on 25 February 1978 [1.64]. The following figure shows an overview of the gold extraction process at a typical CIP plant:

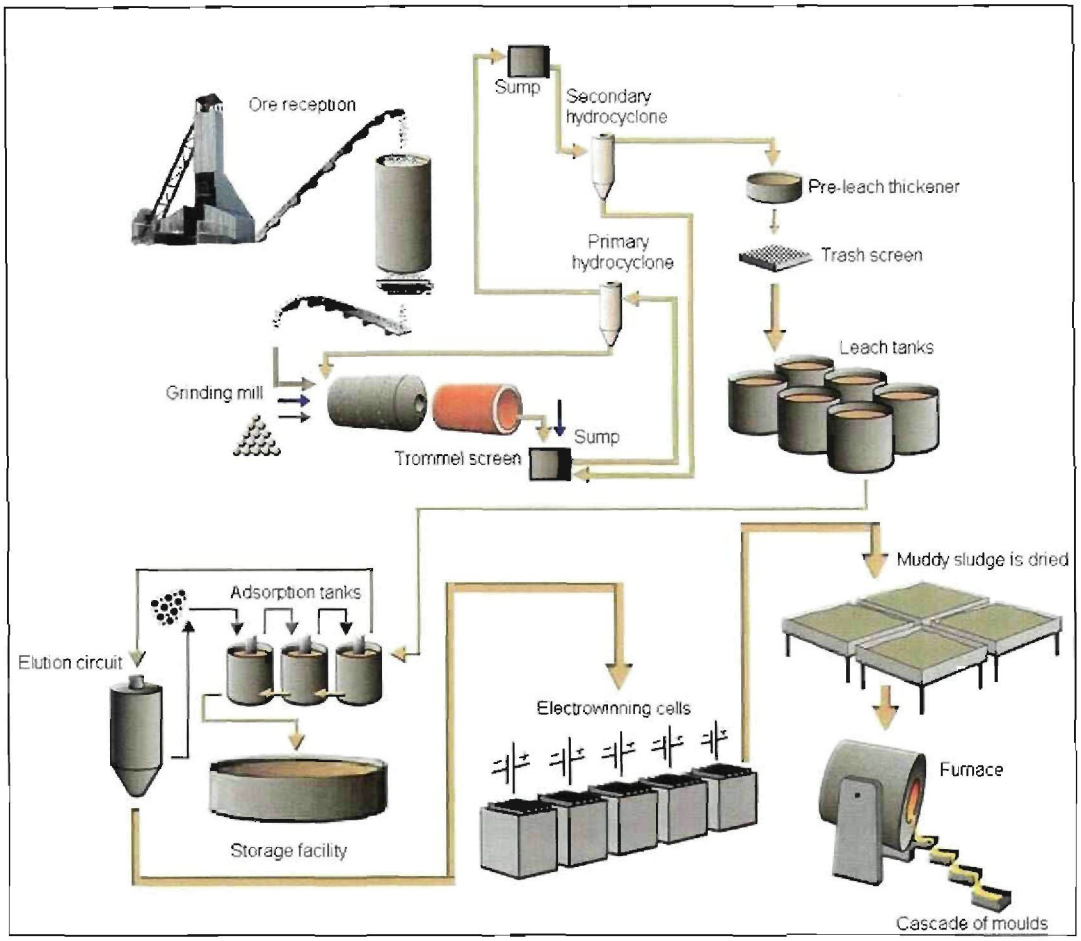


Figure 25: Simplified layout of a CIP gold plant

The overview shown in the figure can be broken down into smaller pieces in order to get a better idea of the workings of the different processes on a typical CIP gold plant.

ORE STOCKPILE

This is the first section of the plant after the shaft. Here ore is transported from one or more shafts by means of trains, trucks and conveyor belts. The ore is usually stored in closed concrete silos that are fed by means of a small shuttle conveyor situated at the top of the silos. In order to retrieve the ore from the silos, a vibrating or drum feeder is typically used.

Typical installed capacities of these feeders are 40 -100 kW. These feeders have set points that control the flow of ore going out of the silos to the mills. In some cases, the ore is stored on open stockpiles next to the mills. The ore is then retrieved by means of reclaimers that feed the mills.

MILLING AND CLASSIFICATION

In this section, ore is fed from the silos or stockpile to the mills by means of feeders and conveyors. The mills are usually of the ROM design similar to those found on platinum concentrators In most cases, the ore itself is used as a grinding medium, however, in some cases steel balls are added to increase the mill throughput, depending on the ore composition. The mill rotates at constant speed while ore, grinding media and water is added to it. The target size for ground ore is 90% smaller than 75 microns. At the discharge end of the mill, the slurry is poured into a sump, from where it is pumped through a series of cyclones for classification.

In the cyclones, the ground ore of correct size and fineness is discharged at the top. This is known as cyclone overflow. This slurry is then put through a woodchip plant, which is just a number of screens and sprays, in order to remove any woodchips from underground props that got through the system. The material that is too large to be ejected as cyclone overflow sinks to the bottom of the cyclone, and is discharged as cyclone underflow. This is reintroduced into the mill until it is fine enough to continue through the system, while the cyclone overflow continues to the thickeners.

THICKENING

After the cyclone overflow has passed through the woodchip plant, it is gravitated into the thickeners. The thickeners are designed like large round dams with a rake pivoting in the centre. The purpose of the thickeners are to settle the gold bearing slurry to the bottom, separating it from most of the water, thereby concentrating the gold in the slurry. In order to achieve this, lime and a flocculent is added to the thickeners.

The purpose of the lime is to bring about the desired alkalinity, therefore preventing the emission of hydro-cyanic gas during the leaching process. The purpose of the flocculent is to bind with the solid particles in the slurry, making them heavier so as to sink to the bottom.

As an illustration of the effectiveness of the thickeners, it must be noted that the pull enters thickeners with a relative density of approximately 1.08 t/m^3, whereas it leaves the thickeners as underflow with a relative density of approximately 1.56 t/m^3. This thickener underflow is pumped to the super leach vessel.

SUPER LEACH AND CARBON IN LEACH (CIL)

In the super leach tank cyanide is added to the thickened pulp. The quantities are in the order of 180 parts per million (PPM) of free cyanide. The super leach vessel is agitated with compressed air in order to provide the oxygen necessary for the leaching process.

The use of cyanide to dissolve gold into solution was first documented in 1783, by Swedish scientist Scheele [1.67]. Because the use of cyanide allows the exploitation of increasingly lower grade gold ores, it plays an important part of most modern gold extraction operations The Elsner equation describes how gold is dissolved in cyanide in the presence of oxygen [1.67]:

$$4Au + 8NaCN + 2H_2O + O_2 \rightarrow 4NaAu(CN)_2 + 4NaOH$$

Equation 1: Elsner equation of gold reacting with cyanide

About 75% of the gold leaching takes place in the super leach vessel. The slurry from the super leach tank is pumped to Carbon in Leach (CIL) tanks, where activated carbon is added to remove the gold from the solution. This carbon is then transported to the elution section to remove the gold.

CYANIDE LEACHING

From the CIL tanks, the remaining slurry is introduced into a series of leach tanks. Leach tanks are flat bottomed tanks that are air agitated. The purpose of these leach tanks are to dissolve a further 22% of gold into solution, which could not be extracted in the super leach vessel. The pulp flows from one leach tank to another with a residence time of approximately 32 hours.

CARBON IN PULP (CIP) ABSORPTION

From the leach tanks, the pulp goes to the Carbon in Pulp (CIP) section. This is similar to the leaching section as it also consists of a series of agitated absorption tanks. In these tanks the slurry is introduced on one side, while activated carbon is introduced on the other side. The carbon concentrations are typically about 18 to 20 grams of carbon per litre of pulp. The pulp is moved in the opposite direction as the carbon, gravitating from one tank to the next.

During this process, the gold in solution moves toward the carbon by means of a diffusive process. This process allows all the gold particles to cling to the carbon. In this manner, almost all the gold is removed by the time the pulp reached the last absorption tank. The pulp is now discarded as tailings, while the carbon is moved to the elution section to remove the gold from the carbon.

ELUTION

The elution section was introduced in order to strip the gold from the carbon. This is normally an eight step process:

1. Water at ambient temperature is used to wash out slime from the carbon bed.
2. Acid wash, where 2.5% HCL at ambient temperature is introduced to remove metallic impurities from the carbon bed.
3. Water wash at ambient temperature to remove the acid from the carbon bed.
4. Hot water, pre-heated at 112 degrees C, in order to pre-heat the carbon before the actual elution takes place.
5. Carbon pre-treatment using caustic cyanide solution at 125 degrees C. This alters the cat ions holding the cyanide-gold complex from the absorbed calcium ion to the sodium ion, which is absorbed weakly into the carbon.
6. Soaking allows the cyanide ions to completely permeate into the larger carbon particles
7. Elution now takes place by using hot water at 125 degrees C in order to remove the gold complexes from the carbon. This solution is taken to electro-winning to remove the gold.
8. The carbon bed is cooled to ambient temperature before being moved to the regeneration kilns.

CARBON REGENERATION

This is where the spent carbon, coming from the elution section, is regenerated or reactivated to its original form. This is achieved by heating the carbon in regeneration kilns to approximately 780 degrees C. In the kilns, the contaminants are evaporated off without damaging the carbon. The carbon is then re-introduced in the circuit for the next elution.

ELECTRO WINNING SECTION

The gold bearing solution coming from the elution column is known as the eluate. This eluate is pumped from the elution circuit to a conditioning tank where the conductivity is adjusted using caustic soda. During this process the tank contents are stirred in order to ensure homogeneity of the solution. After adjusting the conductivity, the solution is called the electrolyte.

This electrolyte is pumped to a circulation tanks by going through a filter to remove any carbon and woodchips that might still be left. From here, it is circulated through the electro-winning cells at a controlled flow rate. The cells have a stainless steel mesh forming the anode, and steel wool for the cathode. An electric current is passed from the anode to the cathode through the electrolyte, plating the gold on the steel wool.

This is done until the gold concentrate of the electrolyte is below 20 g/t. The electrolyte is now considered spent and pumped to a spent electrolyte storage tank, and then to the CIP absorption tank for further absorption.

The steel wool cathode bearing the gold is now removed and washed with high pressure water before draining the gold onto a filter. This gold cake is now dried in an oven and additives like borax and manganese are added before it is smelted in an induction furnace. This smelting produces gold bullion and borax slag.

1.10 POSSIBLE LOAD SHIFT ON CIP PLANTS AND CONCENTRATORS

Now that some background information has been provided on both of the above facilities, the reasons for choosing to perform research on these particular plants can be discussed:

- Even though there are marked differences, the process flows for both plants are similar, providing the possibility of using similar DSM procedures on both types of plants.

- Both plants have large electricity users, namely mills. These mills are of a horizontal rotary type with one or two large driving motors each. Load shift can possibly be performed on these mills, resulting in large savings.

- Both of these plants have possible storage facilities that can be used as buffer capacity in case of the mills being down for load shift.

- There might be additional savings in the form of load shift or energy efficiency on the elution columns and regeneration kilns.

Stopping only one mill on one of these facilities will result in large savings for the DSM savings. This is preferable to implementing a lighting project for example, where large amounts of lights have to be replaced with CFLs before savings of the same magnitude can be expected.

1.11 NEED FOR THE STUDY

From the information provided in this chapter, the need for this study can be summarised as follows:

- Even though the national DSM program in South Africa has contributed to the reduction of electricity usage in the country, the programme has only reached 30% of its targets by the end of 2005.

- One of the main reasons why the DSM programme has not reached its targets was the limited knowledge of how to apply DSM to the different energy sectors.

- As the mining industry is one of the largest electricity users in the country, it is logical that DSM savings in this sector will have a bigger impact on electricity savings as a whole.

- Current applications of DSM in the mining industry, especially precious metals like gold and platinum, are limited to pumps, compressed air, fridge plants and rock winders. No DSM projects are currently being investigated in gold plants and platinum concentrators, even though they use large amounts of electricity.

- Gold plants and platinum concentrators have large equipment like mills that can be used to create large savings by means of load shift.

- No applications of DSM load shift on precious metals processing facilities could be found, as such, it may be a new opportunity to expand the DSM programme.

- Various difficulties plague the application of DSM on precious metals facilities. Examples of these are the high cost of losing production, and the current belief that gold recovery should be performed with as few interruptions as possible.

- There are also no procedures or simulations that can predict the effects of load shift on a precious metals facility such as a gold plant or platinum concentrator. Such a tool would be very useful in performing DSM audits on gold plants, as it allows the ESCO to determine the possible load shift on a gold plant, as well as the long term effect it might have on milling of reef.

    - As such, a new tool is necessary to address the problems associated with the evaluation of possible DSM projects on gold plants.

    - This tool should provide a quick and easy way to determine the viability of load shift on a particular plant, with only basic information.

    - It should also be able to calculate any possible DSM savings that might arise from a possible project.

1.12 CONTRIBUTIONS OF THE STUDY

The unique contributions for the research are the following:

- A *new and unique simulation procedure* was developed to analyze the viability of a DSM project on different mineral processing facilities.

- This research identifies *new energy savings opportunities* in an industry still untouched by DSM at this stage.

- This study proves that load shifting can be applied on minerals processing facilities in the precious metals industry. This is unique, since most experts believe it is impossible.

- The simulation procedure developed provides a *novel approach* with which to analyse the viability of a DSM project with *only basic information* on the operating specifications of a specific facility.

- The simulation procedure can easily be adapted to suit similar system layouts in different industries, which *improves the standardization of ESCO audit procedures in processing facilities.*

- The development of the simulation model *speeds up the DSM audit process* considerably, resulting in faster results for decision making.

- The simulation provides a *unique tool* which improves the DSM process by empowering people with limited knowledge of a specific system to *simulate the possible DSM savings* on a specific plant in a short period of time. This is an *improvement* over the current time consuming methods of performing a DSM audit.

- The simulation model is also a *cost saving tool*, since *it removes the need* for a whole team of engineers to spend extended times at the plant performing audits. It also *reduces transport and development costs* during the viability study of a new DSM project.

- The procedures and tools developed increases the possible DSM projects that can be performed in South Africa. This assists ESKOM in reaching their annual DSM targets. As such, it *provides a contribution to the DSM program*, as well as the further development of South Africa.

1.13 OVERVIEW OF THE THESIS

CHAPTER 1 – INTRODUCTION

Some background has been provided on the energy situation in the World and South Africa. Specific emphasis is placed on the growing need for energy, especially electricity that places a burden on natural resources. A section is dedicated to the legislation and implementation of various energy management structures around the world.

A special emphasis has been placed on the national DSM programme in South Africa. The effect of the mining industry, especially gold mining, on the energy situation in South Africa is introduced. There are also some references to the various successful DSM projects that have been implemented in this industry.

CHAPTER 2 – NOVEL DSM SOLUTIONS FOR MINERAL PROCESSING FACILITIES

Some background has been given on mineral processing. There is also a section dedicated to the mineral industry in South Africa. This includes a look at the various minerals being mined and processed in the country. The focus is moved from a broader look at the mineral industry to include two of the most important minerals in South Africa, namely gold and platinum.

A section is also dedicated to the thoughts behind DSM on mineral processing facilities, with special emphasis placed on the gold and platinum industries. This precedes two sections that describe the workings of platinum concentrators and gold plants. With this background, a short study is done to investigate the different DSM possibilities on these two facilities.

This highlights the gold plant as the only viable option for DSM load shifting. A preliminary study done on a South African gold plant is included, showing the possible problems that might arise, and how it has been addressed. This opens up the door for the development of a new simulation procedure to analyze DSM potential on a gold plant.

CHAPTER 3 – NEW SIMULATION PROCEDURES

This chapter is devoted to discussing a new simulation model that was developed to simulate the viability of DSM load shift on a gold plant. A layout of the different sections of the simulation model is provided and each part is described in detail. Examples of the user interfaces are shown, as well as examples of the results obtained by the simulation.

CHAPTER 4 – VERIFYING THE NEW SIMULATION

In this chapter, the simulation model developed in Chapter 3 is used to simulate the current milling profile of an actual mill. The simulation results were compared to the actual values of the milling circuit in order to prove that the model is an accurate presentation of the actual milling circuit. With the accuracy proven, the simulation is used to simulate potential load shift on the same milling circuit. This prediction is tested for accuracy by providing results of an actual load shift test done on the gold plant during the duration of this research.

CHAPTER 5 – APPLICATION OF THE NEW METHODOLOGY

In this chapter, it is assumed that the accuracy of the simulation model has been proven adequately. The simulation model was used to simulate load shift on five different South African gold plants. The results differed for each plant, depending on the current plant setup. The results for each plant are discussed in terms of savings and viability of DSM on the milling circuits.

CHAPTER 6 – APPLICATION OF THE NEW METHODOLOGY IN OTHER INDUSTRIES

In this chapter the simulation model was expanded to similar plants in other industries. The first section is devoted to implementing the simulation model on a cement plant, while the second section is devoted to the effect of the simulation on a chrome pelletizing plant. Simulation results were generated and provided for each plant. The chapter concludes where the results are discussed in terms of load shift viability and further research

CHAPTER 7 – CONCLUSION

This chapter is devoted to conclusions regarding the results developed, simulated and tested on various mineral processing facilities. The conclusions of the various chapters are summarised in order to come to a final conclusion on the research. A section has been devoted to the shortcomings of this research, while the final part concludes with recommendations for further study in this field.

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CHAPTER 2

NOVEL DSM SOLUTIONS FOR THE PRECIOUS METALS INDUSTRY

2.1 THE MINERAL PROCESSING MARKET IN SOUTH AFRICA

2.1.1 INTRODUCTION

In the past, mineral industries in South Africa operated on a free-enterprise, market driven basis. Any mineral rights were either held by the government or private entities. The bulk of mineral land holdings and production in South Africa has historically been controlled by five mining houses. However, the industry has undergone a major corporate restructuring since 1994. This was aimed at simplifying a complex system of interlocking ownership, diversifying and rationalizing nonperforming assets to make the companies more competitive on the international market [2.1].

The mineral wealth of South Africa is found in diverse geological formations. A few examples of these are the following [2.2]:

- The *Witwatersrand Basin*, which houses a large portion of the world's gold reserves, as well as uranium, silver and pyrite. This complex yields some 98 % of South Africa's gold output.

- The *Bushveld Complex*, which contains more than 50% of the world's reserve of chrome and Platinum-group metals (PGM). There are also vanadium, iron, titanium, copper, nickel and fluorspar to be found in this complex.

- The *Transvaal Supergroup* contains large amounts of manganese and iron ore.

- The *Karoo basins* in Mpumalanga, KwaZulu-Natal and Limpopo are home to coal and anthracite beds.

- The *Phalaborwa Igneous Complex*, which has a large concentration of copper, phosphate, titanium, iron and vermiculite ores.

- *Kimberlite*, which has alluvial and marine diamond deposits.

- *Heavy mineral sands*, which contain Ilmenite, Rutile and Zircon.

The most important minerals produced in South Africa in terms of value are PGMs, gold, coal, ferroalloys, aluminium, steel, titanium, iron ore, diamonds, vanadium and copper. There are also various other metallic and non-metallic minerals produced in the country. [2.1]. South Africa is regarded worldwide as a leading supplier of consistent high quality mineral products. The reach of the mineral industry in South Africa increased to such an extent that some 59 different minerals were produced from 993 mines and quarries in 2005 [2.3].

This makes South Africa one of the most important mineral sources in the world. Examples of this include the following: PGMs (87.7%), manganese (80%), Chromium (72.4%) and gold (40.1%). There are also many more minerals of smaller percentages [2.2]. Because of this, various investments are made in the South African mineral industry.

An example of this is the R 53,213 million that is earmarked for primary mineral projects, and R 1,695 million for mineral processing projects. The largest percentage of these investments was made in the gold and platinum industries. Gold related projects accounted for approximately 32% of the total investment, while PGM related projects accounted for approximately 68%. Examples of projects in these two industries are given below:

2.1.2 GOLD

Historical records indicate that 29 gold related projects were completed between 2002 and 2005. The largest of these projects were completed early in 2005, and encompasses an R 4000 million investment in Placer Dome's South Deep venture with Western Areas.

In 2006, South African gold producers committed 55 gold related projects. Out of the 55 projects, costs could be obtained for 26 of these. The total cost of these 26 projects amounts to R 17,436 million. The largest investment was made by Anglogold Ashanti, namely R 4,185 million for Moab Khotsong mine, followed by Goldfields with R 2,850 million for Driefontein 5 sub vertical shaft. An additional R 1,666 million was earmarked for Kloof 4 vertical shaft [2.3].

2.1.3 PLATINUM GROUP OF METALS (PGMs)

Platinum producers in South Africa completed 40 PGM related projects between 2002 and 2005. The most notable of these is an R 1,800 million project at Anglo Platinum Rustenburg Section. There were also smaller projects at Implats 1 shaft and 12 shaft decline. These were worth R 886 million and R 824 million respectively. Another project worth R 1,450 million was completed at Anglo Platinum's Polokwane smelter during this time.

Commitments were made in 2006 for 95 additional PGM related projects. Of these, costs for only 41 could be obtained. The total cost for these is R 35,778 million. The largest investment was made by Impala Platinum, who invested R 4,500 million in 16 shaft in the North West province. Another large investment is that of R 2,400 million invested by Anglo Platinum in Rustenburg section. Impala Platinum also has a R 2,100 million project on 20 shaft [2.3].

All these investments show that there is a definite interest in the mineral industry in South Africa. It also indicates growing confidence that the industry will continue to play a major role in the growing economy of South Africa. This provides a situation filled with opportunities in terms of DSM. As the investments in the industry increase, so does the energy use, especially electricity. It has been shown before that Eskom is trying to decrease the use of electricity to allow it to continue supplying electricity on a continued basis in the future.

If the companies involved in the mineral industry take part in the DSM program, they will be able to reduce their electricity costs, receive fully paid for equipment, as well as play a part in helping Eskom. Most of the large mining houses in South Africa already realise the need to participate in such initiatives such as DSM. This will not only have an impact on their bottom line, but will become part of their social responsibility campaigns as well.

2.2 DSM SCOPE ON PRECIOUS METALS FACILITIES - FOCUS ON PLATINUM AND GOLD PLANTS

2.2.1 THE IDEA BEHIND LOAD SHIFT ON MINERALS PROCESSING FACILITIES

The idea of performing load shift on a mineral processing facility was born from existing load shift projects on clear water pumping systems, fridge plants, rock winders and compressed air systems on various mines in South Africa. Since these types of projects were completed successfully by ESCO's in South Africa, as described in Chapter 1 it seemed like a natural extension of existing principles to new facilities where no such projects currently exist.

The basic idea behind load shifting requires that there be one or more pieces of equipment that can be switched off during the Eskom peak times, in order to take advantage of the resultant electricity cost saving and load reduction. However, the following criteria need to be in place in order to perform a successful load shift project:

1. The production capability of the facility should not be compromised under any circumstances.

2. There need to be adequate storage facilities following after the equipment under consideration for load shift, in order to allow production to continue as normal with the equipment stopped.

3. The equipment to be stopped need to have adequate overtaking capacity to compensate for any shortfall in production in off-peak periods.

4. If the production is not to be compromised, the project needs to be energy neutral. This means that the same amount of energy needs to be used after implementation of load shift, than before load shift. This is achieved by running the equipment at a slightly higher capacity during off peak times.

The following figure shows a simplified layout of a typical setup amenable to load shift:

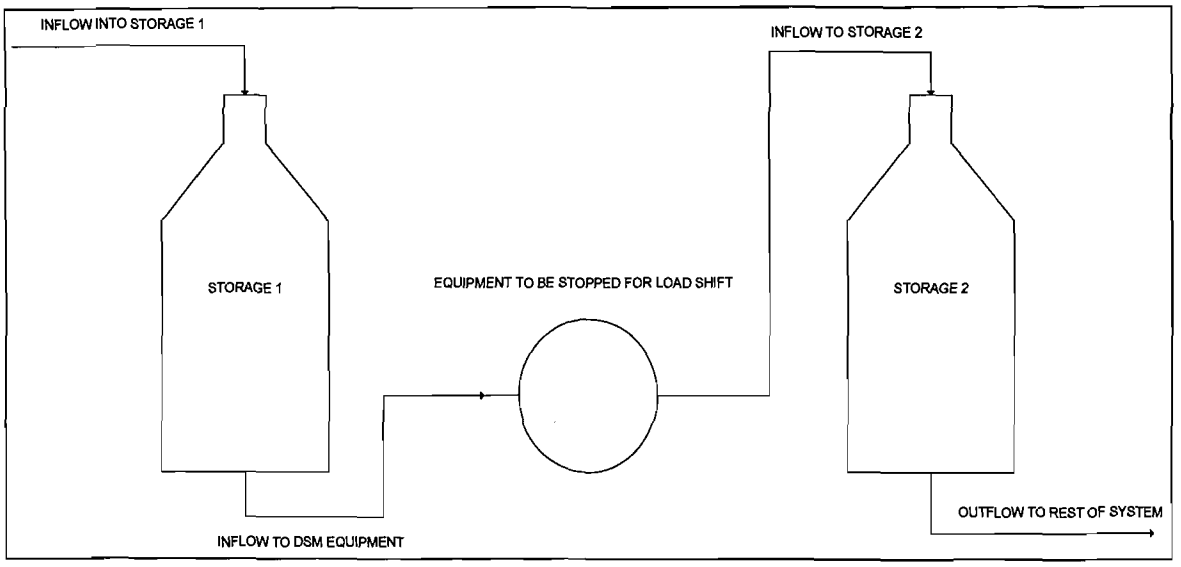


Figure 26: Typical layout of a system amenable to load shift

In the figure, there is a storage facility before and after the equipment on which load shift is performed. This is typical of a system on which load shift can be performed successfully. The equipment can be anything from a pump, to a winder, to a compressor, mill or crusher. Storage facilities range from silos, stockpiles, dams and pressure vessels. The main concern will be that there are materials to feed the load shift equipment, as well as storage to act as buffer capacity when the equipment is stopped.

2.2.2 CURRENT VIEWS ON DSM IN PLATINUM CONCENTRATORS AND GOLD PLANTS

During the course of this research, various gold plants and platinum concentrators have been visited and investigated in terms of load shift potential. It was found that the mere presence of large electrical machines does not automatically mean that DSM potential exists.

This is especially true in the case of mineral processing facilities, since an intervention like stopping a mill or crusher for example, might have a negative impact on the production figures of that facility. This is perhaps better understood if some background is given on the workings of a cylindrical mill typically found in these facilities:

CYLINDRICAL MILL OPERATION

A typical ball mill of the type used in gold and platinum plants has a cylindrical main body. It can only rotate at a certain RPM as set down by the designer. This is because there is a specificoperating speed for most efficient grinding. It must be noted that this speed must be used in conjunction with mill charge size to obtain the most efficient grind.

As the mill rotates at this speed, the material in the mill nearest to the wall breaks free and is quickly followed by the rest of the material as to form a cascading, sliding stream of material. This stream contains several layers of steel balls separated by materials of varying thicknesses. The top layers in the stream travels faster than the lower ones, causing a grinding action between them. Further grinding is achieved by the gyration of individual balls or pebbles and secondary movements causing rubbing or rolling contact [2.4]. The following figure shows the simulated cascading motion of the material inside the mill:

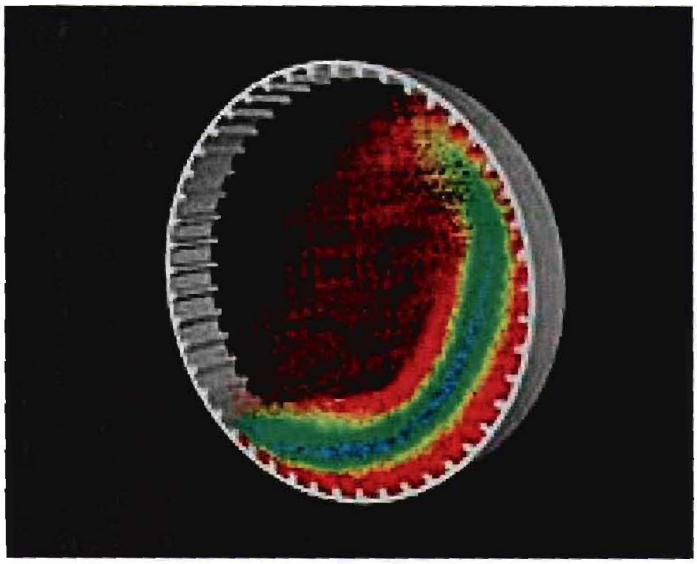


Figure 27: Overview of the typical motion of material in a SAG mill

In this figure, the distribution of particles in the mill can be clearly seen. The colours indicate the speeds of the particles, with red being the fastest, and blue being the slowest or stationary particles.This optimum speed at which the mill needs to turn is called the critical speed of the mill. It can be determined for any size mill by the following formula:

$$CS = \frac{54.19}{\sqrt{MR}}$$

Where,

CS = Critical Speed of the Mill (RPM), and

MR = Mill radius (Feet)

Equation 2: Equation for critical speed of a mill

This relationship shows that a smaller mill will have a higher critical speed RPM than a larger mill. This applies to any mill, regardless of grinding media type [2.4]. Some unpublished studies have also been done by AngloGold Ashanti to show that the mill power draw is in the order of 70 - 75% of the installed capacity of the mill. This might change slightly with the hardness of the material being milled [2.5]. The results of this report are supplied in APPENDIX A at the end of this thesis.

THE EFFECT OF CHARGE SIZE

All the mills considered in this study, for both the platinum concentrators and gold plants, use a wet grinding process. Research has shown that the fastest grinding in wet processes will occur when there is just sufficient material in a mill batch to fill all the voids and slightly cover the grinding media. This is typically in the order of 25% of the total volume with a half ball charge, and 18 % with a third ball charge. The material should never be allowed to drop below the surface of the grinding media, because this causes excessive wear in the mill and contaminates the material.

Charge sizes are normally calculated to coincide with the allowable running time. This is largely experimental and is determined by the specific plant for the specific material to be milled. An example highlights this: Assume that a 25 % batch takes nine hours to grind. This is too long for a typical eight hour shift. The batch size is now increased to fit within the eight hour shift. If an increase to say 40 % takes nine hours again, the batch will have to be reduced again to fit the operation of the plant [2.4].

If the batch is too small, the cascading of the material is not the optimal shape, and the material disperses easily. This decreases the efficiency of the grind, and a batch will typically take longer to mill. This is undesirable at a plant, since it reduces production. On the other hand, if the batch is too large and too heavy, the mill will clog up and start to act like a solid rotating cylinder, and the material will just be rotated without being milled.

Another effect of this heavier mill charge is that the material inside will remain closer to the rotational centre of the mill, requiring less energy to turn the mill. This means the power draw of the mill will be less while the production will also be reduced because of the less efficient milling action.

Various studies have been done to determine a method with which to calculate the power draw of cylindrical mills based on the charge. This task has been made more difficult by the differences between dry and wet milling processes in similar mills. In a 1996 study, Morrel [2.10], proposed a mathematical model to predict the power draw of autogenous, semi-autogenous and ball mills. This model was based on the motion of the grinding charge inside the mill. The model treats the charge as a continuum. This allows analytical solutions to be developed for the equations. The model can be expressed as follows [2.10]:

Gross Power = No-Load Power + (K * Charge-Motion Power)

Where

Gross Power = Power input to the motor

No-Load Power = Power input to the motor when the mill is empty

Charge-Motion Power = Power associated with the movement of the charge

K = Lump parameter that allows for heat loss and energy consumed

Equation 3: Gross power of a cylindrical mill

The model requires that three principles equations be used to calculate power draws in the cylindrical and conical end-sections of the mill. The following figure shows the schematic representation of the mill model used:

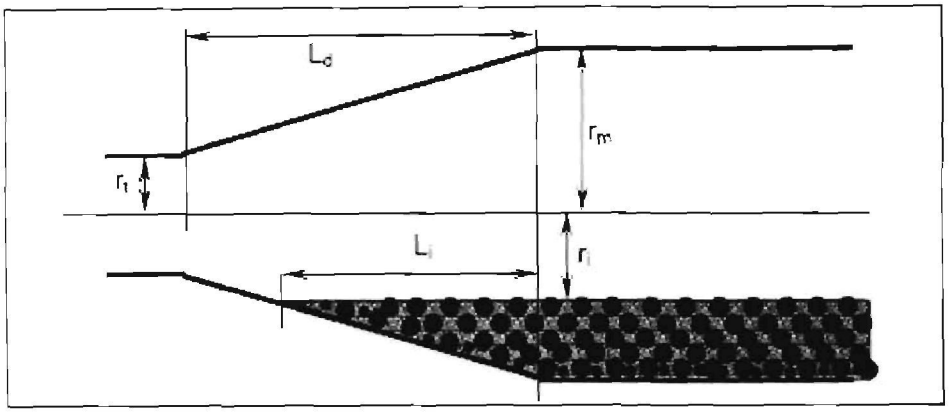


Figure 28: Basic mill model used in determining the mill power equations

For the cylindrical section on the right, the following equation is used to calculate the power draw:

$$Pt=\left[\frac{\pi * g * L * N_m * r_m}{3(r_m - z * r)_i}\right] * \left[2r_m^3 - 3z * r_m^2 * r_i + r_i^3(3z-2)\right] *$$
$$\left[\rho_c * (\sin\theta_s - \sin\theta_T) + \rho_p * (\sin\theta_T - \sin\theta_{TO})\right] + \left[L * \rho_c * \left(\frac{N_m * r_m * \pi}{(r_m - z * r_i)}\right)^3 * \left[(r_m - z * r_i)^4 - r_i^4 * (z-1)^4\right]\right]$$

Equation 4: Power draw of the cylindrical section

For the conical end-sections, the power draw is calculated using the following equation:

$$Pc=\left[\frac{\pi * g * L_d * N_m}{3(r_m - r_i)} * \left[r_m^4 - 4r_m * r_i^3 + 3r_i^4\right]\right] * \left[\rho_c * (\sin\theta_s - \sin\theta_T) + \rho_p * (\sin\theta_T - \sin\theta_{TO})\right] +$$
$$\left[\frac{2\pi^3 * N_m^3 * L_d * \rho_c}{5(r_m - r_t)} * (r_m^5 - 5r_m * r_i^4 + 4r_i^5)\right]$$

Equation 5: Power draw of the conical end-sections

In order to calculate the no-load power, the following formula is used:

$$Py = 1.68D^{2.05} * [\phi(0.667 * L_d + L)]^{0.82}$$

Where

P_t = Power draw of cylindrical section (kW)

P_c = Power draw of conical section (kW)

L = Length of cylindrical section of mill inside liners (m)

L_d = Length of cone-end (m)

N_m = Rotational speed of mill (rev/s)

G = Acceleration due to gravity (m/s^2)

P_c = Density of total charge (t/m^3)

P_p = Density of discharge (t/m^3)

Z = Parameter

D = Diameter of cylindrical section of mill inside liners (m)

r_m = Radius of mill inside liners (m)

r_i = Radial location of inner surface of charge (m)

r_t = Radius of discharge trunnion (m)

Ø = Fraction of theoretical critical speed (%)

θ_S = *Angular displacement of shoulder location at mill shell (radians)*

θ_T = *Angular displacement of toe location at mill shell (radians)*

θ_{TO} = *Angular displacement of surface of slurry pool at toe (radians)*

Equation 6: No-Load power draw

Morrel proved this model by using 14 milling circuits on six different plants as case studies. The results of this study show that the mill load or charge is the principal determinant of power draw on cylindrical mills [2.10].

INSTALLED VERSUS RUNNING CAPACITIES OF A MILL

For the reasons discussed in the previous section, it can usually be found that the running capacities of these mills are typically much lower than the installed capacities of the motors. A comparison of this has been done on a few plants and the following table shows the typical values of total installed mill capacities versus the running capacities of the same:

Plant	Mill installed capacity (KW)	Mill running capacity (KW)	% Running of installed capacity
1	12400	8600	69%
2	12400	10400	84%
3	9300	7800	84%
4	4600	2875	63%
5	9000	5880	65%

Table 4: Comparisons between installed and running capacities of SAG mills

The difference has been calculated and the average mill runs at approximately 73% of its installed capacity. This can be seen in the following figure:

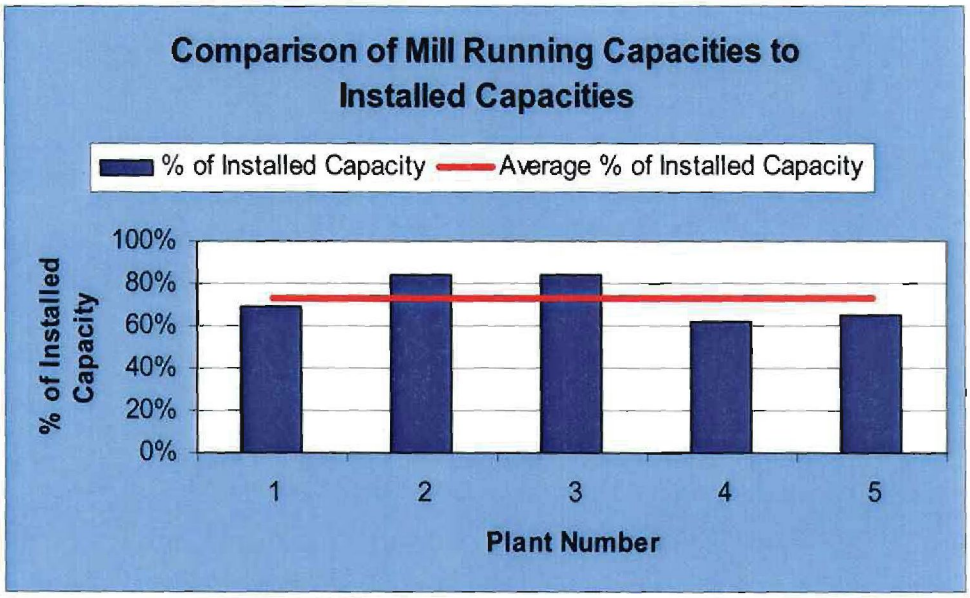


Figure 29: Graphic representation of mill running capacities vs installed capacities

Even though the running capacity of a typical mill in a gold or platinum plant can now be estimated quickly, it still leaves the question as to why the mills do not have smaller motors installed. This would make sense, since it would be relatively easy to choose a motor on the required mill speed and power draw for most efficient milling, and it would save energy for both the plant and the DSM program.

The answer lies in the fact that a typical mill is a high inertia load. The mills used in gold and platinum applications require a very high starting torque to get it going from standstill. A typical semi-autogenous grinding (SAG) mill requires a starting torque in the order of 182% of the running torque, while a ball mill requires a starting torque in the order of 140% of running torque [2.6]. The following figure illustrates this more clearly for a SAG mill:

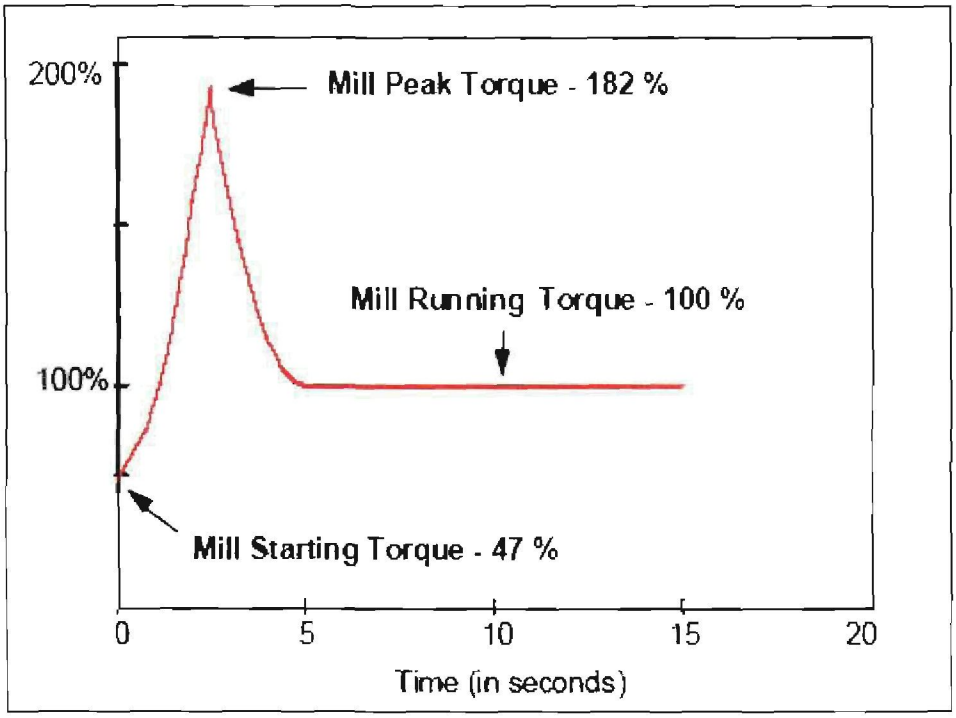


Figure 30: starting and running torque comparison for a typical SAG mill

In order to start these mills under any load condition, it is necessary to have a motor and drive combination that will give the required torque at lows speeds and reduced starting voltages, under high slip conditions. Because the typical mill application runs at low speed, frequent use is made of the low speed characteristics of synchronous motors. Even though synchronous machines offer improvements in terms of power factor correction and efficiency, it has limited starting torque capabilities [2.6].

A typical application on a gold or platinum plant may therefore require the use of a liquid starter and slip ring motor combination. In fact, this combination is installed on all the plants visited during this research period. This allows the transfer of high torque at reduced starting currents, allowing the mill to be started up under load in a relatively short time. As most of this torque is concentrated at the drive shaft, this combination of motor and liquid starter also produces a type of soft start to reduce fatigue on the drive shafts.

By examining some equations for the start up characteristics of a large rotating mill, better insight can be gained into the requirements put on the motor/starter combination. The time to accelerate the mill from standstill to design speed is given by the following equation [2.14]:

$$Time = \frac{WK^2 * SpeedChange}{308 * AvgTorque}$$

Where

Time = Seconds

WK^2 = Inertia of load plus motor

$$AvgTorque = \frac{(FLT + BDT)}{2} + BDT + LRT$$

Where
FLT = Full Load Torque
BDT = Breakdown Torque
LRT = Locked Rotor Torque

Equation 7: Time required to speed up a mill from standstill to design speed

The theory was tested on a large ball mill on a cement plant, and it was found that the start up of the mill is not linear. The speed vs torque has been plotted and the following results have been obtained [2.14]:

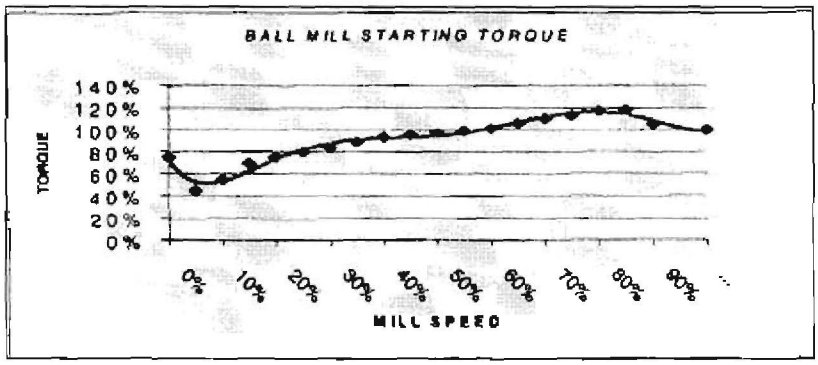


Figure 31: Torque vs Speed for a typical large ball mill [2.14].

This graph shows that the torque exceeds 120% of the running torque at 80% of the design speed.

It can therefore be concluded that the typical rotating mill as those found on mineral processing plants, will require a drive motor with a relatively high installed capacity, because of the torque requirements of starting a fully loaded mill. It was found that the running power of these mills is largely dependant on the mill charge, hardness of the ore being milled, and relative density

considerations. Therefore, the DSM auditor should not be fooled into thinking that the mill will be able to run at a higher power draw during off-peak and standard times. These attempts will only result in reduced power draw and the accompanying production losses.

Due to the possibility of production losses if mills are stopped, DSM has long been ignored or avoided by operators of mineral processing facilities. During the course of the research it has been found that almost anyone working on such a facility will say that DSM is not possible on their facility. Various reasons have been cited, the following list names but a few:

- Increasing occurrence of oxidation of the metal to be extracted, causing a reduction in the yield.

- Reduction in grade of material due to changes in the carefully controlled relative density (RD) of the material in the thickeners.

- Decreased machine life due to increased stop and start cycles.

- Increased maintenance on various pieces of equipment.

- Machines not functioning properly due to the reduced levels and pressure in various sections of the circuits.

- Clogging of pipes or chutes due to slurry hardening. This is especially true in a wet process, as found on a gold plant or a platinum concentrator.

Therefore it is important to make sure that the production or integrity of the process is not compromised when implementing DSM procedures. Careful investigations on both platinum concentrators and gold plants were done to determine if and how it will be possible to perform load shift on these facilities. The results are shown in the following sections.

2.3 POSSIBLE DSM LOAD SHIFT POTENTIAL ON A PLATINUM CONCENTRATOR

By examining the requirements for load shift cited in Section 2.2, and comparing it to the layout of a platinum concentrator as provided in Chapter 1, it seems that load shift should be a straightforward task. This is because there are various large pieces of electrical equipment installed, as well as probable storage capacity that might serve as buffer during load shift activities. Let us examine the different options in detail:

2.3.1 CRUSHING AND SCREENING

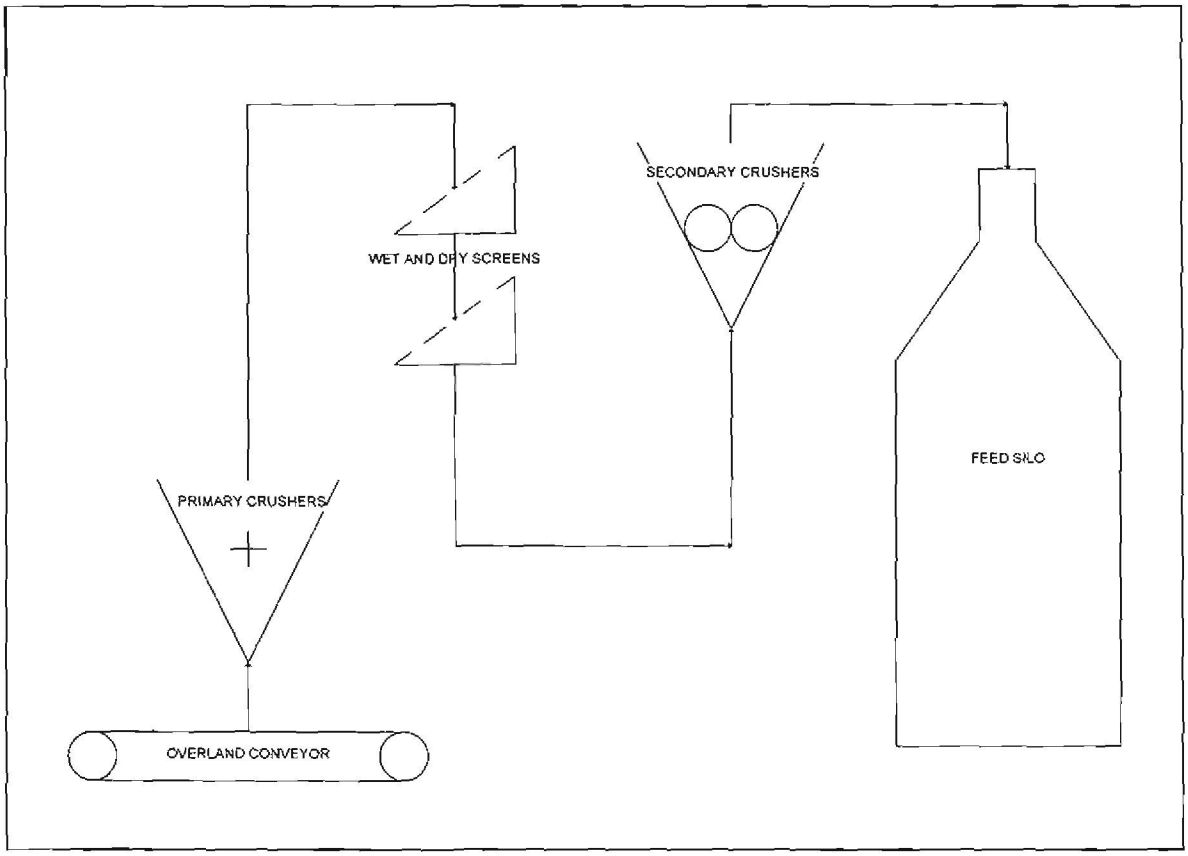


Figure 32: Simplified layout of the crushing and screening section

In the crushing and screening section, there are various pieces of equipment that make use of electrical motors. These include the crushers, conveyors and screens. These types of equipment typically lend themselves to easy rescheduling if the system allows it. This usually means some type of storage facility between the shaft and the crushing section is required. In a typical

platinum concentrator, this is not the case as illustrated by the above figure. This is also true for the site visited during the audit.

MATERIAL FEEDING THE CRUSHING AND SCREENING SECTION

Ore is transported from underground by means of an incline conveyor. From there, it is thrown onto an overland conveyor that transports it to the primary crushing section. From the crushing section, the crushed ore is stored in a mill feed silo shown in *Figure 32*. The purpose of the silo is to feed the primary mill in case of a breakdown in the crushing section. As the mill works continuously, the crushing plant must use all available time to fill the feed silo with crushed ore.

This is achieved by crushing as much ore as possible, as soon as the shaft extracts it. Historic values of ore being transported to the primary milling section by means of the overland conveyor have been obtained from the plant. The average hourly tons transported over a month period have been calculated and is given in the following figure:

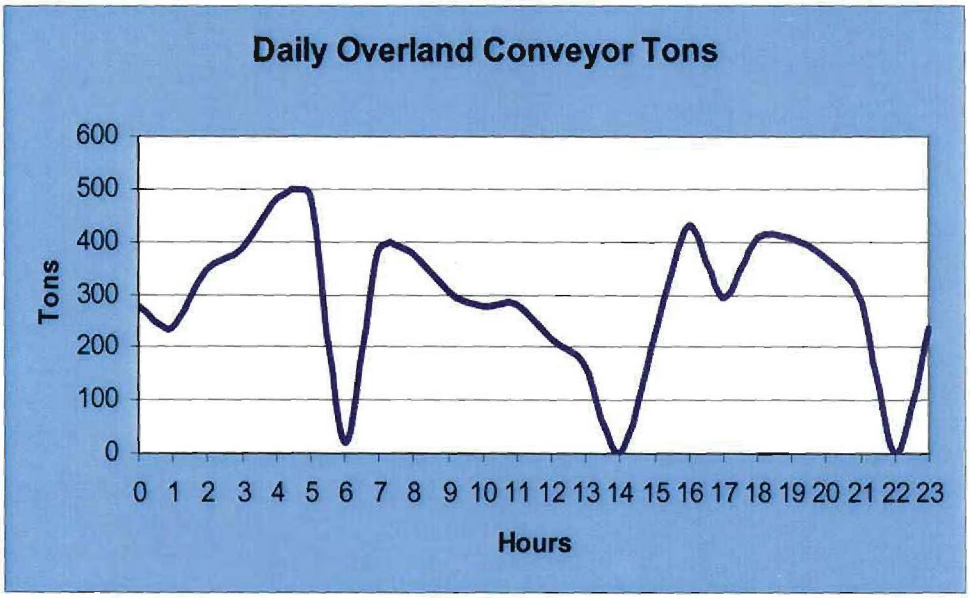


Figure 33: Illustration of the hourly tons on the overland conveyor

From the figure, it can be seen that there are three times per day when no ore is transported on the overland conveyor. The reason for this is the change-over times between shifts. At these times, there are no personnel around to supervise the conveyors, as such; it is shut down by the control room operator. These stops are normally only of short duration in order to transport as much ore as possible to the crushers. If these and other maintenance stops are excluded, the ore transport system work 24 hours per day, 7 days per week.

PRIMARY MILL TONS AND FEED SILO LEVELS

In order to determine how this crushing schedule affects the levels of the feed silo, it was necessary to determine the amount of ore going out of the silo into the primary mill. This was done by taking the historical data of the primary mill ore feed, and calculating the average daily tons for a month period. The same month was used as for calculating the ore on the overland conveyor. The silo tons going to the primary mill is shown in the following figure:

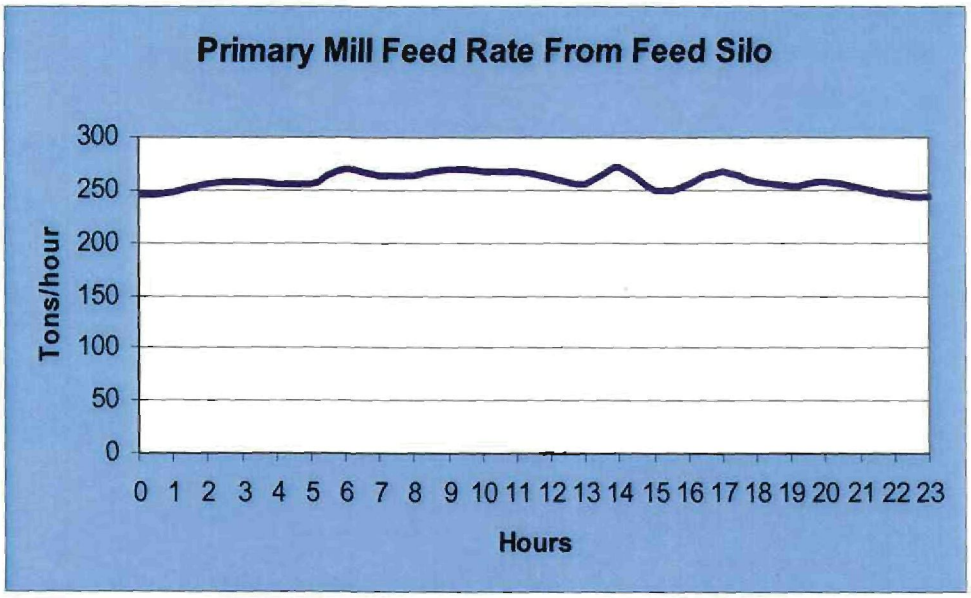


Figure 34: Hourly representation of ore being fed into the primary mill

From the above figure it is evident that the mill feed rate is constant throughout the day. This was expected, as the continuous nature of platinum concentration has already been discussed in Chapter 1. With such a constant feed rate, it seems possible that the feed silo will soon run empty. However; a quick comparison of available tons shows that this is not the case. The following table provides the specifics of the feed silo and the material movement surrounding it:

Silo Capacity	Max Level (90%)	Min Level (5%)	Tons into silo	Tons out of silo
8000 tons	7200 tons	400 tons	288 t/h	258 t/h

Table 5: Specifics of the feed silo

The table shows that the tons coming into the silos from the crushing section are more than the tons going out to the primary mill. This means that the crushing section has an overtaking capacity of approximately 10% over the primary mill, in spite of the stoppages due to shift

change on the crushing section. A small check will show that this overtaking capacity will fill the feed silo from the minimum level of 400 tons, to the maximum level of 4200 tons, in approximately 10 days. This is shown in the following figure:

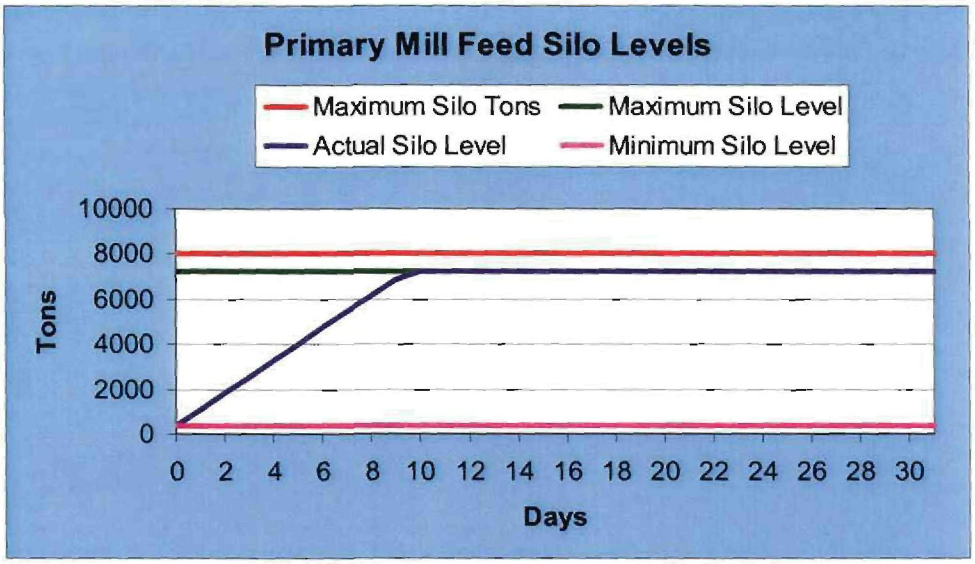


Figure 35: Illustration of the overtaking capacity of the primary mill

If a protracted breakdown should occur in the crushing section, the primary mill needs to keep on running to avoid production loss. For this reason the mill feed silo was built as a buffer. The following figure shows what will happen to the silo level if the crushing section is down for an extended time:

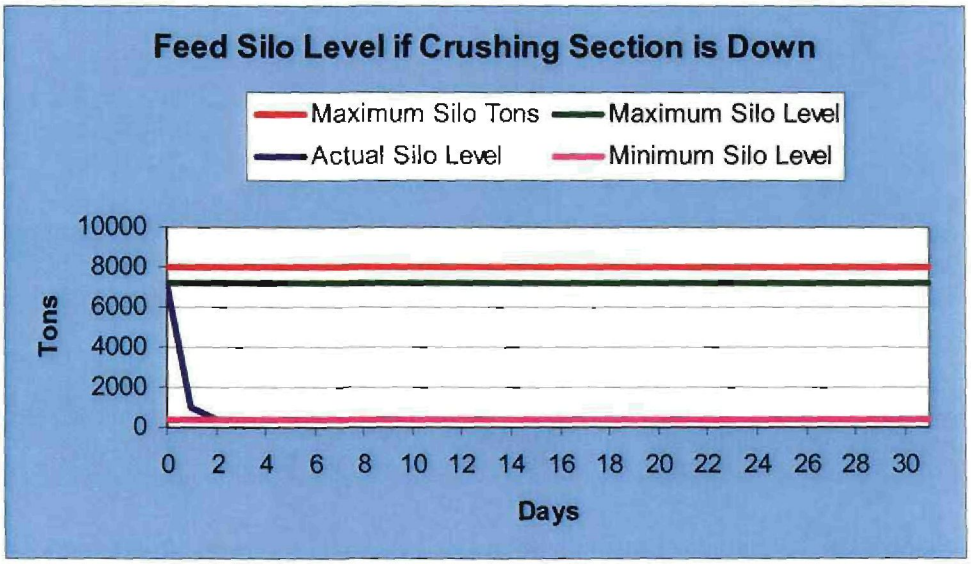


Figure 36: Feed silo level reduction in case of crushing section breakdown

From the figure it is evident that the silo level will drop from completely full (7200 tons), to minimum (400 tons), in just more than one day. As such, it can be concluded that personnel having to affect repairs on any equipment of the crushing section, have only a few hours to get it up and running again before the production is compromised.

LOAD SHIFT ON THE CRUSHING AND SCREENING SECTION

Previous studies on the power consumption of grinding equipment have shown that the fracture of rock is a very complex process. Various attempts have been made to determine the power draw of different types of grinding equipment. One of the most successful attempts resulted from extensive experimental work done by Bond [2.12].

The research stated that in rock breakage, the total work which has to be applied to a given weight of homogenous material is inversely proportional to the square root of the diameter of the product particles. Since any mixture contains a range of particle sizes, it was assumed that the particle size can be expressed as d_{so} (μm). This means that 80% of the cumulative mass of the particles are below this size [2.12]. Therefore, the total work (W), required for a size reduction from d_1 to d_0, can be written as follows:

$$W = W_0 - W_1 = \left(\frac{K}{\sqrt{d_0}} - \frac{K}{\sqrt{d_1}}\right) \quad (\text{kWh tonne}^{-1})$$

Where

K = Constant value.

Equation 8: Bond total work equation

The constant can be eliminated by using a term known as the work index (W_i). W_i is the total work required to reduce a particle from an infinite size to a size of 100 μm [2.12]. Substituting into the above equation:

$$Wi = \frac{K}{\sqrt{100}} - 0$$

The equation can then be written as follows:

$$W = 10Wi\left(\frac{1}{\sqrt{d_0}} - \frac{1}{\sqrt{d_1}}\right)$$

Where d, the particle diameter, is given in µm

Equation 9: Reduction of Bond total work equation

The work index is a measure of the energy used in breaking the material. It also includes the mechanical efficiency of the machine. Typical values for the work index have already been determined from laboratory tests, and these can be found in literature on the subject [2.12].

Instead of trying to use the above equations to determine the power draw of the crushing section. Historical kW values were extracted from the SCADA system at the plant. From these values, it was possible to calculate the electrical baseline for the section. This baseline shows the average daily electricity usage profile for the whole section and is shown in the following figure:

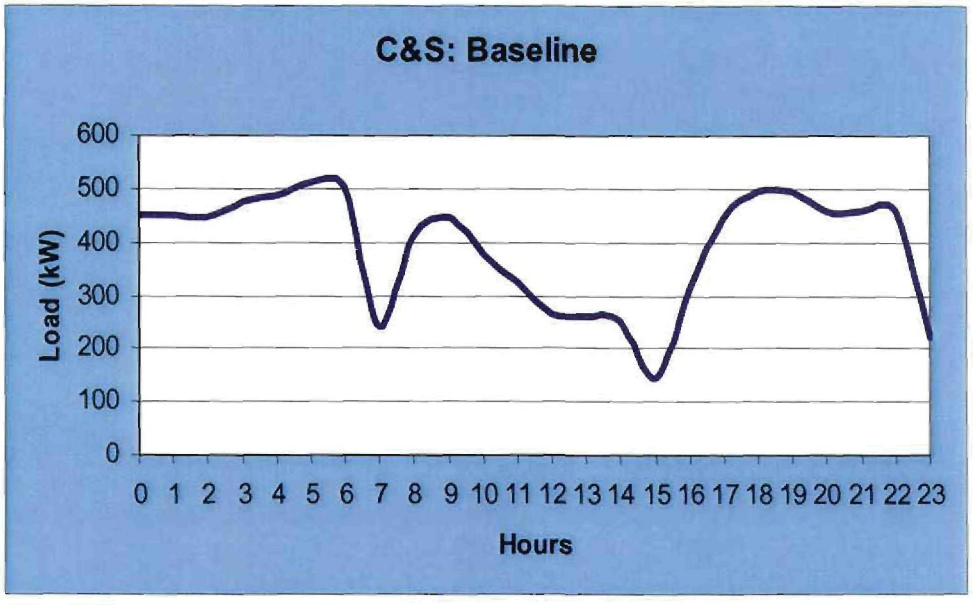


Figure 37: Crushing and Screening section baseline

This baseline was used as benchmark against which all possible DSM energy and cost savings are measured. This was done by simulating an optimised crushing schedule for this section. The purpose of the simulation was to see if it is possible to reschedule the equipment to run only out of peak times. If possible, it might result in possible MW and electricity cost savings for the plant. An effort was made to ensure that the new proposed crushing schedule is energy neutral. In other words using the same amount of energy as the current setup; represented by the baseline. The following figure shows the baseline compared to the optimised crushing schedule:

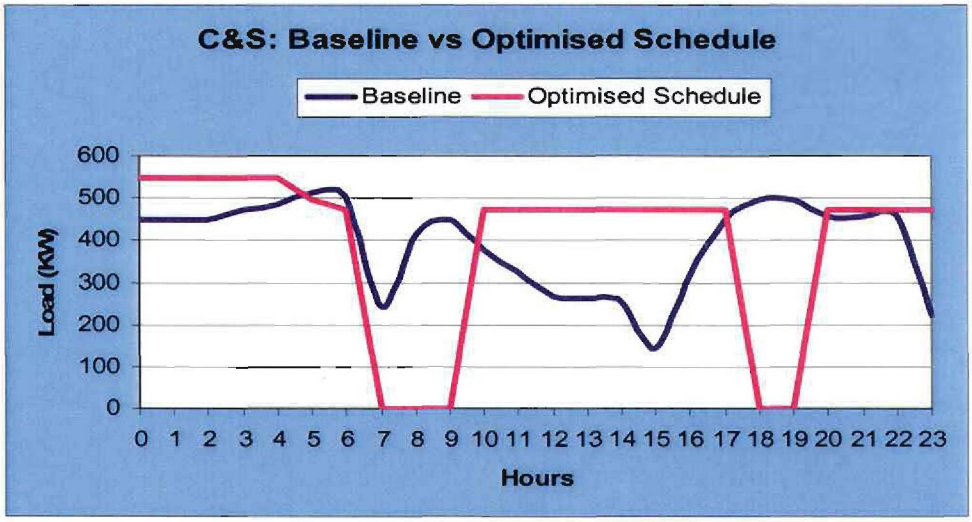


Figure 38: C&S section Baseline vs Optimised Schedule

The figure shows what seems like possible savings in the morning and evening peaks. These savings are calculated by subtracting the energy usage of the optimised schedule, averaged over the peak hours, from the corresponding baseline values. In order to provide more clarity, the actual values used for this calculation is given in the following table:

Hours	Baseline (kW)	Optimised Schedule (kW)
0	450	550
1	450	550
2	449	550
3	474	550
4	486	550
5	512	497
6	504	474
7	243	0
8	412	0
9	449	0
10	377	474
11	327	474
12	265	474
13	261	474
14	254	474
15	143	474
16	316	474
17	449	474
18	497	0
19	497	0
20	458	474
21	457	474
22	457	474
23	221	474

Table 6: Crushing and Screening section baseline vs Optimised schedule

If the average savings are calculated from *Table 6*, the following savings result:

Morning Load Shift	Evening Load Shift	Total Load Shift	Cost Savings
400 kW	500 kW	900 kW	R 95,350 p.a.

Table 7: Load shift and electricity cost savings fir the C&S section

This shows that some savings can theoretically be realised on this section. However, there might be some operational constraints that could disqualify this section as a potential DSM project. It is therefore important to compare the results to the criteria set for successful load shift.

SYSTEM CONSTRAINTS COMPARISON

In section 2.3, four criteria were given by which to judge the potential practicality of a load shift project. The following results were found for the crushing section:

***Criterion 1**: The production capability of the facility should not be compromised under any circumstances.*

Result Comparison: If the overland conveyor is stopped for any reason, there is no ore available for the crushing section. As there are no storage facilities between the overland and the crushing section, the following will result:

- The primary crusher will have to stop because of a lack of ore to crush.
- Because the equipment of the primary, secondary and tertiary crushing sections is all connected in series, a stop of the primary crusher will result in a stop of all the subsequent equipment.
- There will be a backlog of ore in the shafts that needs to be taken out at a later time, thereby reducing the production capabilities of the shaft concerned.
- The mill feed silo will run empty during the times the crushing section is off, thereby endangering the ore supply to the primary mill. This might compromise production.
- Even though it is theoretically possible to achieve load shift, it entails the stopping of machines in times of full production. This will affect production.

The results above show that any DSM load shift stops will result in a possible loss of production, and is therefore not desirable.

***Criterion 2:** There needs to be adequate storage facilities following after the equipment under consideration for load shift, in order to allow production to continue as normal with the equipment stopped.*

Result Comparison: In the case of the crushing section at the concentrator, there is adequate storage in the shape of the primary mill feed silo. The purpose of this silo is to provide the primary mill with ore on a continuous basis, even when the crushing section is down for an extended period of time. Therefore it can be said that this criterion for load shift is in place

Criterion 3: *The equipment to be stopped needs to have adequate overtaking capacity to make up any shortfall in production in off-peak periods.*

Result Comparison: It has been shown by calculation, that the crushing section has adequate overtaking capacity in the case of any equipment being down for repairs.

Criterion 4: *If production is not to be compromised, the project needs to be energy neutral. This means that the same amount of energy needs to be used for production after implementation of load shift, than before load shift. This is achieved by running the equipment at a slightly higher capacity during off peak times.*

Result Comparison: The optimised schedule shown in *figure 42* has been calculated to have the same area under the curve as the baseline. This was achieved by running the equipment at other times of the day not currently in use. This resulted in an energy neutral power profile for the section. Therefore, this criterion has been satisfied.

CONCLUSION

Three of the four criteria have been met in the case of the crushing section. However, the most important one, namely Criterion 1, has not been complied with. It is clear that any DSM procedures applied to this crushing section will result in a loss of production. This is totally undesirable, and also against the rules of the DSM program.

Changing the shift times of the plant might go a long way in achieving the calculated savings. However, this will probably affect the production schedule of the whole plant, while disrupting the shift routines of the plant employees. Even if this were possible, there is still no storage capacity in front of the section, therefore still producing a backlog at the shafts.

It can therefore be concluded that load shift on the crushing and screening section is not practically feasible.

2.3.2 PRIMARY MILLING

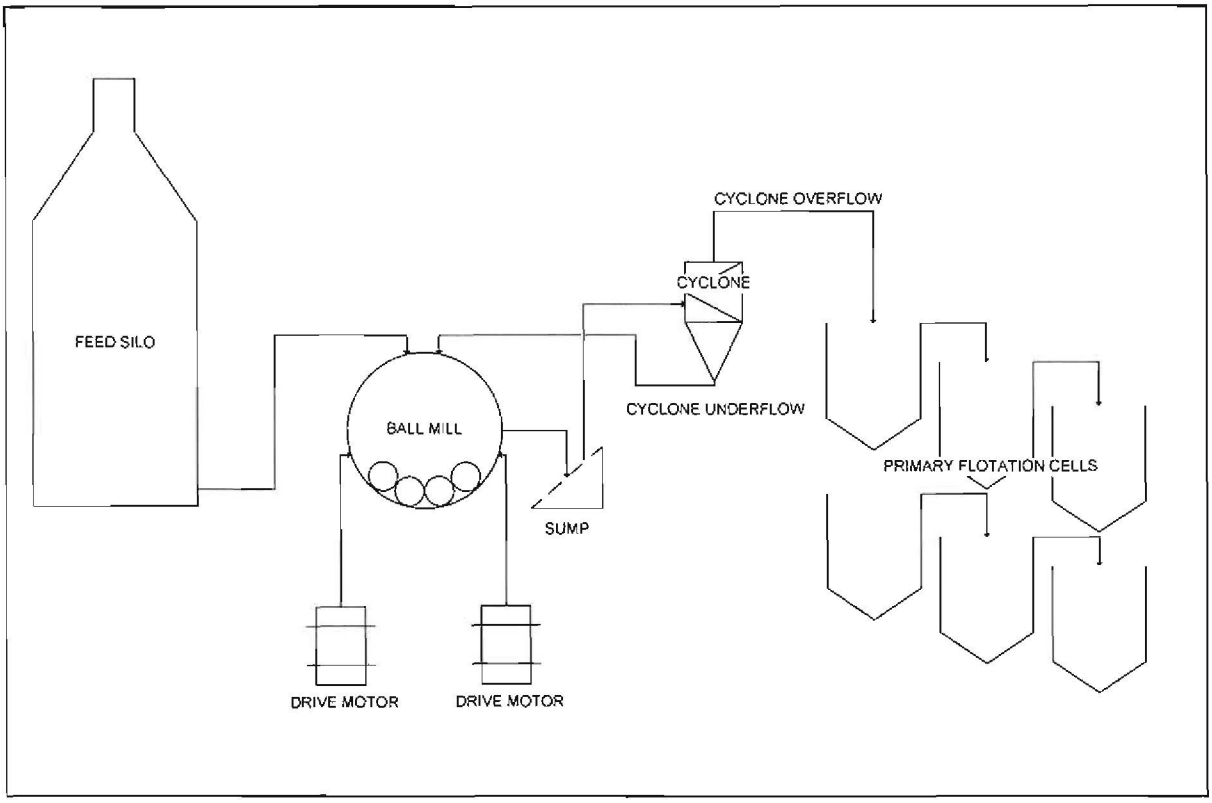


Figure 39: Simplified layout of the primary milling section

From the figure above it can be seen that the primary mill at the concentrator is an important piece of machinery in the milling circuit. It is a common cylindrical ball mill type with two drive motors of 3,200 kW each. It uses steel balls as grinding media to crush 90% of the platinum reef to -75 μm. A wet milling process is used at the plant.

In order to determine if it is possible to perform load shift on the primary mill, it is necessary to determine the current operation of the mill. This is easily determined by calculating the baseline for the mill. According to plant personnel, the mill runs continuously, and this was confirmed by the baseline in the following figure:

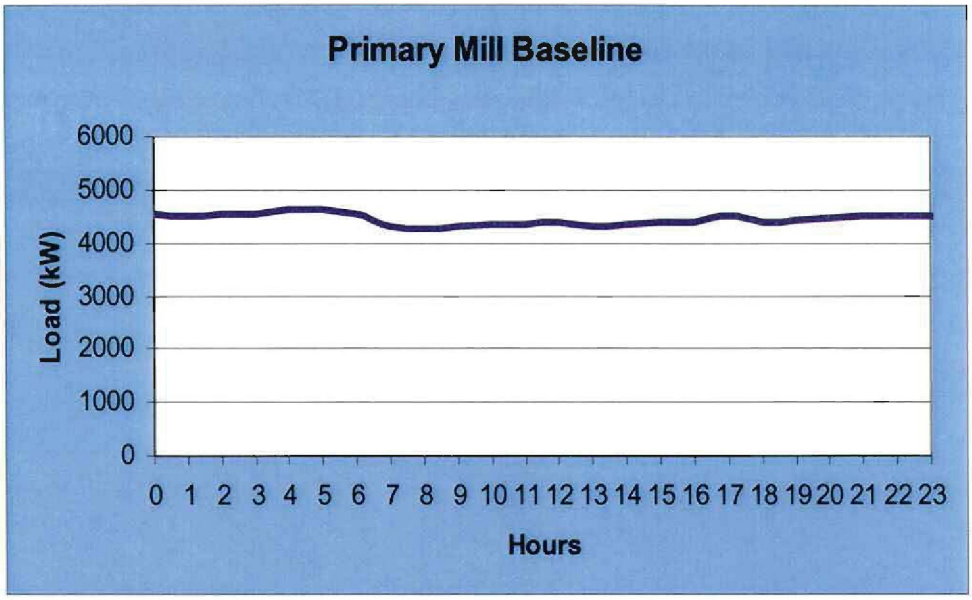


Figure 40: Primary mill baseline

LOAD SHIFT ON THE PRIMARY MILL

It has been shown that to perform load shift on a specific piece of equipment, it is necessary to run it at a higher kW value during off-peak and/or standard times, while it is shut down during peak times. This allows the application to be energy neutral, thus keeping the area below the curve the same before and after.

However, it has been shown earlier in this document that a typical cylindrical mill will only work effectively in a very narrow kW band due to various system constraints. As such, the power draw of a mill cannot just be increased at will; it has to be controlled very carefully to obtain the most efficient grind.

As such, in order to perform load shift on a mill, the actual operating schedule of the mill must be structured in such a way that there are times available during the day during which the mill is not in use due to lack of ore or empty silos. The tons not milled during peak hours can then be shifted to these times by carefully controlling the mill feed silo levels.

The easiest and quickest way to see whether the schedule of a specific plant allows load shift, is to look at the baseline. If the attention is focused on *Figure 37*, it can be seen that the baseline is almost a straight line. This means that the mill is running 24 hours per day, 7 days per week, breakdowns and maintenance permitting.

Even if load shift is performed during the peak times, it will not be possible to increase the power draw by increasing the mill charge. This will only result in a drop in production and power usage. As a further constraint, the mills are already using the only available method for increasing production, namely the addition of steel balls as grinding media, in the current production cycle.

BUFFER STORAGE CAPACITY

If the subject of storage capacity after the primary mill is examined, it can be seen that the only possible option with the current design is to use the primary flotation tanks as buffers when the mill is down for load shifting. However, there are some problems in this approach, as summarised in the following list:

- The design of the flotation cells are such that the discharge from one cell flows to the next one which is situated somewhat lower. This overflow is achieved by means of pipes situated near the top edges of each tank. The levels of the material in these cells are carefully controlled to be above the level of these overflow pipes.

- If the level drops below the level of the pipes, valves will close automatically to prevent any further draining of the cells.

- The closing of these valves prevents any further outflow and stops the whole flotation process from continuing. This practically stops the complete production cycle of the concentrator.

- If the material is left in the flotation cells for longer than approximately 30 minutes, oxidation starts to take place on the exposed surfaces of the milled ore in the slurry. This renders the batch useless, as the extraction chemicals will not react to it. This slows the production as the batch must be re-milled from scratch.

As such, it may seem that the flotation cells are not a good buffer to use for stopping the mill. Another option that was investigated was to install a tank between the mill and the flotation cells. The idea behind this was to allow the tank to take up the buffer capacity while the flotation cells continue to do their work. However, the problem of oxidation once again prevented this from being a viable option.

As a final test, the primary milling section was once again compared to the four criteria for a viable load shift project:

Criterion 1: *The production capability of the facility should not be compromised under any circumstances.*

Result Comparison: It has been shown that stopping the mill will not only result in a lower milling rate, but also in a complete stop of the primary flotation cells. Therefore this criterion is not met.

Criterion 2: *There needs to be adequate storage facilities following after the equipment under consideration for load shift, in order to allow production to continue as normal with the equipment stopped.*

Result Comparison: It has been shown that the flotation cells are not suitable as storage capacity when the mill is down. The addition of a storage tank after the mill will also not be feasible due to the problem of oxidation of the PGM slurry. Therefore, this criterion cannot be met.

Criterion 3: *The equipment to be stopped need to have adequate overtaking capacity to make up any shortfall in production in off-peak periods.*

Result Comparison: Overtaking capacity is not an issue here as stopping the mill will bring the production to a halt almost immediately. Therefore, this criterion is not met.

Criterion 4: *If the production is not to be compromised, the project needs to be energy neutral. This means that the same amount of energy needs to be used for production after implementation of load shift, than before load shift. This is achieved by running the equipment at a slightly higher capacity during off peak times.*

Result Comparison: Because the baseline is almost a straight line, and the mill constraints do not enable the baseline to be lifted significantly without affecting the production negatively, this criterion is not met. From the above comparisons it can be concluded that the primary milling section of a concentrator is totally unsuitable to DSM load shift procedures.

2.3.3 SECONDARY MILLING

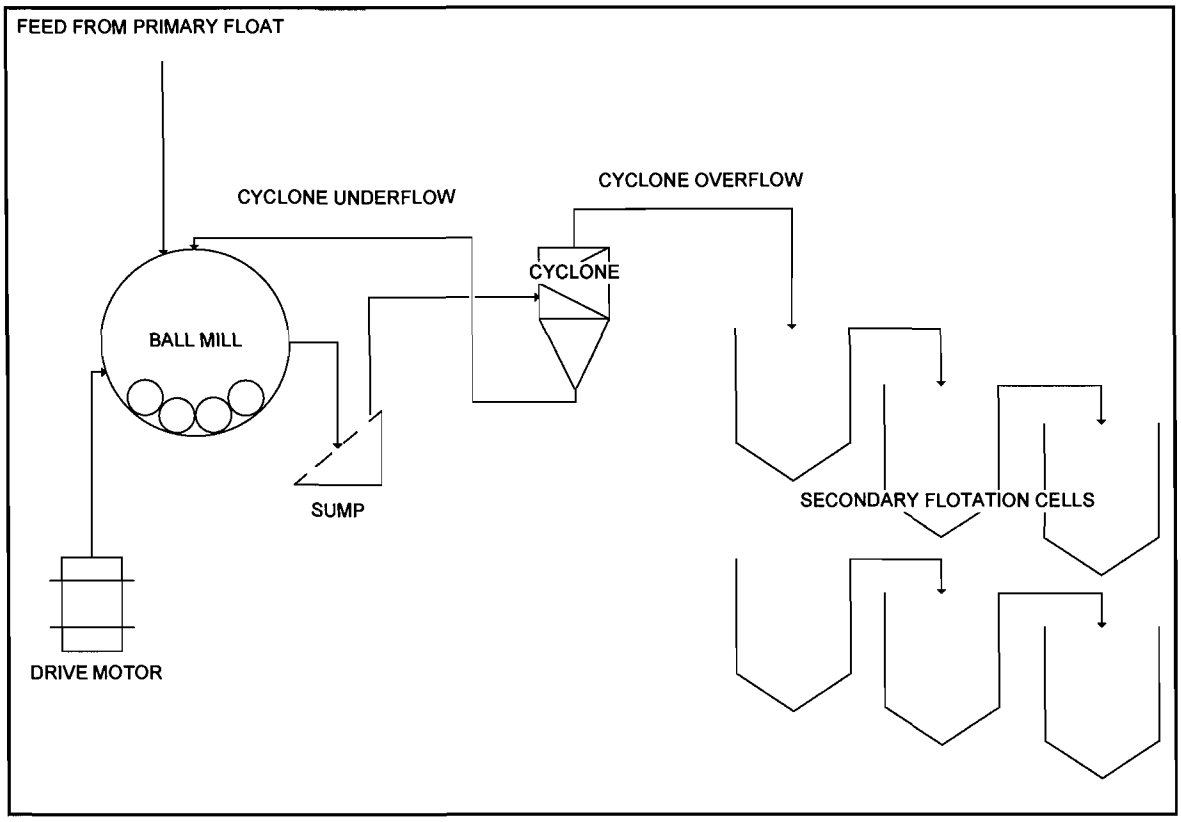


Figure 41: Simplified layout of the secondary milling section

Figure 41 shows that another large piece of equipment, namely the secondary mill, is used in a platinum concentrator. This mill is similar to the primary mill, the only difference being only one drive motor of 3,200 kW installed capacity. The secondary mill is fed from the primary flotation cells and it feeds the secondary flotation cells.

The main purpose of this mill is not really to mill the material, as it is already very fine slurry at this stage. Rather, it is employed to scrub the surfaces of the material affected by oxidation in the primary float, before it is sent to the secondary float.

The fact that the concentrator has a mill solely for this purpose is testimony to the severity of the oxidation problem experienced. To date, many different methods have been tried to achieve the same result, all without success. The most recent method includes the process known as scrubbing. Scrubbing is the continuous stirring of the slurry in a large tank known as a scrubber. A mechanical agitator is used to perform this task in an attempt to remove the oxidation. However, this method has not been proven successful to date.

POSSIBLE LOAD SHIFT ON THE SECONDARY MILL

In an attempt to prove the viability of load shift on this mill, the baseline was calculated from historical plant data. This is shown in the following figure:

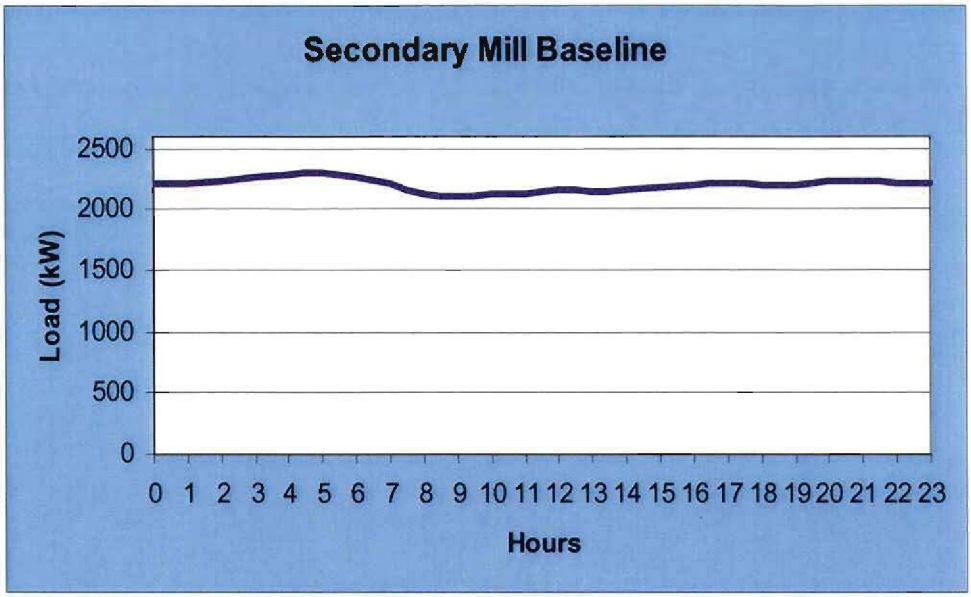


Figure 42: Secondary mill baseline

As expected, this mill also has a straight line baseline due to the fact that it is fed by the primary float, which is a continuous process. It also feeds the secondary float, which is also a continuous process. As such, the problems encountered with the primary mill will be repeated almost exactly on this mill. The most prominent example of this is the fact that stopping the mill with the current continuous process will result in a loss of production in the milling circuit.

For the same reasons as for the primary float, the secondary float cannot be used as storage capacity for load shifting the mill. This leads to the comparison of the system to the four load shift criteria:

***Criterion 1**: The production capability of the facility should not be compromised under any circumstances.*

Result Comparison: Stopping the mill in a continuous milling process will result in a loss of production which cannot be regained at a later time. Furthermore, the primary float feeds the mill, meaning that the mill cannot be stopped without affecting the production of the primary float. This criterion is not satisfied.

Criterion 2: *There needs to be adequate storage facilities following after the equipment under consideration for load shift, in order to allow production to continue as normal with the equipment stopped.*

Result Comparison: As with the primary float, the secondary float cannot be used as storage capacity.

Criterion 3: *The equipment to be stopped need to have adequate overtaking capacity to make up any shortfall in production in off-peak periods.*

Result Comparison: Overtaking capacity is not an issue here as stopping the mill will bring the production to a halt almost immediately. Therefore, this criterion is not met.

Criterion 4: *If the production is not to be compromised, the project needs to be energy neutral. This means that the same amount of energy needs to be used for production after implementation of load shift, than before load shift. This is achieved by running the equipment at a slightly higher capacity during off peak times.*

Result Comparison: Because the baseline is almost a straight line, and the mill constraints do not enable the baseline to be lifted significantly without affecting the production negatively. As such, this criterion is not met.

CONCLUSION

From the research results provided in this section it can be concluded that a platinum concentrator is not a viable option for load shift applications of DSM. It might be possible that there are options to implement energy efficiency projects on such a facility, but this was not part of the scope of this research. As such, the attention was shifted to load shift opportunities on CIP gold plants, in an attempt to satisfy the needs for this study.

2.4 EXISTING RESEARCH ON DSM IN GOLD PLANTS

In the course of the research it was found that a previous study was done by Den Boef [2.7] to try and determine the DSM possibilities on a gold plant. The report showed the typical breakdown of electricity use on a specific gold plant. This is shown in the following figure:

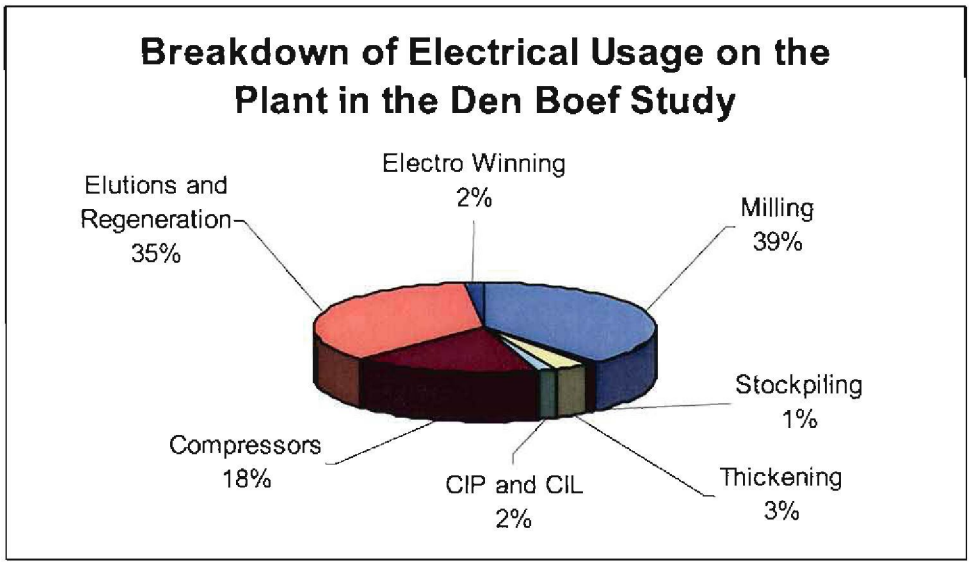


Figure 43: Breakdown of electrical usage on the gold plan in the Den Boef study.

This shows that the largest users of electricity on the plant are the milling section, closely followed by the elution and regeneration section as well as the compressors. From a DSM point of view it would make sense to focus on these three sections. The following sections discuss the results obtained from this study by Den Boef [2.7].

2.4.1 MILLING SECTION

From the breakdown, Den Boef showed that the milling section on the specific gold plant uses 39% of the electricity on the plant used in his study. According to the study, this is the section that shows the most DSM promise. The following figure shows the breakdown of the different equipment compiled as part of the study:

quipment	Qty	Unit Power (kW)	Total Power (kW)
Mill feed vibrators	6	7.5	45
Mill Feed Conveyors	6	5.5	33
Mills	6	1,760	10,560
Cyclone feed pump	6	132	792
Linear screen	3	4	12
		Total	**11,442**

Table 8: Breakdown of equipment electricity usage

The table shows that a total of 11,442 kW worth of equipment is installed in this section alone. It must be noted that this will not be the total DSM potential, since the machines are not used to full capacity.

As part of the study, Den Boef proposed using different numbers of mills to simulate the current energy usage of this section. The amount of mills necessary to achieve the current profile was simulated accurately to within 10% of the measured values. The following figure shows the verification model for a week:

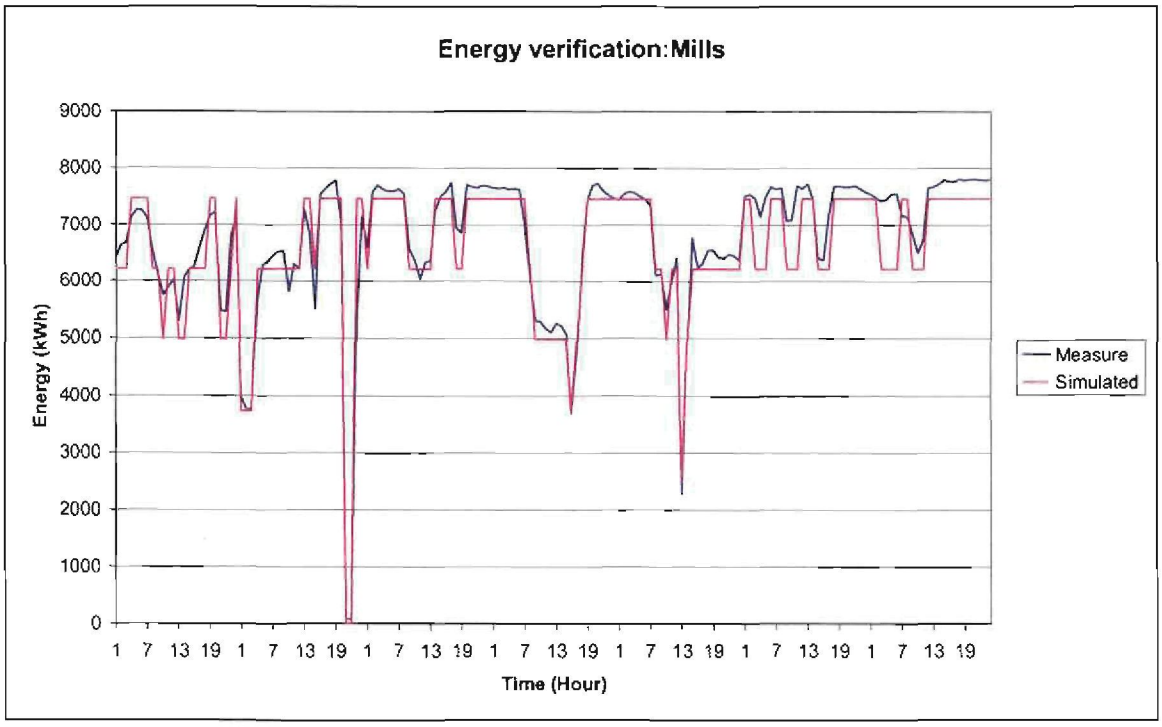


Figure 44: Mill energy verification done by Den Boef

However, this model only simulates the current situation at the plant. No practical solution was proposed as to how the mills need to be scheduled to achieve active load shift. As such, the

model was of no practical value in the prediction of load shift potential on the milling section of a plant.

Den Boef proposed to use the thickeners as storage capacity when the mills are down. This is the most logical solution in the case of the plant, since the mills feed almost directly into the thickeners. However, Den Boef treated the thickener the same as a dam full of water, assuming that the level of slurry inside has no impact on the relative density (RD) of the thickener underflow.

He simulated the thickener level by using the relevant flow data gathered from the plant, as shown in the following figure:

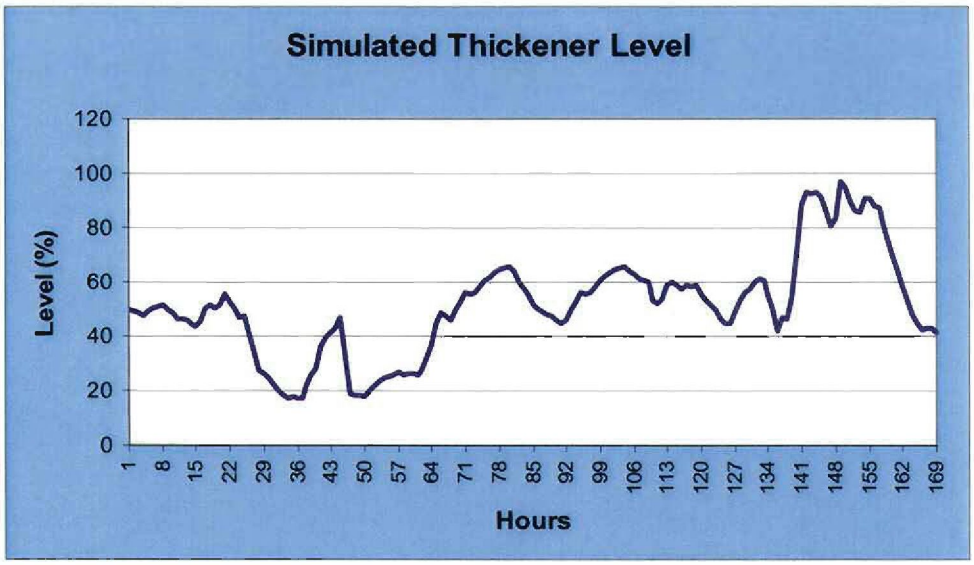


Figure 45: Thickener level as simulated by Den Boef

This may seem like an obvious answer, but the problem with this approach is the fact that the RD of the thickener underflow is not within the narrow specification range for effective gold extraction. This requires that the RD of the thickener underflow remain between 1.5 and 1.6 t/m^3. If the RD shifts from of these parameters, the efficiency of the gold extraction is compromised, thereby effectively loosing production.

In order to show that the thickener cannot just be used as a dam without taking into account the densities, the thickener level simulation above was used to calculate the corresponding RD of the slurry in the thickener. The results are shown in the following figure:

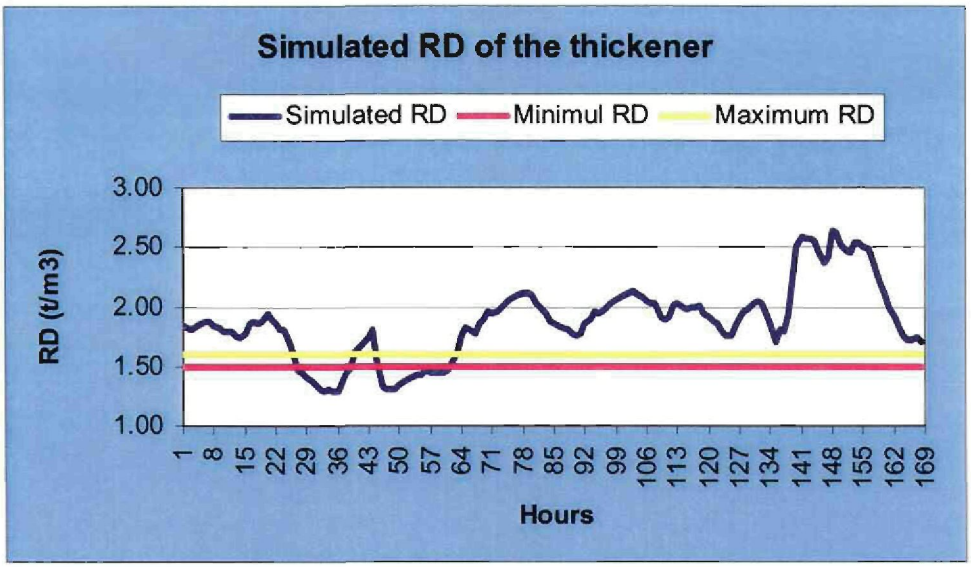


Figure 46: Desired RD levels compared to the values simulated by Den Boef

From the figure it can be seen that the proposed usage of the thickener as storage capacity resulted in a discharge RD that was too high most of the time. This means that even though the idea of using the thickener as buffer for stopping the mills seemed viable, the production will be affected negatively because the operational constraints have not been taken into account. It can therefore be concluded that the main contribution made by the previous study was to show that the milling section shows the most promise for DSM load shift.

2.4.2 ELUTIONS AND REGENERATION

According to Den Boef, this section consumes about 35% of the plant's electricity, making it the second largest contributor to the electricity account. The following table shows the installed capacities noted in the study:

Equipment	Qty	Unit Power (kW)	Total Power (kW)
Loaded Carbon Screen	2	4	8
Eluted Carbon Screen	2	4	8
Rotary Kiln	2	530	1,060
Dilluted Acid Mixing Tank Agitation	1	1.5	1.5
Dilluted Acid Transfer Pump	2	4	8
Potable Water Pump	2	5.5	11
Caustic/Cyanide Mixing Tank Agitation	1	1.5	1.5
Caustic/Cyanide Transfer Pump	2	4	8
Kiln Drive Motors	2	5.5	11
Kiln Screw Feeder	2	1.1	2.2
Boilers	6	1,566	9,396
		Total	**10,515**

Table 9: Equipment breakdown in the elution and regeneration section

Even though there are numerous pieces of equipment on this list, it is clear that the machines with seemingly the most potential are the rotary kilns and the elution boilers. It is therefore no wonder that the study focussed on these as potential DSM candidates.

ELUTION COLUMNS

If the focus is moved to the elution columns, this study also showed a simulation of the current use of the elution boilers. These results were compared to the actual energy usage of these boilers over a period of time. The following figure shows this comparison:

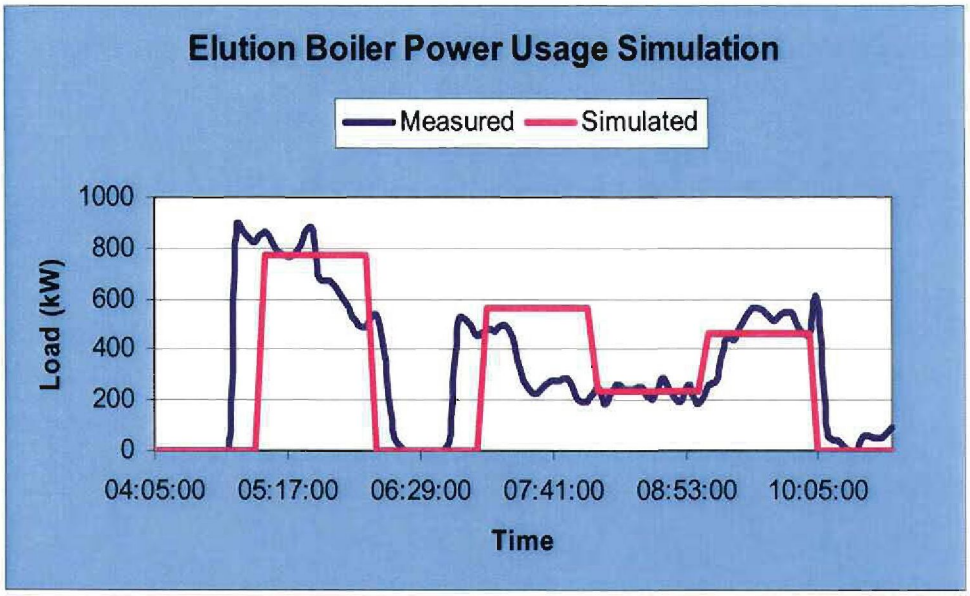


Figure 47: Elution column energy verification done by Den Boef

This simulation was accurate to within 10% of the measured values. Even though this simulation accurately portrayed the actual power draw of the boilers, no attempt was made to determine the practical implications of switching off the boilers during peak times. Once again, the DSM application still needs to be found.

ROTARY KILNS

The temperature of the rotary kilns is controlled by electrical elements in two or more zones. Each of these zones is heated separately by the elements and the temperature is controlled at 780 °C during the regeneration cycle. The study used thermal modelling techniques to simulate the temperature changes that occur during heating and cooling [2.7]. The following figure shows the schematic representation of the thermal model:

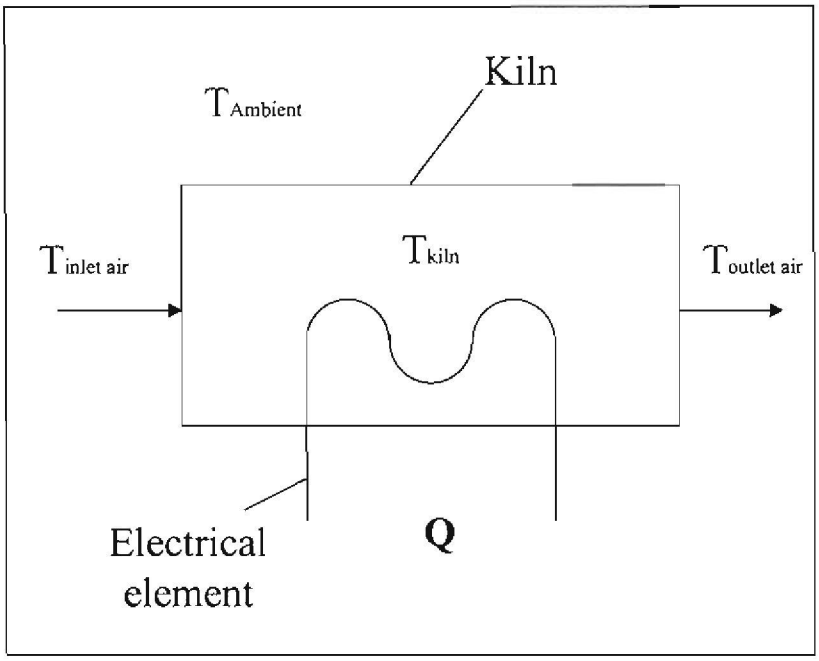


Figure 48: Thermal model of the kiln developed by Den Boef

The energy balance on the system in *Figure 48* can be written as follows:

$$C\frac{dT_{kiln}}{dt} = U_{kiln}A_{kiln}(T_{ambient} - T_{kiln}) + m_{air}cp_{air}(T_{inletair} - T_{kiln}) + Q$$

The effect of heat loss due to the air that infiltrates the kiln along with the carbon that is fed to the kiln is negligible. The equation above can now be reduced to the following:

$$C\frac{dT_{kiln}}{dt} = U_{kiln}A_{kiln}(T_{ambient} - T_{kiln}) + Q$$

Separating the variables and using the initial values $T_{kiln} = T_{kiln}^{0}$ at $t = 0$ the kiln temperature can be solved using the following equation.

$$T_{kiln} = \frac{1}{a}\left[(aT_{kiln}^{0} - b)\exp\left(\frac{-a\delta}{C}\right) + b\right]$$

Where $a = U_{kiln}A_{kiln}$

And $b = U_{kiln}A_{kiln}T_{ambient} + Q$

Equation 10: Energy balance equations to simulate the regeneration kiln

The values of the thermal capacity (C) and the heat transfer coefficient ($U_{kiln}A_{kiln}$) can be calibrated using the measured temperature profile of the kiln. This resulted in the following simulation model verification:

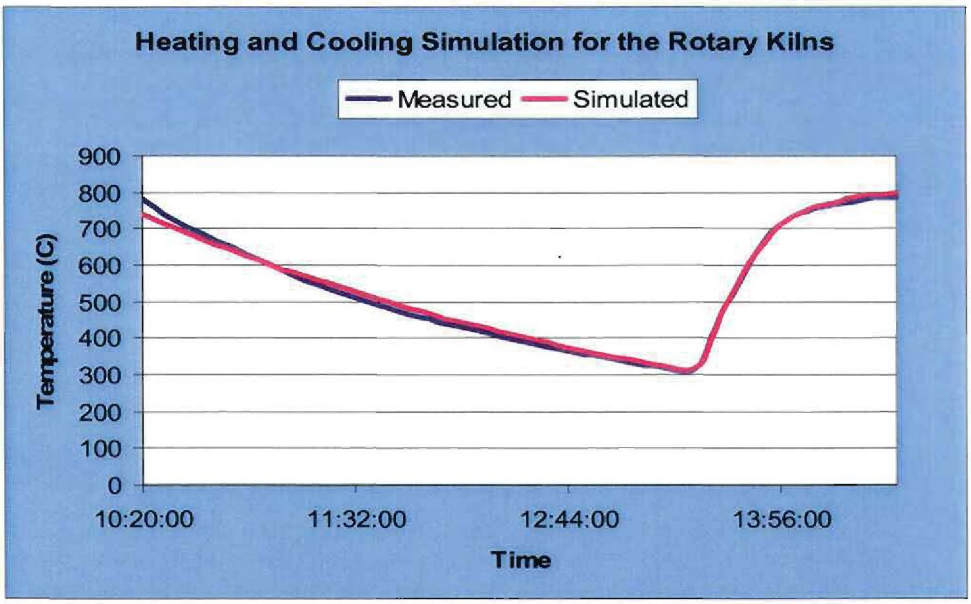


Figure 49: Temperature verification using the developed mathematical model

It can be seen that the simulation model was very accurate. In this case it was accurate to within 2% of the measured values. It is a very significant simulation, since it shows both the times required to cool down the kiln to 300 °C if it is switched off, and the time required to heat it up again from 300 °C

Even though the temperature was simulated accurately, no reference has been made to the actual DSM savings that can be achieved if the kilns are switched off during peak times. As such, it is not possible to say if the kilns will be a viable DSM option from the current literature.

2.4.3 COMPRESSORS

Den Boef [2.7] also showed that the air compressors are large users of electricity. This is expected, since it is very energy intensive to make compressed air [2.8]. The following table shows the installed capacities of the compressors audited by Den Boef:

Equipment	Qty	Unit Power (kW)	Total Power (kW)
Instrumentation Compressors	3	430	1,290
Compressors 1 - 4	4	750	3,000
Compressor 5	1	960	960
		Total	**5,250**

Table 10: Equipment breakdown in the compressor section

Even though these compressors use approximately 18% of the plant's total electricity, they are used almost continuously to supply the plant with process air. This means that it will be very difficult to find any load shift potential on the compressors. Because of this, Den Boef did not attempt to simulate the system.

CONCLUSION

It was concluded that DSM on air compressors are a whole new field of speciality. It can be used as a suitable subject for further research, and has therefore been left out of the rest of this thesis as a possible DSM opportunity.

2.5 A NEW APPROACH TO IDENTIFY LOAD SHIFT POTENTIAL ON A GOLD PLANT

2.5.1 INTRODUCTION

Using the research done by Den Boef [2.7] as a starting point, a new, fresh look has been taken at the load shift opportunities on a gold plant. It has already been identified that the milling and elution circuits are the two most probable places where load shift can be implemented successfully. As such, the research was moved from looking at the larger picture, to focussing on the milling and elution sections.

These following sections will therefore be dedicated to the research done by the author of this thesis on the different possibilities of performing load shift on the milling and elution circuits of a gold plant. The first section will focus on the elution circuit, investigating various DSM possibilities and the implications of each.

This will be followed by the results of the author's investigation into load shift possibilities on the milling circuits of a gold plant. The shortcomings of the previous research will be removed by the addition of new research results regarding load shift viability. After these results have been provided, a chapter will be devoted to developing a novel simulation model to predict the possibility of load shift in gold plant milling circuits.

2.5.2 ELUTION CIRCUIT

In order to determine the load shift possibilities on a typical elution circuit, research was done on a few gold plants in South Africa to determine the energy sources used by different plants for heating the elute. Since the purpose of this study is to find ways to save electricity costs by means of load shifting, only plants with electrode boilers were considered for the study.

As a representative example, the elution circuit of a gold plant in the Vaal River operations of AngloGold Ashanti group was used. This plant currently has five boilers used for the elution operations. These boilers are of the electrode type, and were supplied by the Marshall-Fowler company. These boilers are powered by electricity and have the following specifications:

Boiler type	ES 130
Power	1320 kW
Volts	380 V
Amps	2000 A
steam	2000 kg/h

Table 11: Specifications of the ES 130 boiler

The following figure presents the reader with a picture of one of these boilers:

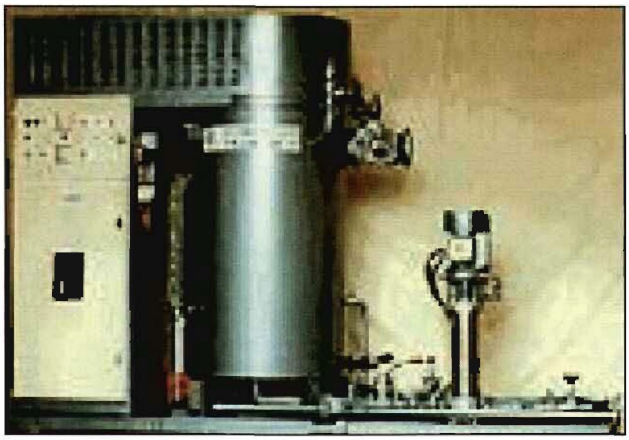


Figure 50: Picture of an ES range boiler

One of the benefits of these boilers is that they are compact, which means that they can be installed in confined spaces. A further benefit is that they are pollution free, which means they can be installed adjacent to the steam using facility without fear of contaminating the atmosphere for the personnel working there.

The electrode boiler works by conducting electricity directly through the water itself. As water is a pure resistance load, the power factor is unity and the heat input is directly equivalent to the electrical energy input [2.9].

The only heat losses are through the shell, top cover and other exposed parts. This type of boiler has a high efficiency – in the order of 95% to 98%, with no reduction when working with reduced load or low feed water conductivity. The following figure shows the typical efficiency curve of an electrode boiler [2.13]:

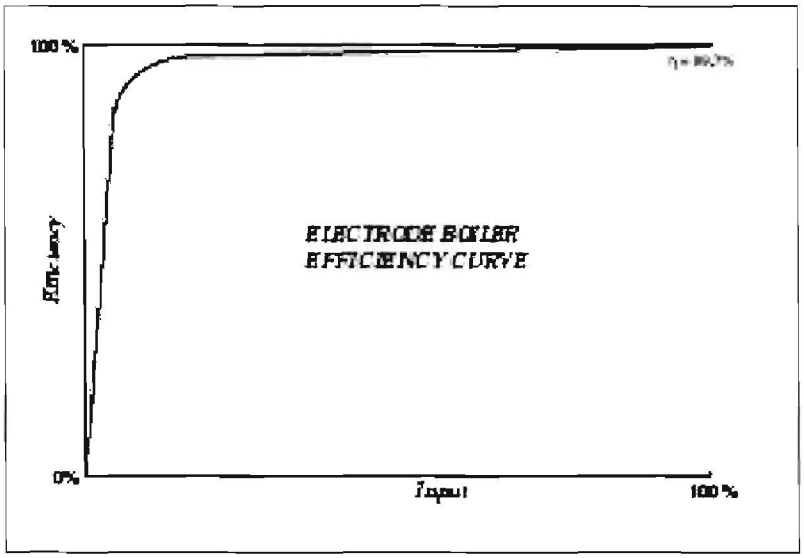


Figure 51: Efficiency curve of an electrode boiler [2.13].

The boiler is a simple machine, with the only main parts being the pressure vessel and electrode assembly, feed water pump, regulating fittings and a control panel. The operation of these boilers can be briefly explained as follows:

As current flows through the water between the electrodes, the electrical energy is converted directly into heat. The current drawn is a function of the surface area of the electrodes exposed to the water, as well as the conductivity of the water. This means that the current draw can be regulated by controlling the water level in the boiler, therefore altering the exposed surface

area of the electrodes. The control settings of the boilers allow them to be controlled between 5% and 100% of the rated output. This can either be done manually or automatically, allowing these boilers to run trouble free for extended periods of time [2.9].

QUESTION REGARDING LOAD SHIFT ON THE BOILERS

Since Anglo Gold is currently committed to reduce energy costs in its operations, the question was raised whether it would be viable to perform DSM on the elution circuit at a specific gold plant. The possible solution included replacing or substituting the current boilers with boilers powered by alternative fuels. As such, energy cost comparisons were done for different types of fuels, compared to electricity.

CURRENT ELECTRICITY USAGE OF THE ELECTRODE BOILERS

In order to determine the actual electricity usage of the boilers, data loggers were installed on boilers 1 and 2 at the plant for a period of approximately 10 days. From these logged values, the baselines for these two boilers were calculated. The average kW usage of boiler 1 and 2 was taken as being representative of a typical boiler. These are shown in the following figure:

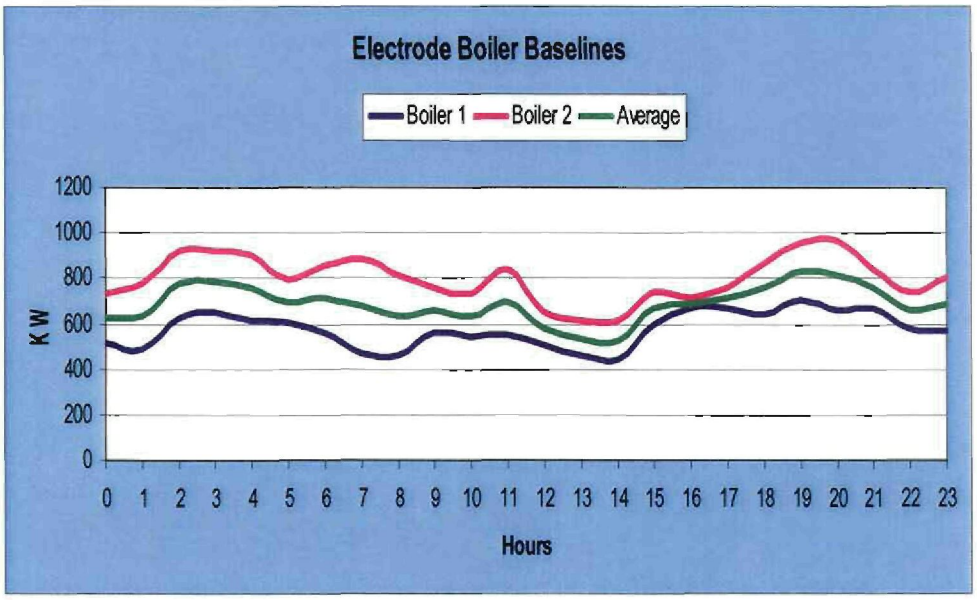


Figure 52: Baselines for the electrode boilers

The average baseline in *Figure 52* was taken as benchmark for performing energy cost calculations for both electricity and alternative fuels. In order to have a viable DSM project, it

is necessary that the total cost of an alternative fuel boiler be less than the current cost of running the electrode boilers. The average baseline was used to determine the amount of

energy (kWh) used by a typical boiler. By summing the hourly kW values of the average baseline in *Figure 52*, it was determined that the average daily energy usage of an electrode boiler is **16,468 kWh**.

ENERGY COST OF USING ELECTRODE BOILERS

In order to compare the energy cost of different fuels, the cost of running a single electrode boiler was calculated using the MegaFlex tariffs. This cost was used as a base value with which to compare the energy costs of using different fuels. For the sake of comparison, it was assumed that the boilers were running on weekdays only for a whole year. The following table provides the electricity cost for a boiler for a typical year:

Summer days	Winter days	Summer cost	Winter cost	Total cost
195	66	R 305,057 p.a.	R 216,804 p.a.	R 521,861 p.a.

Table 12: Annual electricity cost for running an electrode boiler

Three of the boilers were assumed to use the full amount of kWh as calculated in the baseline, while two of the boilers were assumed to use 50 % of the total kWh. As such, the total yearly cost of the electrode boilers was calculated to be the following:

Amount of Boilers	Energy Cost per Electrode Boiler	Total Electricity Cost
3 Boilers	R 521,861	R 1,565,583
2 Boilers	R 260,930	R 521,860
	Total	**R 2,087,443**

Table 13: Annual electricity cost of running all five electrode boilers

ENERGY COST OF USING ALTERNATIVE FUEL BOILERS

Since it has already been determined that the daily energy usage of a single electrode boiler is 16,468 KWh, a comparative study was done to calculate the cost of using alternative fuels to obtain this value. The fuels chosen are the practical alternatives for running a boiler as was discussed with gold plant personnel. Conversion software was used to determine the specific energy value for each type of fuel. The results of these calculations are shown in the following table:

Average kWh	16,468	kWh						
Fuel Type	Amount of Fuel				c/l	R/ton	Cost/day	Cost/year
Diesel Oil	336.92	gal(UK)	1,532.99	L	552.5		R 8,469.75	R 2,210,604.14
LPG	489.94	gal(UK)	2,229.23	L	319		R 7,111.23	R 1,856,023.11
Kerosene	347.15	gal(UK)	1,579.53	L	447.2		R 7,063.67	R 1,843,617.70
Coal	2.02	Ton of coal				335	R 676.79	R 176,618.70

1 gal(UK) = 4.55 L

Table 14: Cost comparison of using different alternative fuels

If we compare these energy costs in *Table 14* with the cost of running the electrode boilers provided in *Table 14*, it can be seen that only coal will provide a cheaper option for running the boilers. However, the figures only reflect the energy cost, and not the total cost of maintenance and supply of fuel. Since coal is the least expensive option in terms of energy, calculations were done to compare the total energy cost of the current five boiler setup at the gold plant in terms of coal and electrode boilers.

Just as with the current usage of the electrode boilers, three of the boilers were assumed to generate the full amount of KWh, while the remaining two boilers only produce 50% of the total KW. The energy cost results for the coal boilers are provided in the following table:

Amount of boilers	Energy cost per coal boiler	Total Energy cost
3 Boilers	R 176,618.70	R 529,856.10
2 Boilers	R 88,309.35	R 176,618.70
	Total	**R 706,474.80**

Table 15: Energy cost for using coal boilers

If the results are now compared to the energy cost of the electrode boilers, it can be seen that the energy cost saving will be almost R 1.4 million p.a. if the electrode boilers are completely replaced with coal fired boilers. This is shown in the following table.

Amount of boilers	Energy cost of electrode boilers	Energy cost of coal fire boilers	Annual energy cost saving
3 Boilers	R 2,087,442.44	R 706,474.80	**R 1,380,967.64**

Table 16: Total annual energy cost savings from using coal fired boilers

Instead of completely replacing the electrode boilers with coal fired ones, a different saving scenario was investigated as possible DSM intervention. For this scenario, the possibility of using a combination of alternative fuel and electrode boilers was proposed. The idea behind this is to retain the use of the efficient and simple electrode boilers for most of the day, while switching to alternative fuel boilers during peak times in order to save electricity.

This type of intervention is not load shift, but rather an energy efficiency application of DSM. Even though the total energy used remains the same, the amount of electricity used is reduced in expensive MegaFlex times. Even though this should not have a negative effect on the heating requirements of the elution circuit because of the substitution by alternative fuel boilers, it can qualify as an energy efficiency project as per Eskom DSM regulations.

The following sections are devoted to exploring this scenario. The scenario looks at the effect of switching to the alternative fuel boiler in the evening peak. This will have the benefit of providing Eskom with a reduced power demand in the troublesome evening peak, while still providing the elution circuit with the necessary energy for the heating requirements.

SAVING SCENARIO: RUNNING THE COAL-FIRED BOILER IN THE EVENING PEAK

Using the baseline calculated for the electrode boiler, the energy profile of this scenario will appear as follows:

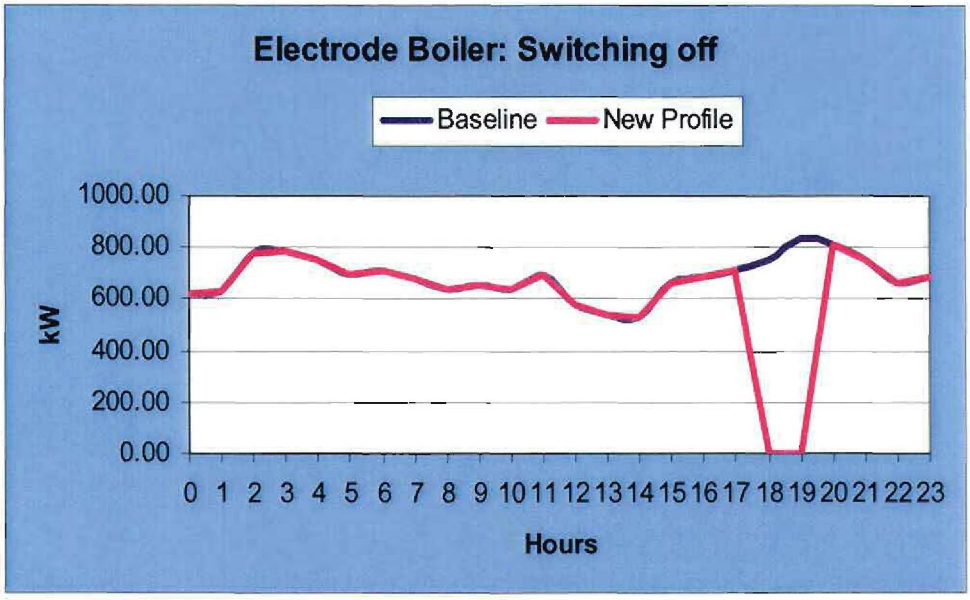


Figure 53: Electricity profile if boiler is switched off.

As discussed earlier, this reduced energy in the evening peak will be made up with the alternative fuel boiler to keep the elution circuit running as normal. By switching off the boilers as shown in the above figure, the annual cost savings calculated from the MegaFlex profile is the following:

Avg Monthly Savings		
summer	Jan	R 5,518.23
summer	Feb	R 5,283.24
summer	Mar	R 5,429.12
summer	Apr	R 5,574.99
summer	May	R 5,429.12
winter	Jun	R 18,482.94
winter	Jul	R 18,482.94
winter	Aug	R 19,310.94
summer	Sep	R 5,753.21
summer	Oct	R 5,664.10
summer	Nov	R 5,753.21
summer	Dec	R 5,574.99
		R 106,257.03

Table 17: Electricity cost savings if boiler is switched off.

In order to determine if it is viable to augment the electrode boilers with alternative fuel boilers, it is necessary to compare the savings in *Table 17* with the cost of running the alternative fuel boilers.

COST OF USING ALTERNATIVE FUEL BOILERS IN THE EVENING PEAK

It must be noted that the alternative fuel boiler cannot be run only for two peak hours. According to the Marshall-Fowler company; it must also be run beforehand for at least 3-4 hours in order to get it up to temperature and pressure. This stands in stark contrast to the electrode boiler that only needs 15 minutes to get up to temperature and pressure. In this scenario, the worst case, namely four hours were used.

This means that the coal boiler will have to run approximately six hours each weekday in order to provide the necessary steam during the two evening peak hours. The following table provides the costs of running different fuel boilers for a period of six hours every weekday:

Average kWh	4179	kWh						
Fuel type	Amount of fuel				c/l	R/ton	Cost/day	Cost/year
Diesel oil	85.50	gal (UK)	389.03	L	552.50		R 2,149.36	R 560,983.78
LPG	124.33	gal (UK)	565.70	L	319.00		R 1,804.59	R 470,997.41
Kerosene	88.10	gal (UK)	400.86	L	447.20		R 1,792.62	R 467,874.75
Coal	0.51	ton of coal				335.00	R 170.85	R 44,591.85

Table 18: Cost of using alternative fuel boilers for six hours every weekday

From *Table 18* it can once again be seen that the only fuel less expensive than electricity is coal. The actual savings in electricity cost is therefore the savings generated by switching off the electrode boilers, minus the cost of burning the coal for six hours per weekday. This is shown in the following table:

Electricity Cost Saving p.a.	Coal Cost p.a.	Energy Cost Saving p.a.
R 106,257.03	R 44,591.85	**R 61,665.18**

Table 19: Actual energy cost saving per boiler if coal is used during the evening peak

From these results it is clear that the combination of coal and electrode boilers will produce an energy efficiency saving of almost R62,000 p.a. for each boiler. If the savings are calculated for the five boilers in the current setup, the total energy efficiency savings can be calculated. The following tables compare the total savings gained by using the coal-fired and electrode boilers:

Amount of boilers	Electricity cost per boiler	Total Electricity cost
3 Boilers	R 106,257.03	R 318,771.09
2 Boilers	R 53,128.52	R 106,257.03
	Total	**R 425,028.12**

Table 20: Total annual electricity cost for the electrode boilers

Amount of boilers	Energy cost per coal boiler	Total Energy cost
3 Boilers	R 44,591.85	R 133,775.55
2 Boilers	R 22,295.93	R 44,591.85
	Total	**R 178,367.40**

Table 21: Total annual energy costs per coal boiler

The annual energy cost savings were calculated to be the following:

Energy cost of electrode boilers	Energy cost of coal fired boilers	Annual energy cost saving
R 425,028.12	R 178,367.40	**R 246,660.72**

Table 22: Total annual energy cost savings

From *Table 22* it can be seen that the total energy efficiency saving will be almost R250,000 p.a. Even though this saving is substantially less than can be achieved by completely replacing the electrode boilers with coal-fired boilers, the savings are still substantial and will go a long way in helping Eskom achieve its DSM target.

NOTES ON USING COAL-FIRED BOILERS

In order to verify if coal is a viable option for steam creation, a telephone call was made to the Marshall-Fowler company regarding the use thereof. The following points were highlighted:

- Maintenance cost is high on a steam boiler.
- The boiler takes 3-4 hours to heat up.
- The steam boilers must be kept on temperature the whole time so to be available at short notice.
- A permanent boiler operator is necessary for each boiler.
- It produces air pollution which might be a problem. This may require expensive treatment facilities.

On the other hand, the current electric steam boilers have the following advantages:

- Full steam raised in 15 minutes.
- Constant pressure to meet fluctuating demand.
- No pollution or noise.
- No fuel store or chimney required.
- Can be left unattended.

COST OF INSTALLING COAL FIRED BOILERS AT THE GOLD PLANT.

Quotes have been obtained from a boiler supply company for the installation of coal-fired boilers at the plant in question. The current steam needs of the elution circuit have been used as size specification for the new boilers. The coal fired boilers have been quoted as R5,200,000 for supply and installation. This is a budget quote only and it does have standard exclusions not quoted on. The quote is supplied in APPENDIX B.

PAYBACK PERIOD FOR FULL-TIME USE OF COAL-FIRED BOILERS

By taking the R5,200,000 from the quote as the cost for supplying and installation of these boilers, the payback period can be calculated if the current electrode boilers are entirely replaced by coal fired boilers. The results for the break even analysis are shown in the following table:

Annual cost saving	Cost of boilers	Payback period (years)
R 1,380,967.64	R 5,200,000.00	**3.77**

Table 23: Payback period calculation results

This payback analysis is shown in the following figure:

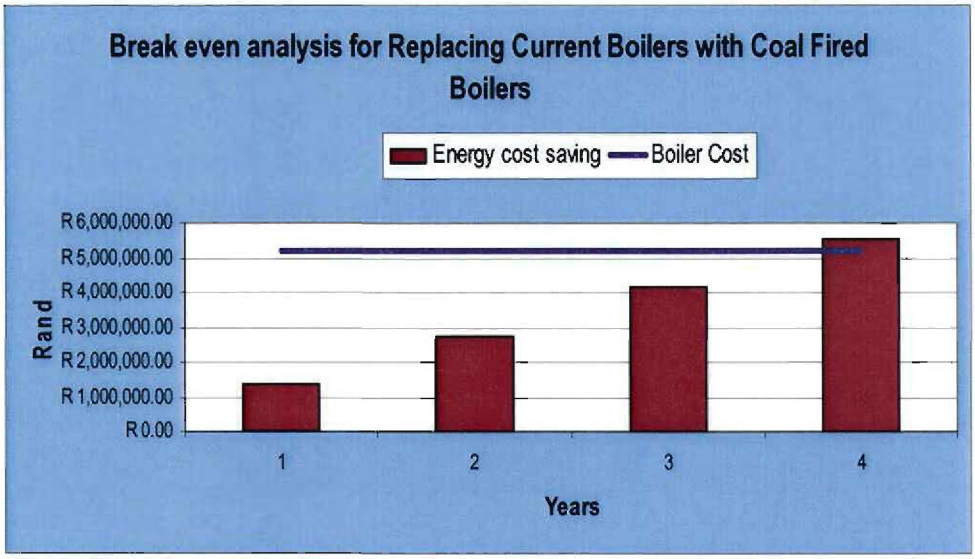


Figure 54: Breakeven analysis if electrode boilers are replaced completely

If the current boilers are replaced completely with the coal fired boilers, the payback period will be 3.7 years.

PAYBACK PERIOD FOR EVENING PEAK USE OF COAL-FIRED BOILERS

A similar payback period can also be calculated if the coal fired boilers are only used to produce steam during the peak times. This is shown in the following table and figure:

Annual electricity cost savings	Cost of Boiler installation	Payback period (years)
R 246,660.72	R 5,200,000.00	**21.08**

Table 24: Payback period calculation results

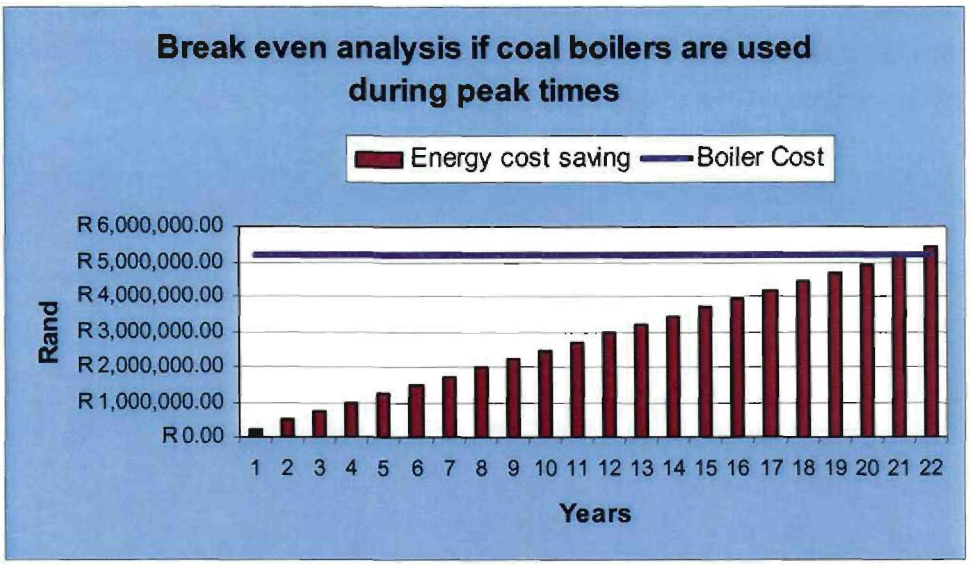


Figure 55: Breakeven analysis for using coal fired boilers in the peak times

With the quoted cost of installing the coal fired boilers, the payback period will be 21 years if only the peak times are taken into account.

CONCLUSION

This investigation compared the energy costs of the current ES130 electrode boilers at a gold plant, to the energy cost of similar alternative fuel boilers. Two scenarios were investigated, namely completely replacing the electrode boilers, and using the alternative fuel boilers to augment the electrode boilers during peak times. The following results have been obtained:

- Maintenance and operator costs were not taken into account during the calculations, only energy cost.
- The least expensive alternative fuel in terms of energy cost is coal.
- The energy cost of coal fire boilers is much less than the similar MegaFlex electricity cost.
- A new installation of coal fired boilers will cost approximately R5,200,000.
- If the coal fired boilers are used in conjunction with the electrode boilers during the evening peak, the cost savings will produce a payback period of 21 years.

- If the electrode boilers are completely replaced by the coal fired boilers, the energy cost savings will produce a payback period of approximately 3.7 years.

- There still is some maintenance and pollution issues to be addressed before a final, more detailed, viability study can be completed.

2.5.3 THE MILLING CIRCUIT

Before finding a way to perform load shift on a milling circuit at a gold plant, discussions were held with the plant personnel on the current production and maintenance practices at the specific plant. This includes the plant specific equipment constraints, dynamics of the ore supply to the plant, overtaking capacity of the mills, etc.

Most importantly, it was necessary to understand the layout of the milling circuit of a CIP gold plant. The following figure shows a layout of a milling circuit for a typical CIP plant milling circuit:

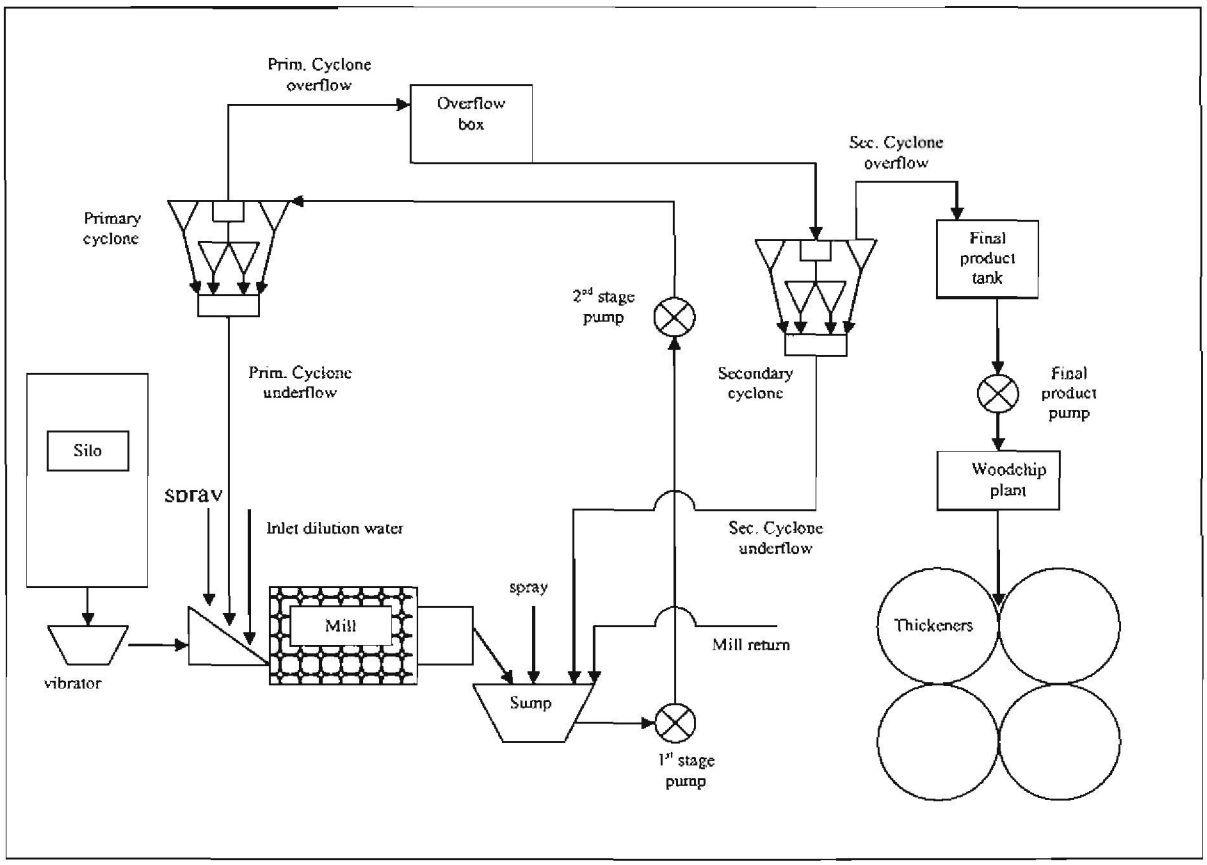


Figure 56: Layout of the gold plant milling section

Figure56 can be used to provide a short description of the milling process:

1. Gold reef is removed from the shafts by means of rock winders, and transported to the storage silos in front of the mills. This ore is usually transported by means of overland and/or incline conveyors. Sometimes trucks and trains are used if large distances are involved.

2. The reef is mixed with spray water and inlet dilution water before being fed into the mill.

3. Inside the mill, the reef is crushed in a wet milling process. The type of mill may differ, but the most common is the Run of Mine (ROM) mill. This mill uses the reef itself, with the help of pebbles and waste rock under certain circumstances, to crush the reef by means of a continuous lifting and falling action brought on by the rotation of the mill as described in Chapter 1.

4. Leaving the mill, the crushed slurry is ejected through a trommel screen, where all the oversize pebbles are rejected, and the fine slurry is thrown into a sump.

5. In the sump, more spray water is added, along with mill return water and secondary cyclone underflow. The purpose of the water is to dilute the slurry before going to the cyclones, as well as ensuring the proper relative density of the slurry.

6. From the sump, the diluted slurry is pumped to a primary cyclone, where dense and less dense particles are separated by means of rotational forces.

7. The denser material goes to the primary cyclone underflow, which is fed back into the mill for re-crushing, while the less dense material, known as primary cyclone overflow, goes to a secondary cyclone for further separation.

8. From the secondary cyclone, the underflow is returned to the sump, where it is pumped back to the primary cyclone, while the secondary cyclone overflow is transported to a final product tank.

9. From here, the slurry is pumped through a woodchip plant, which removes all the light woodchips that escaped through the system, before going to the thickeners.

10. The thickeners are of similar design to settling tanks, where the slurry, which reacts to a coagulant, sinks to the bottom, while the clean water settles on top. The settlers are raked continuously to prevent the slurry from setting.

11. This slurry in the thickeners contains all the gold in solution. This solution needs to be kept at an RD of approximately 1.5 t/m^3, in order to get maximum extraction of gold from the slurry.

12. This slurry is now pumped from the thickeners at a constant rate and RD of 1.5 t/m^3, to the leaching process, the first step in extracting the gold from the slurry.

The idea behind load shift on this plant was to stop the milling circuit before the thickeners during Eskom peak times, with the possible exception of the water pumps. This should allow the plant to gain the benefits of electricity cost savings. Of course, this should be done in a controlled manner, in order to introduce as little as possible disturbance to the circuit or damage to equipment.

In order to perform load shift on any facility, it is necessary to have storage capacity at least after the equipment to be stopped during peak times. In the case of a gold plant, the only such storage available would be the settlers.

During the first visits to the gold plant to discuss the possibility of load shift on the mills, the plant personnel were very reluctant to pursue the idea of stopping the mills. This was understandable, since the conventional wisdom they have been taught holds that a mineral processing plant will perform best when run as a continuous operation. Any disturbance in the process leads to substantial delays in the production schedule, and might possibly cost much money in terms of production losses.

AUDIT PROCEDURES: PROCESS QUESTIONS

During the audit done on a gold plant, time was spent with the control room operators, plant engineers and technical advisors. The purpose of these discussions was to obtain valuable insight into the inner workings of the milling circuit on a CIP plant. A list of questions was compiled by the author and posed to the abovementioned plant personnel. These are shown below:

1. **Q:** How often do planned shutdowns happen on the plant?
   A: The whole plant is stopped once every six months.

2. **Q:** How are the relining stops done?
   A: Relining is done piece-by-piece every week for six months. Then no relining is done for the following six months.

3. **Q:** How long is this weekly stop?
   A: 12 hours, first the one mill is stopped and completed before the next one is stopped the following day. These stops are also used to service pumps and leaking pipes.

4. **Q:** Are there any specific breakdowns that occur regularly?
   A: There are no specific recurring breakdowns.

5. **Q:** Do the mills stop often for too little ore in the silos?
   A: No, only about once or twice a month. Most of the stops are due to mechanical breakdowns.

6. **Q:** How long does it take for the specific density in the thickeners to go down if the mills are stopped?
   A: If both mills are standing, it takes approximately 8 to12 hours. It takes even longer if only one mill is stopped.

7. **Q:** Which material provides the greatest difficulty in the quest for good RD?
   A: If the ore is waste, it is difficult to return to good RD after a shutdown.

8. **Q:** How long does the system take to recover to a good RD after it has dropped too far?
   A: The system takes about 5 hours to recover if good ore is milled.

9. **Q:** How old is the plant, this might contribute to the breakdowns?
   A: The plant is two years old. This might be the reason why the frequent breakdowns still occur (teething problems).

10. **Q:** During which times do the shaft put ore into the silos?
    A: The shaft pulls during off-peak and standard times. During the peaks they stop. During these peaks, the mills run to get ahead of the shaft.

11. **Q:** What is the preferred silo level to keep pressure off the plant?

    A: If the silos remain under 40%, there is no pressure on the plant from the shaft.

12. **Q:** Which has preference, the shaft or the plant?

    A: It is more desirable to stop the mills because of empty silos, than the shaft because of full silos. It is more expensive to stop the shaft, because this forces all the miners to stop for something over which they have no control. This means they will do no work, but will still have to get paid as normal.

The answers to these questions seem to indicate that there might be a possibility to perform load shift on the mills. However, this will have to be verified by using actual data from the plant. Historical data from the plant was used to determine the possible savings that can be achieved. This is discussed in the following section:

HISTORICAL PLANT DATA

The plant has three mills installed, of which two are used to mill reef. The third mill is used to mill the waste dump at the plant. The focus was kept on the two reef mills for this research. The two reef mills at this plant have an installed capacity of 6 MW each. Even though the motors are so large, the actual power usage is closer to 4 MW because of the reasons discussed in Chapter 1. Historical data was gathered for three consecutive months in order to determine the baselines. The following figures show the baselines for the two reef mills as they currently are:

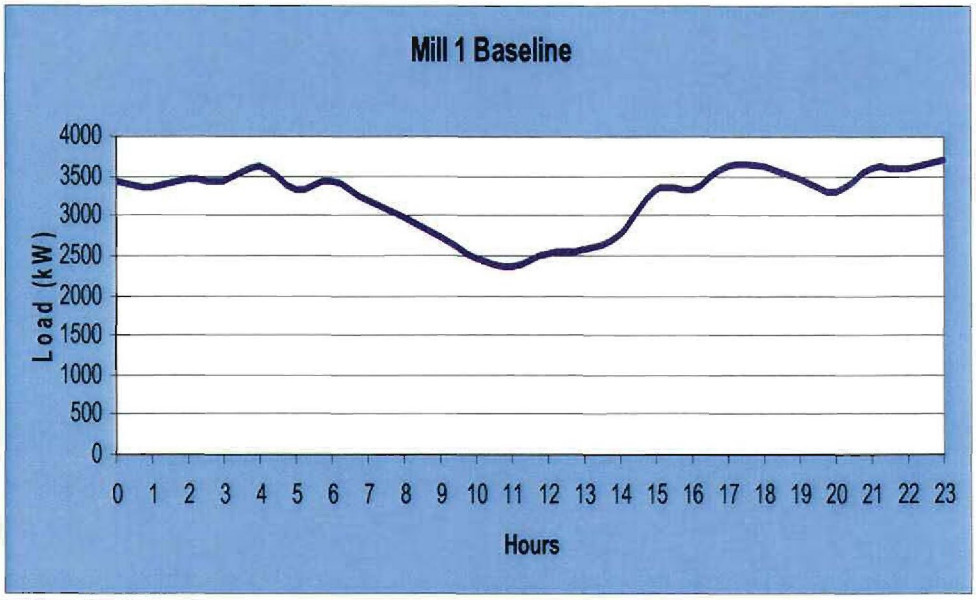


Figure 57: Mill 1 Baseline

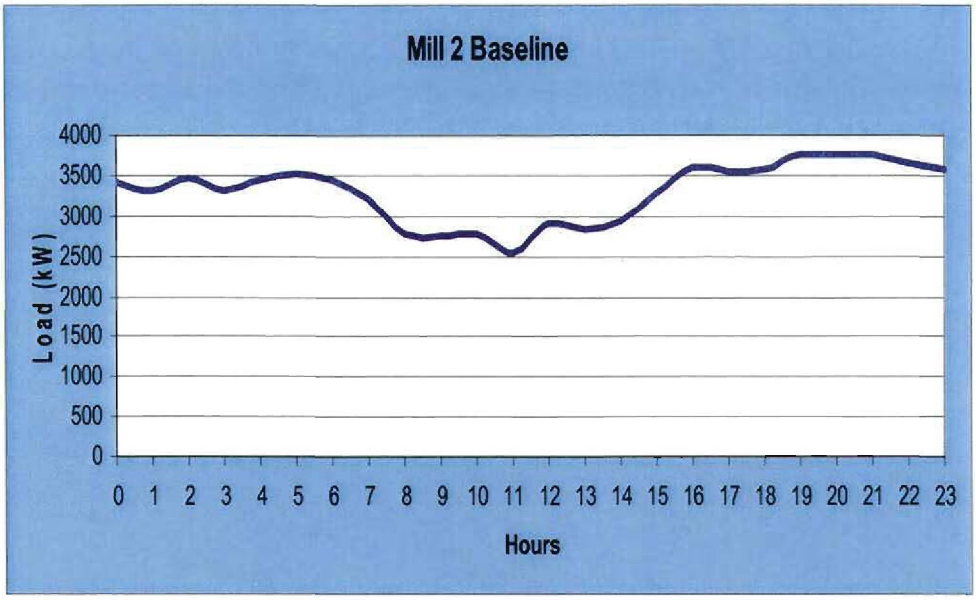


Figure 58: Mill 2 Baseline

The two mills are of similar design and capacity, explaining the similar baselines in the above figures. These two baselines were used as starting point for determining possible load shift on the mills of a gold plant. The procedures followed are discussed in the following section:

POSSIBLE DSM SAVINGS

In order to show any load shift savings on the mills, it is necessary to move the running times of the mills from either the morning peaks (07:00-10:00), or the evening peaks (18:00-20:00), or both, and make up for lost production in less expensive times during the day. This is necessary since all the gold plants in South Africa are currently on the MegaFlex tariff structure described in Chapter 1 of this thesis. From the plant's perspective, it would be desirable to use the morning peaks for load shift. The reasons are the following:

- It is a longer period of savings (3 hours as opposed to 2 hours).
- The morning peak falls into the normal maintenance period of the plant.
- Artisans are available during this shift to perform any opportunity maintenance that might arise.

- The shafts also try not to hoist ore during peak times; giving the plant a break during which DSM stops can be done.

- The greater part of the ore from the shafts is being transported to the plant during the evening shift, which is off-peak time according to the MegaFlex structure.

Eskom, on the other hand, would like to have the plant stop the mills during the evening peak. The reasons for these are the following:

- Of the two daily peaks, the evening peak is the most critical. It is much higher than the morning peak due to the reasons discussed in Chapter 1.

- The DSM program currently only makes provision for funding if load shift is done during the evening peak.

- This means that if the plant only performs load shift during the morning peaks, it will not get funding from Eskom for additional equipment that might aid with the load shift.

It is therefore important to realise that this is not a clear-cut situation as to which peak time to use for load shift. Eskom and the plant have different priorities and the real challenge of the DSM program is to let these two parties meet somewhere in the middle, which will be beneficial to both. However, this might not always be possible given the nature of a gold plant operation.

As part of determining the maximum possible savings that can be achieved by performing load shift on the mills, a basic energy balance simulation was done. This means that the maximum load shift is calculated for both the morning and evening peaks by comparing the new energy profile to the historical baseline. It was previously discussed that a load shift application must be energy neutral. This was kept in mind during the calculation of possible DSM savings.

MAXIMUM LOAD SHIFT FROM BOTH PEAKS

In order to achieve the maximum possible load shift on a given day, both the morning and evening peak periods should be utilised. This is shown in the following figure:

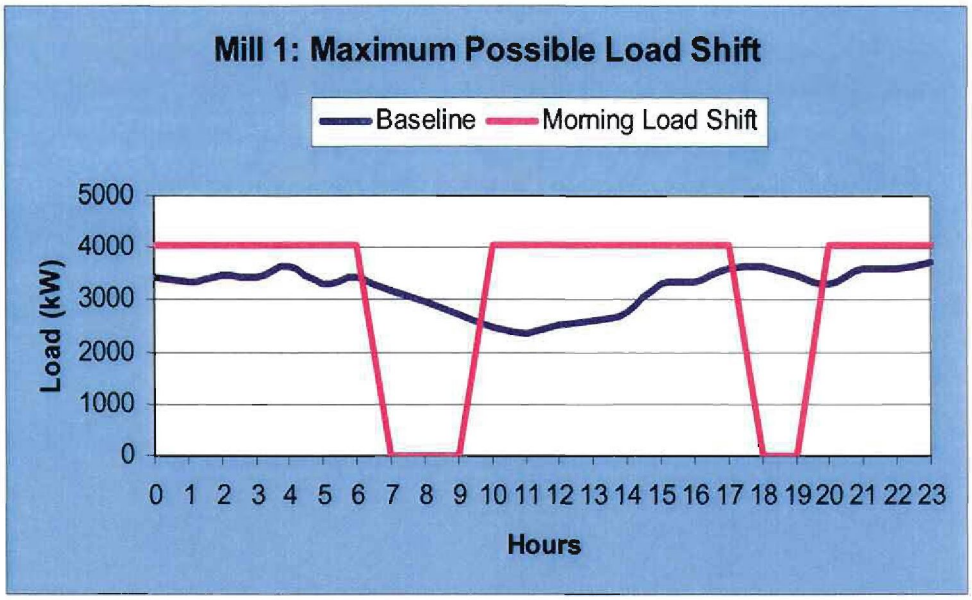


Figure 59: Maximum total load shift for mill 1

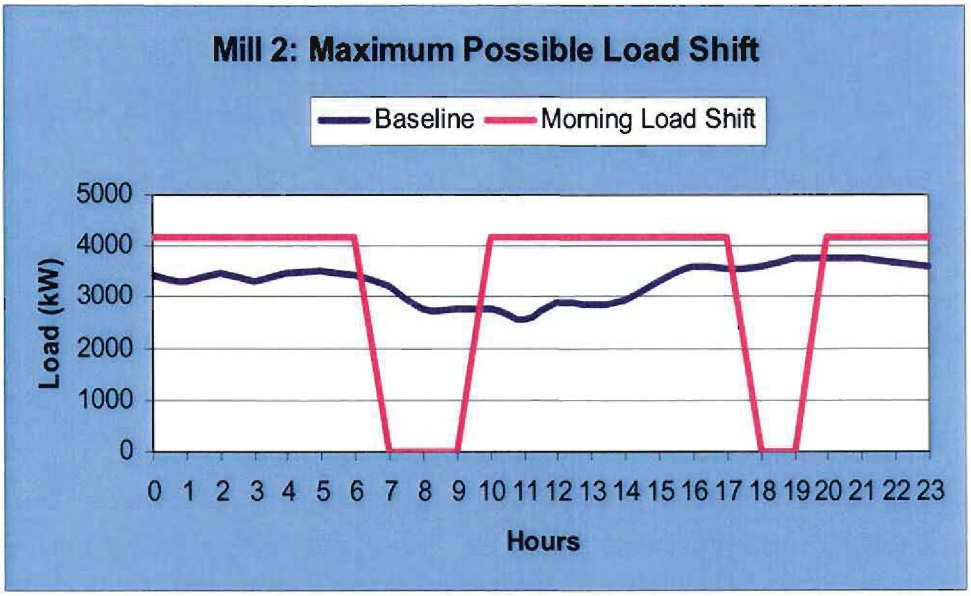


Figure 60: Maximum total load shift results for mill 2

The actual hourly values for the simulated profiles and baselines are shown in the following table:

Hour	Mill 1 Baseline (kW)	Mill 1 Optimised Schedule (kW)	Mill 2 Baseline (kW)	Mill 2 Optimised Schedule (kW)
0	3,440	4,067	3,414	4,170
1	3,354	4,067	3,317	4,170
2	3,452	4,067	3,464	4,170
3	3,442	4,067	3,321	4,170
4	3,627	4,067	3,451	4,170
5	3,323	4,067	3,530	4,170
6	3,426	4,067	3,450	4,170
7	3,183	0	3,206	0
8	2,975	0	2,775	0
9	2,733	0	2,764	0
10	2,480	4,067	2,786	4,170
11	2,352	4,067	2,553	4,170
12	2,523	4,067	2,909	4,170
13	2,591	4,067	2,840	4,170
14	2,766	4,067	2,932	4,170
15	3,322	4,067	3,288	4,170
16	3,335	4,067	3,599	4,170
17	3,612	4,067	3,561	4,170
18	3,630	0	3,575	0
19	3,466	0	3,752	0
20	3,308	4,067	3,749	4,170
21	3,610	4,067	3,753	4,170
22	3,610	4,067	3,662	4,170
23	3,712	4,067	3,589	4,170

Table 25: Values used in the savings calculations for mills 1 and 2

By subtracting the load shift profile from the baselines averaged over the peak hours, the maximum load shift can be determined for both peak periods. The values were also compared to the MegaFlex cost structure in order to calculate the annual electricity cost savings that can be obtained. These kW and cost savings are shown in the following table:

Mill	Morning Load Shift (kW)	Evening Load Shift (kW)	Electricity Cost Saving (R/annum)
Mill 1	2,964	3,548	R 758,214 p.a.
Mill 2	2,915	3,664	R 774,145 p.a.
Total	**5,879**	**7,211**	**R 1,532,359 p.a.**

Table 26: Savings results for mills 1 and 2

In this case, the maximum load shift will be in the order of 13 MW. This will result in an electricity cost saving of R 1.5 million p.a., which is quite substantial in any budget. It must be noted that these savings were calculated merely as a first step in determining load shift potential on the mills. These types of calculations give an indication of the maximum savings

which can be expected from a specific project, should it be possible to continue with load shift. Investigations onto this option follow in the next section.

USING THE THICKENERS AS STORAGE CAPACITY DURING LOAD SHIFT

As mentioned before in the thesis, the most probable piece of equipment to use as storage after the mills on a gold plant is the thickener dam. Den Boef [2.7] has also mentioned this and he showed how stopping the mills will affect the level of the material in the thickener.

It has also been discussed that it is important to keep the Relative Density (RD) of the thickener material between 1.5 and 1.6 t/m^3, as this allows the maximum extraction of gold from the slurry. This allows only a very small margin of error in the mixing of the slurry in the thickener. A simulation model was developed by the author to show this relationship of the required RD to the volumetric percentage of water and solids in the slurry. The RD was calculated using the following relationship:

$$M\%Solids = \frac{100*(RD-1)}{2.7-1}$$

If the above equation is rewritten, the RD can be calculated as follows:

$$RD = 1 + \frac{(1.7*M\%Solids)}{100}$$

Where

RD = Relative Density of the slurry (t/m^3)

M% Solids = Volumetric Percentage of the Solids in the Slurry (%)

Equation 11: Equation to calculate the volumetric % of solids in gold slurry

Using the equation, the relationship was developed into a graphical form showing how the volumetric % of the water and solids change in relation to each other for a specific RD. It was found that the acceptable RD level only comprise a very small part of all the possibilities that can be achieved. This is shown in the following figure:

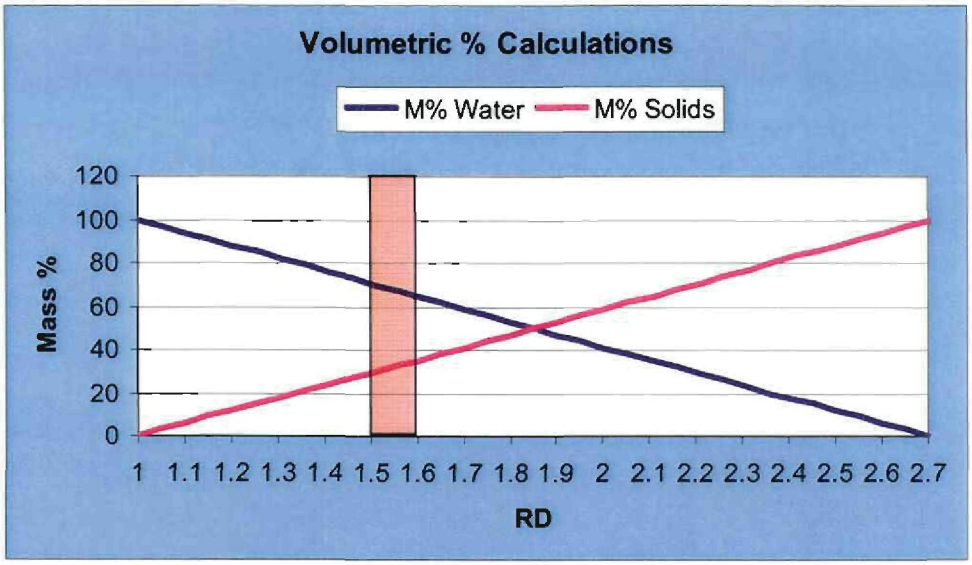


Figure 61: Results of the volumetric percentage simulation

The pink block in *Figure 57* shows the close ranges of the mass percentages necessary to achieve the required RD of 1.5 – 1.6 t/m^3. This should give some indication as to why the plant personnel may be reluctant to pursue a load shift project where the thickener slurry RD may be compromised. In order to prove that their fears are unfounded, an investigation was launched into the viability of using the thickeners as storage capacity.

During this investigation, plant personnel confirmed that even though load shift on the mills will reduce the thickener levels, it should be 8 to 12 hours before the RD of the slurry drops to an unacceptable level. This is somewhat different from their first reaction of completely dismissing the idea.

Since it would not be prudent to accept this as fact, the effect of a mill stop was simulated on the thickener of the plant. When a mill is stopped, there is no more slurry flowing into the thickeners. Since the thickener also has an outflow, known as the thickener underflow, the thickener level will start to drop, causing a change in the mass percentage of the slurry and a drop in the RD.

Stopping the mill is not uncommon on a gold plant, meaning that the plant personnel should have a way of handling this drop in RD on a relatively common basis. The current way of stopping the reduction in RD, is to reduce the thickener underflow for the time that the mill is

down. This keeps the RD constant, while not completely stopping production on the specific thickener.

Usually on a plant there is more than one thickener for each mill, as well as more than one mill, where one serves as a backup in case the underflow of one needs to be stopped. This redundancy ensures an almost constant production, even though a mill may be down for some time. This is good news for load shift on the mills, since it means that the possibility of using the thickeners as storage is increased.

In order to prove that the reduction of thickener underflow is practised on a regular basis, some actual underflow figures were gathered from the plant. These were used to show the underflow values for two typical days at the plant, and are provided in the following figure:

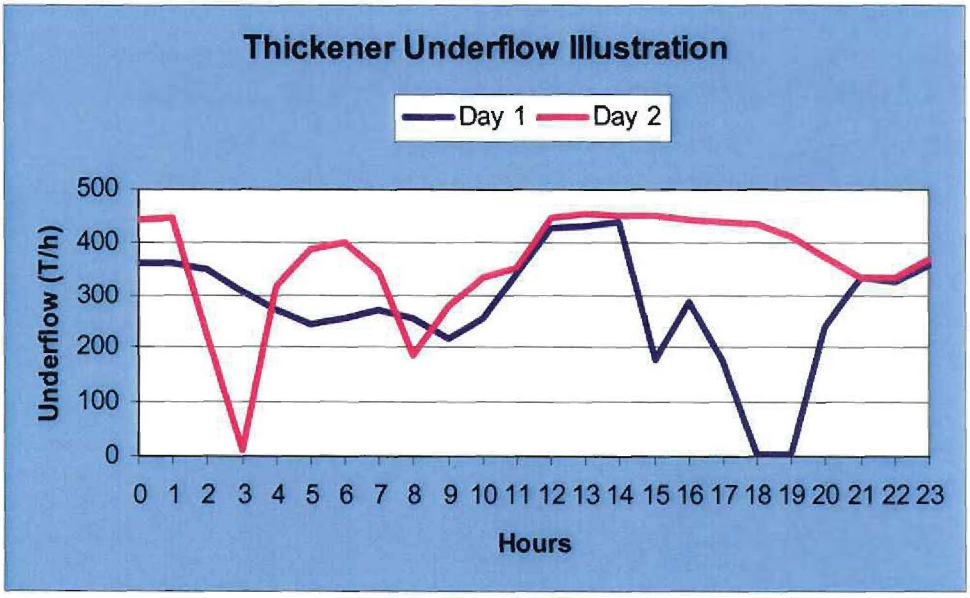


Figure 62: Actual thickener underflow tons on different days

This figure clearly shows that the underflow changes on a regular basis. It must be noted that this is not random, but it is carefully controlled by automatic control systems in the control room. There also is a clear indication that the underflow can be completely stopped if the need should arise. In order to predict how long the RD will stay within acceptable levels, a simulation model was created to simulate the effect of a stopped mill and reduced thickener underflow on the slurry RD.

Average values calculated from the actual thickener inflow and underflow values were used in the simulation. A mill drop was simulated in conjunction with a reduced underflow, until the RD dropped below an acceptable level of 1.5 t/m^3. The following values resulted from the simulation:

Hours	Solid tons into thickener (T/h)	Solid Tons out of thickener (T/h)	RD (Tons/m3)
0	196	190	1.56
1	196	190	1.57
2	196	190	1.57
3	196	190	1.57
4	196	190	1.57
5	196	190	1.57
6	0	30	1.56
7	0	30	1.55
8	0	30	1.54
9	0	30	1.53
10	0	30	1.52
11	0	30	1.51
12	0	30	1.50
13	0	30	1.49
14	196	190	1.49
15	196	190	1.49
16	196	190	1.49
17	196	190	1.49
18	196	190	1.50
19	196	190	1.50
20	196	190	1.50
21	196	190	1.50
22	196	190	1.51
23	196	190	1.51

Table 27: Thickener in and outflows

These results were used to create a graph showing how the RD reacted to the stopped mill:

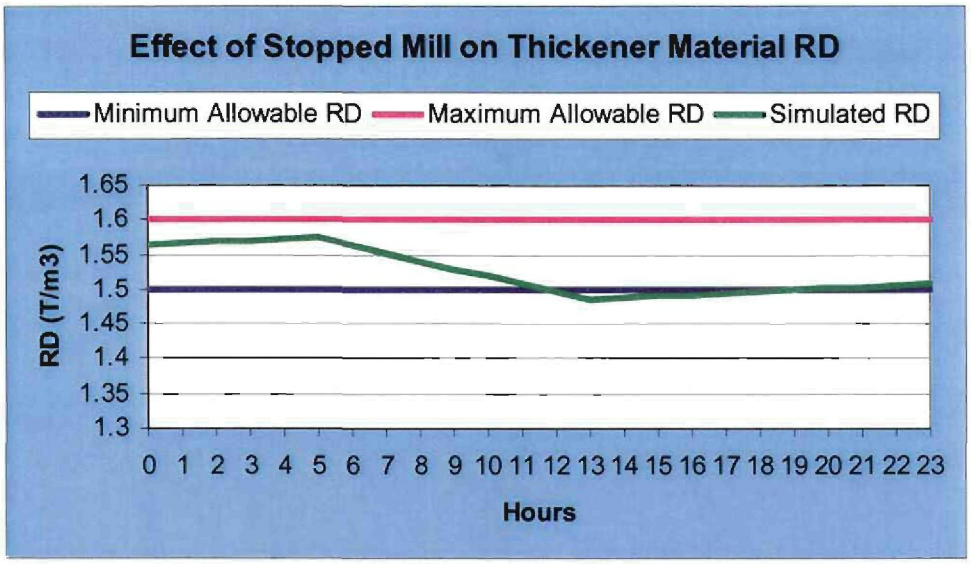


Figure 63: Effect of the stopped mill on the RD of the thickener

The simulation results confirm that the RD will only drop below unacceptable levels after the mill has been down for eight hours. This confirms the original estimates from the plant personnel on the RD retention time in the thickeners.

2.6 DISCUSSION OF RESULTS

From the three scenarios, the obvious conclusion to make would be to stop the mills every weekday for both peak periods; however this is not as straightforward as it might seem. As discussed before, the typical gold plant has various operational constraints that do not allow random cycling of critical equipment like mills.

The calculated savings in the three scenarios can only be used as an upper limit of possible savings that might be attained at the plant. The actual practical savings will probably be much less due to the constraints on the plant. As mentioned at the beginning of this chapter, the different role players in Eskom and on the plant have different needs regarding DSM. The primary concern of Eskom is to get as much load shift as possible during the time of greatest concern, which is the evening peak, while the primary concern of the plant is sustained production.

A plant may be willing to help Eskom by contributing to the DSM program, but only if their production is not compromised. The task of the ESCO in this process is to act as mediator between the plant and Eskom. It is the task of the ESCO to determine if it is at all possible to

perform DSM on the plant. If this is possible, a way is needed to determine the viability quickly and easily.

2.7 CONCLUSION

In conclusion to this chapter, it can be said that there is a definite benefit in stopping mills for DSM purposes. It has been shown that the savings can be quite high, both in terms of MW savings and electricity cost savings. It has also been shown that the thickeners can be used as storage capacity for slurry during peak times when the mills are not running, without compromising the production of the plant.

However, there is a practical side to performing load shift on the mills. One needs to take into account the actual process constraints like silo size, mill tons, mill availability, unplanned stops, planned maintenance and possible load shift. As it is no simple task to take these into account, a simulation model was developed to use all these parameters as inputs to calculate the actual viability of load shift on a gold plant. The following chapter is devoted to the development of this simulation model. The purpose of the simulation model is to provide a more detailed tool with which a person can prove the viability of load shift on a gold plant.

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CHAPTER 3

NEW SIMULATION PROCEDURES TO DETERMINE LOAD SHIFT VIABILITY ON MILLS

3.1 INTRODUCTION

In order to satisfy the unique contributions of this thesis, it was necessary to develop a unique simulation model. The purpose of this model is to provide a tool for determining load shift potential on the milling circuit of a precious metals facility. This simulation has to take into account all the operational requirements of the specific plant, as well as the limitations of the storage and supply systems such as silos, stockpiles and materials handling equipment.

3.2 IDENTIFYING CONSTRAINTS FOR THE SIMULATION

Before trying to create a simulation, it is necessary to perform some planning on the parameters required for such a simulation. This is important as it provides a structured approach to the development of the simulation. This allows the simulation to develop naturally in a structured fashion, until it provides an accurate and useful result. The following constraints were taken into consideration in the development of the simulation:

1. Actual material inflows from the shaft need to be taken into account.
2. Will the existing storage capacity be adequate, or will a DSM project only be possible with more storage?
3. Time, day and duration of planned maintenance need to be taken into account.
4. The effect of unplanned stops needs to be taken into account somehow.
5. The effect of milling on weekends should be visible.
6. The effect of load shift should be taken into account.
7. The minimum and maximum levels required in the storage facilities need to be adhered to.

If these constraints are taken into account during the development of the simulation, it should prove to be an accurate representation of the actual milling circuit which can then be used to determine the viability of different load shift scenarios on the mills. As the following step in developing the simulation model, some actual system information was gathered from the gold plant.

3.3 GATHERING SYSTEM INFORMATION

As part of the simulation DSM investigation process, a questionnaire was developed that can be used to gather typical operational information for a specific plant. This questionnaire was used throughout this research on various gold plants as well as on other types of plants discussed in Chapter 6. It has proven to be a useful tool on the audits since it is easy to fill in the entire page by spending a relatively short time with the relevant personnel at a plant. The relevant information could normally be gathered by spending only one day at a specific plant.

This provides a quick way of collecting all the relevant plant information, while negating the need to do a complete walkthrough audit on the plant. This method saves a large amount of time during the DSM audit. An example of the questionnaire completed with fictional inputs is shown in the following table:

Name	Mill 1	Mill 1	Mill 1
Type (reef / waste / both)	Reef	Reef	Reef
Installed capacity (kW)	3,000	3,000	3,000
Running capacity (kW)	2,700	2,700	2,700
How often does planned maintenance occur?	Once every 10 days, inspection or relining	Once every 10 days, inspection or relining	Once every 10 days, inspection or relining
How long is this planned maintenance? (hours)	5 – 7 Hours	5 – 7 Hours	5 – 7 Hours
On what day of the week does planned maintenance occur?	Shifting, depending on the schedule	Shifting, depending on the schedule	Shifting, depending on the schedule
Average running hours on Saturdays	24	24	24
Average running hours on Sundays	24	24	24
Mill flow rate (t/h)	81	81	81
Ore reception on weekdays (tons/day)	2,075	2,075	2,075
Ore reception on Saturdays (tons/day)	1,299	1,299	1,299

Ore reception on Sundays (tons/day)	769	769	769
Silo capacity for each mill (tons)	4,000	4,000	4,000
Target Availability for mill	96 %	96 %	96 %
Actual utilization of the mill	91.7 %	91.3 %	94.2 %

Table 28: Questionnaire used to gather system information

3.4 DEVELOPING A NEW SIMULATION MODEL

In order to develop the new simulation model, a modular approach was used. This approach consisted of the development of logical steps or parts that would be necessary to simulate the results calculated manually in the previous chapter. The simulation was divided into different sections working together to simulate the final result. The different simulator sections comprise of the following:

SIMULATOR 1

SIMULATOR 1 is the basic simulation engine used to simulate the more basic operational constraints of the plant. Typical results obtained are the simulated hours available for unplanned stops, daily silo levels and available running hours. All these are used as inputs for more extended simulations done in SIMULATOR 2.

SIMULATOR 2

SIMULATOR 2 is a more extensive section used for the main decision making processes. Here the current milling section operations are simulated to the final stages. These results are compared manually to the actual current operational parameters of the plant and fine tuned until an accurate picture of the current operation is obtained.

The second phase of the simulation is also initiated here, with the addition of load shift hours into the current milling operations. This upsets the whole balance of the current operations and some fine tuning of the plant operations are done here to try and achieve a viable DSM solution.

If a solution cannot be reached, the specific plant is discarded as a potential DSM host. However, if the simulation results show that a plant has promise as a DSM project, the following simulation sections are brought into play.

ENERGY SIMULATOR

The main purpose of this simulator is to optimise the load shift schedule against the baseline of the mill to achieve the highest possible kW or MW savings that can be achieved for the current situation. The output of this simulator is an hourly optimised power curve for the specific mill.

MEGAFLEX SIMULATOR

The optimised power curve calculated by means of the ENERGY SIMULATOR is fed automatically into another section called the MEGAFLEX SIMULATOR. This simulator uses the latest costs of the MegaFlex profile to calculate the electricity cost savings for the specific mill for each month of the year. This provides a quick reference as to what to expect in terms of savings in the summer and winter months.

MILLING SCHEDULE SIMULATOR

After it has been proven that it is possible to shift load on a specific mill, and after the expected savings have been calculated, it is necessary to find a way to actually implement this solution on the plant. In order to streamline the process of determining the actual actions that need to be taken on the plant, a MILLING SCHEDULE SIMULATOR has been developed.

This simulator takes the silo level, running hours and downtime results obtained in the previous simulators, and expands it to provide an hourly running schedule for the mill in question. The plant control room operators now only have to follow the new optimised milling schedule hourly in order to obtain the simulated savings. This schedule can also be pre-programmed into the plant control system or SCADA, allowing the savings to be obtained automatically. The whole simulation model can be better visualised by examining the flow sheet of the complete simulation model in the following figure:

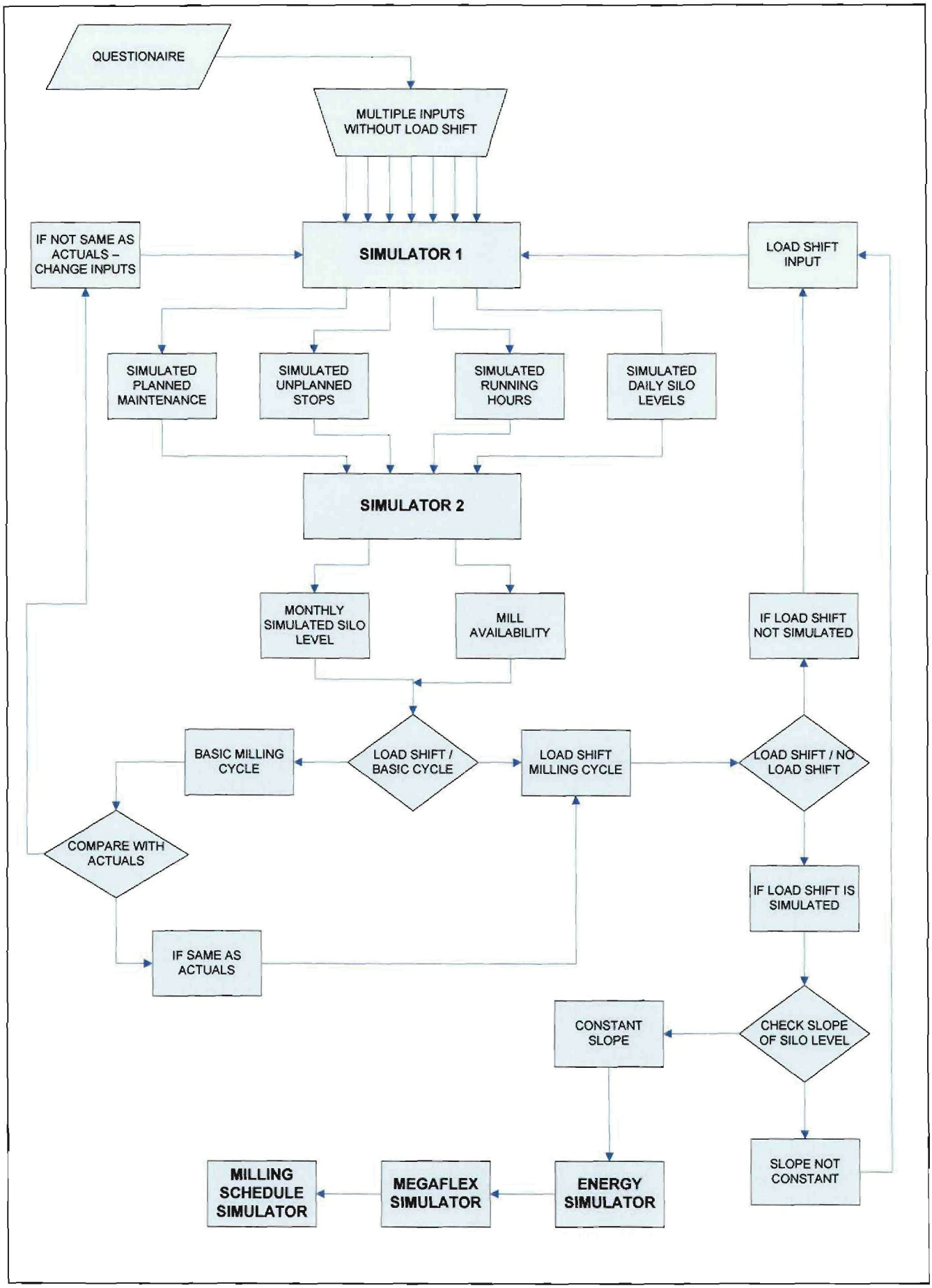


Figure 64: Flow sheet of the simulation model developed

3.5 INTERACTIVE USER INTERFACES

Developing an *interactive* simulation was one of the unique contributions of this study. This section is devoted to showing the interfaces of SIMULATORS 1 and 2, as well as the typical results obtained with these simulators.

SIMULATOR 1

For this simulator, the first interface allows the user to insert basic information about the mill and silo on the specific plant. These values are to be found in the questionnaire and sets limits to the storage capacity before the mill, as well as the simulated milling rate. The following figure shows this interface:

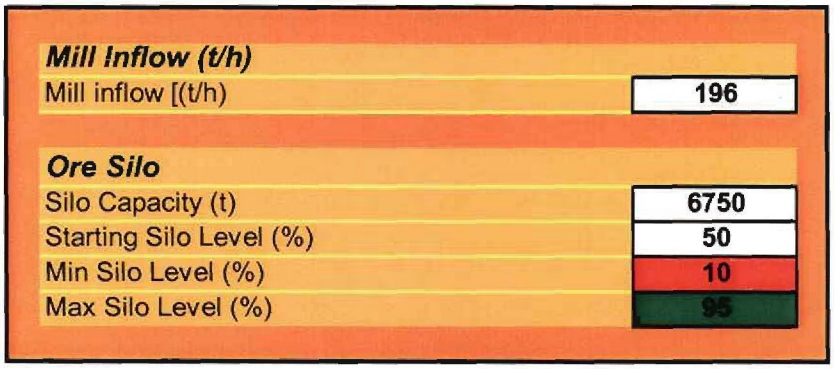


Figure 65: User interface for the mill tons and storage silo

Now that the limits for ore flowing out of the mill have been set, it is necessary to provide the simulation with the tons flowing into the silo from the shaft. This is done by means of the following interface:

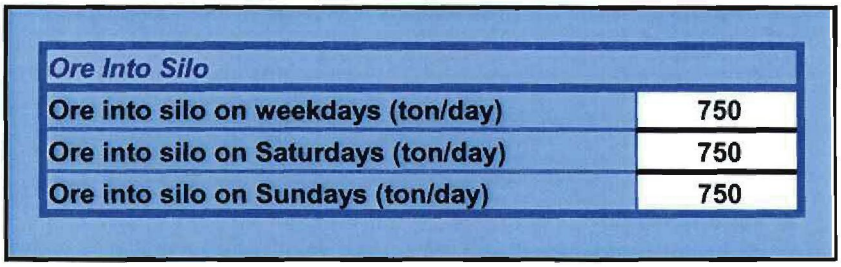


Figure 66: Ore reception user interface

Another important constraint obtained during the preliminary investigation is the planned maintenance schedule and the typical unplanned stops on a specific mill. These are entered into the simulation by means of the following interface:

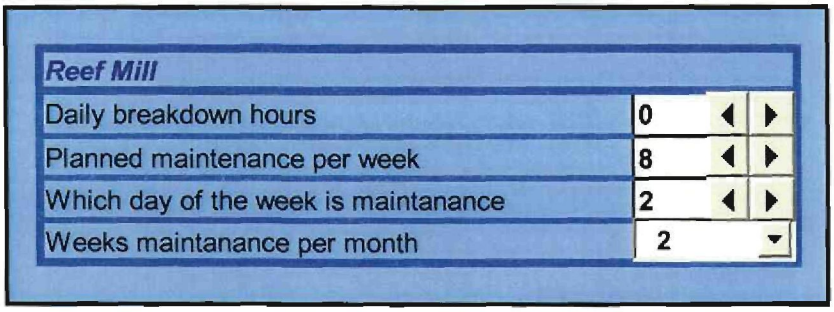


Figure 67: Maintenance stops user interface

The results of this simulator were calculated on a daily basis. In order to provide more usable results, SIMULATOR 2 was developed to expand the daily results to include the silo levels for 31 days. This provides a DSM planning guide for the plant, a month in advance.

SIMULATOR 2

One of the first results calculated by SIMULATOR 2 is the silo levels for a month period. This is saved in tabular form by the simulation should it be required at a later stage, but is also shown in graphic form as below to simplify the interpretation of the results.

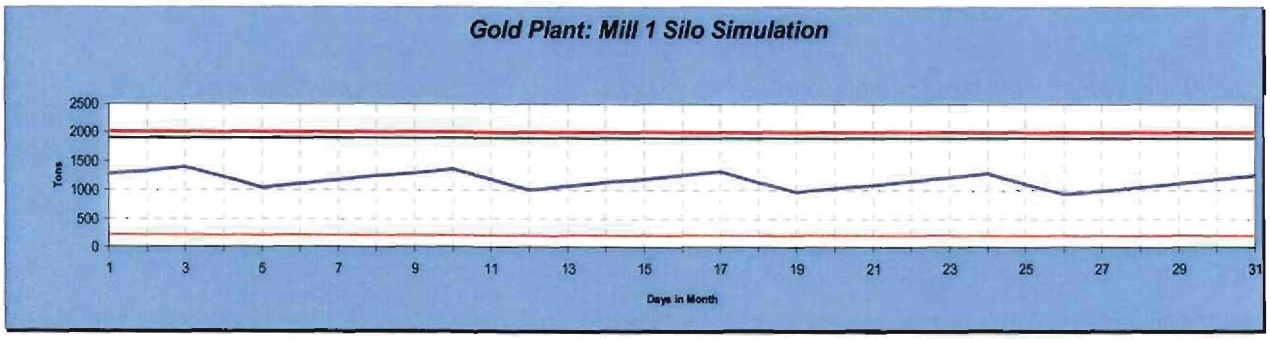


Figure 68: Typical silo simulation result for the simulation model

The values obtained here are compared to the actual data received from the plant during the initial investigation. If the simulated results are accurate compared to the actual data, the simulation is accepted to be accurate. This allows the load shift cycle of the simulation to be completed.

The first inputs required are the load shift hours to be performed on the different days of the week. An example of the interface is shown in the following figure:

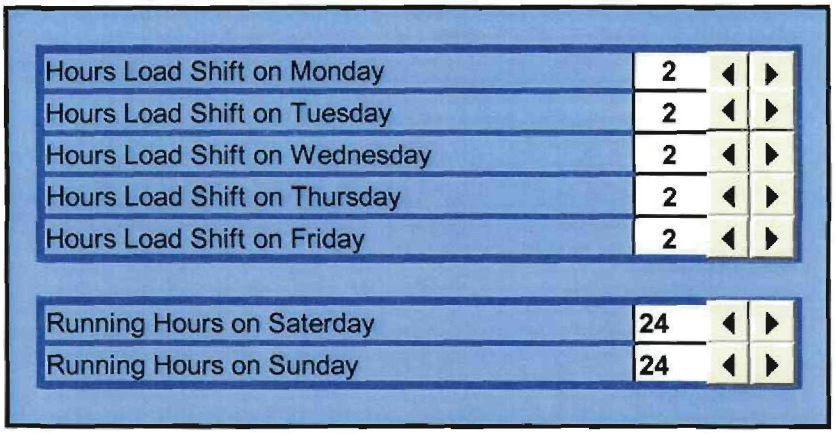


Figure 69: User interface for the load shift hours

The load shift inputs are combined with the original inputs that simulated the current milling operations. The addition of the load shift hours has a marked effect on the milling schedule to the effect that there are less hours available to mill the ore coming into the silo. As a remedy for this, the planned maintenance schedule has to be changed to accommodate maintenance in the hours used for load shift when the mill is off. Some of the results obtained during this simulation cycle are the average tons milled daily and monthly. These are shown in the following figure:

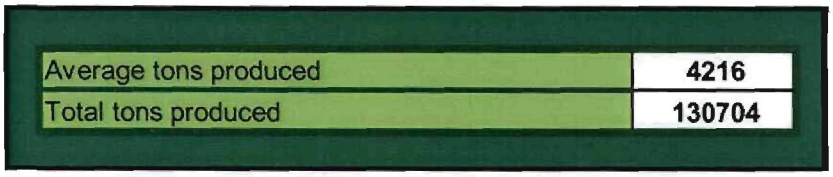


Figure 70: Interface that shows the tons milled

As the addition of load shift has markedly changed the operational schedule of the plant, the silo levels will also be affected. Once again the new silo levels are stored in tabular form by the simulation, while the graphic representation of the new optimised silo levels are provided for quick reference. This is shown in the following figure:

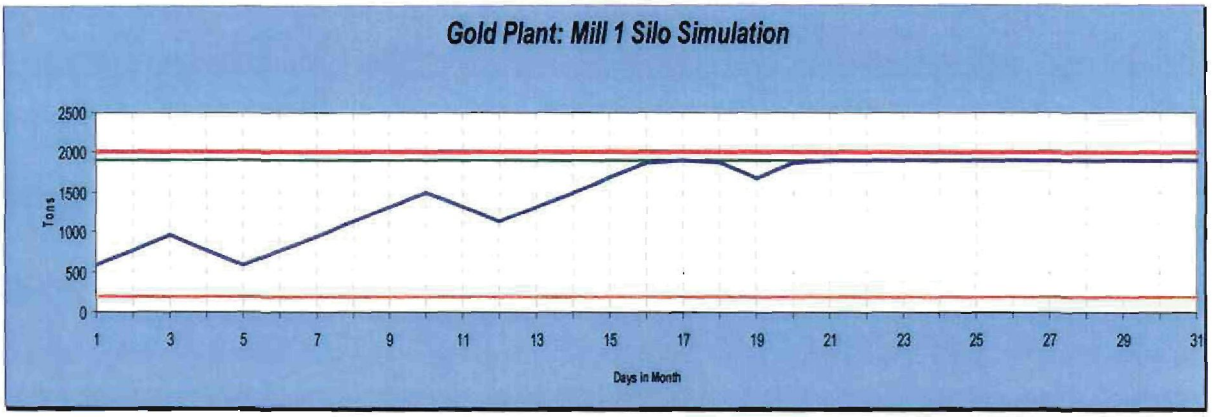


Figure 71: Silo level resulting from the simulation model

In order to allow the plant to have continuous production, it is important that the silos feeding the mills are kept within certain limits all the time. In order to ensure this, the minimum and maximum silo levels were used as constraints for the simulation. An added requirement for continuous production is that the slope of the silo level be kept as close to zero as possible. In other words, the average function of the silo level slope should be as horizontal as possible.

If this control strategy is maintained, the silo level at the end of one day will be the same as the silo level for the start of the following day. If this is maintained by the plant control system, the silo level should always stay relatively level given the specific circumstances. As a quick reference for the person using the simulation, an average trend line of the silo level over a month is calculated by the simulation. This is shown in the following figure:

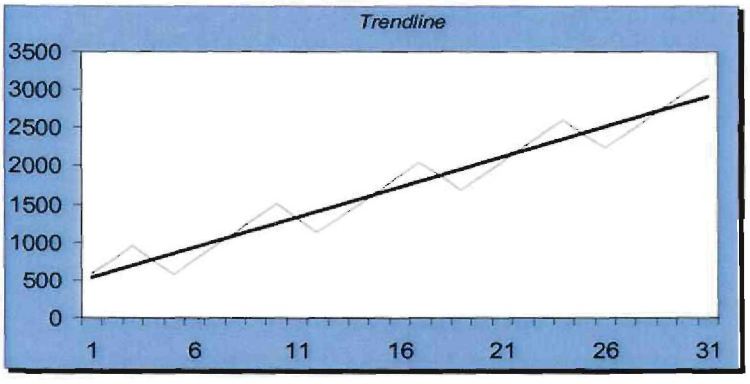


Figure 72: Trend line of the silo level simulation - showing the slope of the silo level

If the above figure is examined, it is obvious that the example used has a rising silo level. This means that the silo will fill up over time, forcing the shaft supplying the ore to stop until he silo

level has dropped again. This is undesirable, and the main aim of the simulation is to keep this line horizontal as far as possible.

3.6 REFINING THE SIMULATION

In order to perform a complete DSM project investigation, it is necessary to use the simulation in conjunction with optimised energy usage profiles and financial analysis of the possible savings benefits to be gained from such an intervention. In order to expand the developed simulation, the optimised energy usage profiles, as well as the financial analysis were included in the simulation.

Such an expansion has the added advantage that the actual optimised schedule for the specific plant is readily available, and can be implemented immediately in order to obtain the desired results. As part of this refinement, the ENERGY SIMULATOR, MEGAFLEX SIMULATOR and MILLING SCHEDULE SIMULATOR were developed.

A brief introduction to these simulators has already been given previously in this chapter. As such, the focus will now be shifted to the results obtained with these different simulators.

ENERGY SIMULATOR

As discussed before, the main purpose of this simulator is to find an energy neutral load profile as compared against the baseline. The results are given in graphical representation below:

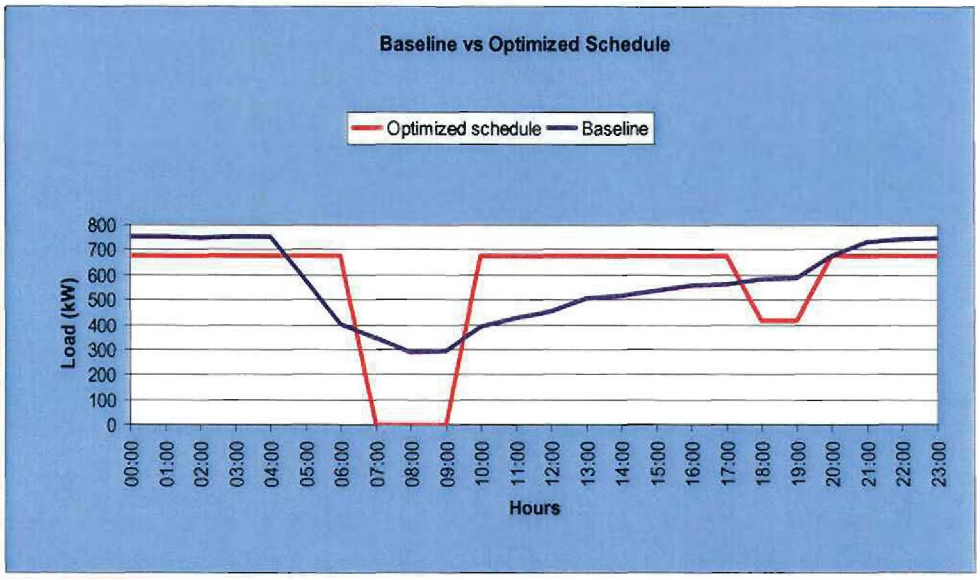


Figure 73: Results of the ENERGY SIMULATOR showing the baseline and optimised milling schedule

The values used to draw the graphs in *Figure 69* are provided in the following table for scrutiny and use in further simulations:

Hour	Baseline (kW)	Optimised (kW)
0	755	677
1	752	677
2	750	677
3	755	677
4	755	677
5	579	677
6	403	677
7	343	0
8	289	0
9	293	0
10	392	677
11	429	677
12	456	677
13	504	677
14	518	677
15	539	677
16	557	677
17	563	677
18	584	416
19	587	416
20	677	677
21	732	677
22	742	677
23	750	677
Difference	Total kW	Total kW
1.38	13,703	13,701

Table 29: Values of both the baseline and optimised schedule to show that the results are energy neutral

In the above table generated by the simulation, it can be seen that the total power draw of both the baseline and the optimised schedule is almost identical, differing only by a value of 1.38 kW. This means that the solution is energy neutral, and therefore a load shift profile. The load shift values are also calculated in this step and these are prominently displayed in the interface as below:

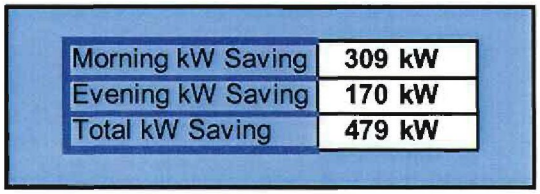


Figure 74: Results produced by the simulation to show the load shift of the specific application

MEGAFLEX SIMULATOR

This is a very intricate simulator utilising the MegaFlex tariffs for both the summer and winter months. These values have to be updated yearly to make sure the latest values are used in the simulation. The results provided by this simulator are the annual electricity cost savings for the specific milling profile, calculated on a monthly basis. The following figure shows a typical results table:

Average Monthly Savings		
Summer	Jan	R 1,526
Summer	Feb	R 1,457
Summer	Mar	R 1,480
Summer	Apr	R 1,502
Summer	May	R 1,480
Winter	Jun	R 11,278
Winter	Jul	R 11,278
Winter	Aug	R 11,802
Summer	Sep	R 1,594
Summer	Oct	R 1,548
Summer	Nov	R 1,594
Summer	Dec	R 1,502
Annual Saving		**R 48,040**

Table 30: Typical results of the MEGAFLEX SIMULATOR, showing the rand savings achieved over a year

As the electricity cost on the MegaFlex structure is much more expensive in the three winter months (June, July and August) than in the summer months (See Chapter 1 on the MegaFlex structure), it is expected that the bulk of the savings will be achieved in winter. This is true if *Table 30* is examined, the winter savings are much larger than the summer savings. This makes load shift so much more important in the three winter months.

MILLING SCHEDULE SIMULATOR

Now that the simulator has been used to determine the viability of load shift on the mills, the question remains on how to implement it practically. As a solution to this problem, the MILLING SCHEDULE SIMULATOR was developed. This simulator uses the results obtained from the previous simulators to calculate a practical milling schedule that will result in the calculated load shift savings.

The simulator indicates to the operator on an hourly basis when the mill should be on or off, for a 31 day period. The schedule table shows a **1** when the mill should be running and a **0**

when the mill should be off. This schedule can be programmed into the control system of the plant so that automatic load shift control can be maintained on a continuous basis. The following table shows an example of a milling schedule used to control a mill:

Weekday		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
3	01	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	02	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
5	03	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	04	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	05	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	06	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	07	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
3	08	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	09	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
5	10	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	13	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	14	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
3	15	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	16	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
5	17	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	20	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	21	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
3	22	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	23	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
5	24	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	27	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	28	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
3	29	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	30	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
5	31	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 31: Typical optimised milling schedule calculated by the simulator

3.7 CONCLUSION

This chapter has been devoted to the development of a simulation model and procedures that can be used to simulate load shift on a CIP gold plant. The workings of the model have been described at the beginning of the chapter and a flow sheet has been provided to explain how it all fits together. Thereafter, the model has been developed by means of commercially available software packages.

Since the simulation model has been designed to be an interactive tool, various user interfaces have been developed, enabling the user to insert the parameters necessary to perform the simulation. The results of the simulation are displayed in the following forms:

- A graph showing the average silo levels over a 31 day period
- A trend line graph to show the slope of the average silo level
- A graph that shows the baseline and the energy neutral optimised milling schedule
- A table showing the kW and Electricity cost savings for each month of the year
- A table showing the optimised milling schedule for each hour of the 31 days.

It can therefore be concluded that not only have new DSM possibilities being researched and presented, a unique simulation model has also been developed to perform load shift audits on these facilities.

CHAPTER 4

VERIFYING THE NEW SIMULATION MODEL

4.1 INTRODUCTION

Now that the simulation model has been developed, it is still necessary to test its accuracy against actual current milling operations. This is necessary to verify if the model is indeed accurate enough to be used as a tool for performing DSM audits. In order to prove this, a gold plant near the town of Evander was used as pilot project. This plant has six mills and is situated in the Mpumalanga province of South Africa.

This chapter is dedicated to providing and discussing the results of the tests on this plant. The tests took the form of a typical audit on the specific plant. The tools and techniques developed were used just as it would be normally by an ESCO. The results obtained are then discussed and compared to actual values.

4.2 GATHERING SYSTEM INFORMATION

4.2.1 THE QUESTIONAIRE

As described in the previous chapter, an on-site investigation was done on the plant in order to gather the information required for the simulation. The first meeting was conducted with the plant manager in order to inform him on the nature of the investigation. He was very willing to let the investigation continue, since any positive results may also have an impact on the running costs of the plant.

The questionnaire developed in the previous chapter was used to organise the plant information. The actual investigation data is shown in the questionnaire below:

	Mill 1	*Mill 2*	*Mill 3*	*Mill 4*	*Mill 5*	*Mill 6*
Name	FAG milling	FAG milling	FAG milling	FAG milling	FAG milling	FAG milling
Type (reef / waste / both)	Kimberly reef	Kimberly reef	Kimberly reef	Kimberly reef	Kimberly reef	Kimberly reef
Installed capacity (kW)	1500	1500	1500	1500	1500	1500
Running capacity (kW)	980	980	980	980	980	980

How often does planned maintenance occur?	Every Second Week	Every Second Week	Every Second Week	Every Second Week	Every Second Week	Every Second Week
How long is this planned maintenance ? (hours)	6 Hours	6 Hours	6 Hours	6 Hours	6 Hours	6 Hours
On what day of the week does planned maintenance occur?	Tuesdays	Tuesdays	Tuesdays	Tuesdays	Tuesdays	Tuesdays
Average running hours on Saturdays	24	24	24	24	24	24
Average running hours on Sundays	24	24	24	24	24	24
Mill flow rate (t/h)	40t/hr dry tons	40t/hr dry tons	40t/hr dry tons	40t/hr dry tons	40t/hr dry tons	40t/hr dry tons
Ore reception on weekdays (tons/day)	4500 t/d (total tonnage for all six mills)	4500 t/d (total tonnage for all six mills)	4500 t/d (total tonnage for all six mills)	4500 t/d (total tonnage for all six mills)	4500 t/d (total tonnage for all six mills)	4500 t/d (total tonnage for all six mills)
Ore reception on Saturdays (tons/day)	4500t/d	4500t/d	4500t/d	4500t/d	4500t/d	4500t/d
Ore reception on Sundays (tons/day)	4500t/d	4500t/d	4500t/d	4500t/d	4500t/d	4500t/d
Silo capacity for each mill (tons)	2000	2000	2000	2000	2000	2000
Target Availability for mill	97%	97%	97%	97%	97%	97%

Table 32: Questionnaire with data gathered from the plant for the simulation

The information contained in the questionnaire is only the target values provided during the initial plant visit. Each of the mills is of the same size, type and rating, and should theoretically all be the same. However, it must be noted that there are problems and peculiarities unique to each mill, as such, in order to determine the most accurate simulation results, each mill must be examined on its own merit.

In order to ensure that the questionnaire data is correct, historical data was gathered from the plant. These have been analysed thoroughly for each mill and the results have shown that such a closer inspection of the actual figures is necessary in order to validate the claims made by the plant personnel. As an example to show how similar mills can differ in actual operation on the same plant, a quick comparison was done on the different mills

The comparison shows how the actual operational values of the mills compare to the target constraints. During this stage of the research it was found that two of the mills (Mill 3 and 4) were down for some time due to extensive maintenance in other sections of the plant. As such information of these two mills could not be obtained and the study was only conducted on the four remaining mills. The results of this study are shown in the following table:

	Target	Mill 1	Mill 2	Mill 5	Mill 6
Mill dry tons	40 t/h	35 t/h	36 t/h	36 t/h	35 t/h
Daily downtime	0 h/d	3 h/d	4 h/d	4 h/d	7 h/d
Mill availability	97%	90%	86%	85%	77%

Table 33: Comparison of target vs actual production figures on the mills

This table clearly shows that the actual operational values of the plant are not always the same as the target values. The main reason for this is mostly the unplanned stops due to breakdowns and power dips. The breakdowns also mean that the availability of the mills is lower due to the fact that less time is available to mill the same ore. The end result of this is that less ore gets milled at the end of the day, resulting in lower gold production. This is very undesirable, and plant personnel are always looking for ways to increase the availability and efficiency of the milling circuit.

4.2.2 MILL BASELINES

As data could only be obtained for four of the mills, only four baselines could be calculated. The baselines are the average power usage of the mills over a three month period. These are shown in the following figure:

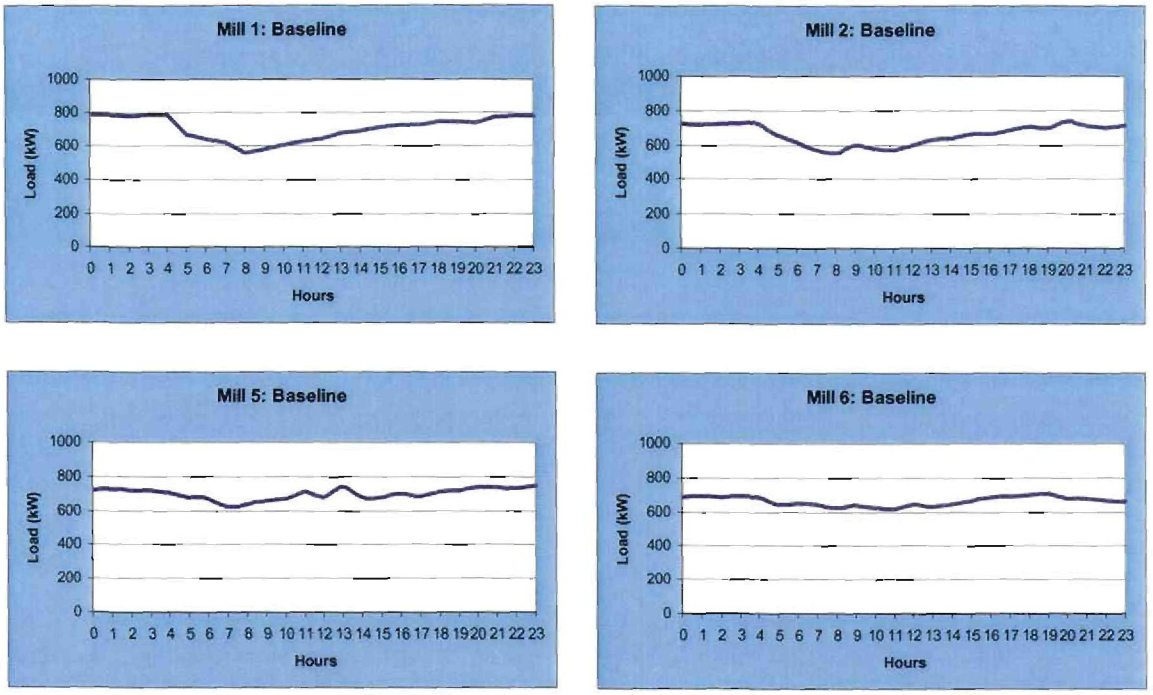


Figure 75: Baselines of the four mills used in the verification of the simulation

These baselines were used in the simulation to calculate the possible load shift values, as well as the annual electricity cost saving. As such, it is necessary to enter the baseline values into the simulator at the start of the simulation.

4.3 SIMULATION SETUP

As described in the section on developing a new simulation, the data in the questionnaire was used as inputs to the simulation models. The following figures show the user interfaces of the different simulators with these values entered:

SIMULATOR 1

Even though the mills appear to be the same, they each have specific problems and production figures. These are entered in the interfaces shown in the following figures:

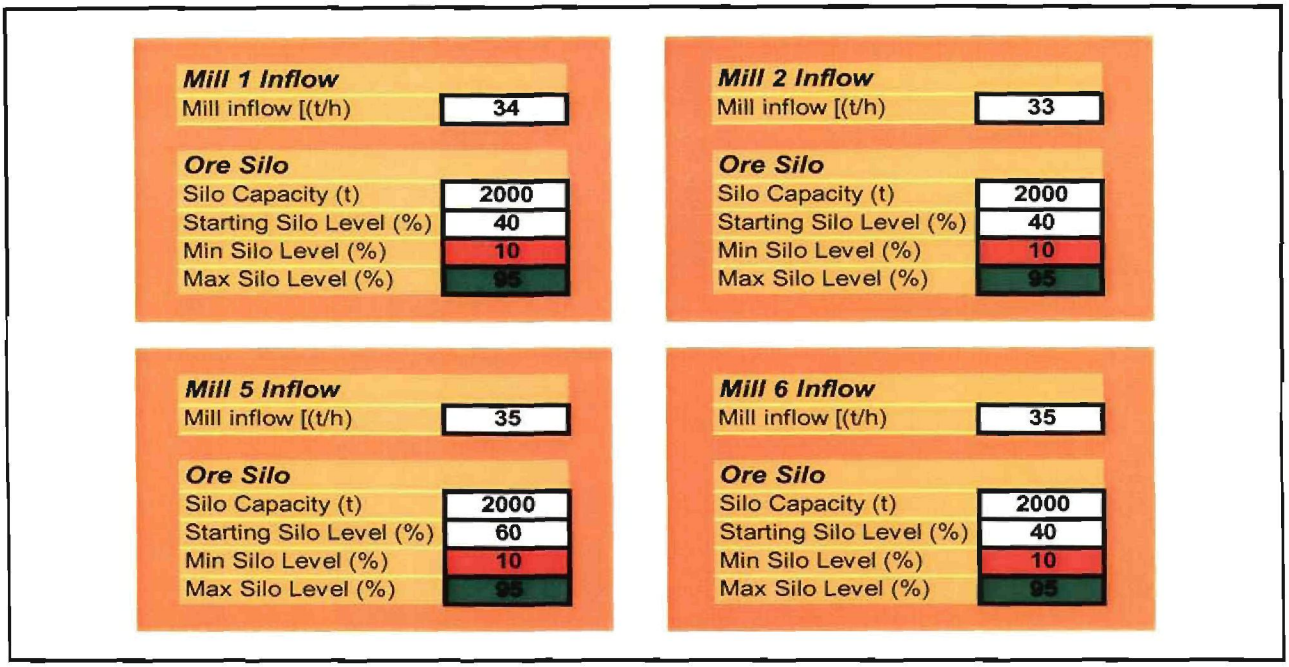


Figure 76: Input values of the four mills for SIMULATOR 1

The average ore figures coming into the plant from the shaft could not be verified with actual data, so the values provided by the plant manager were used for all the mills. These were entered into the following interface:

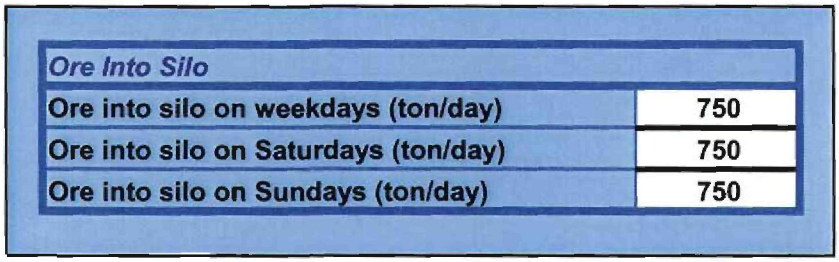


Figure 77: Tons received per mill as used in the simulation

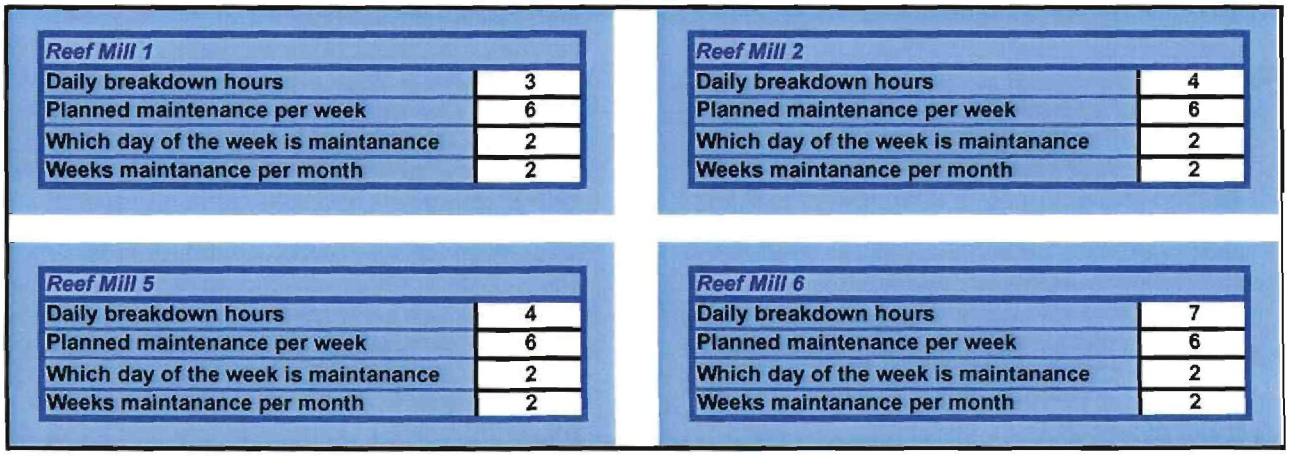


Figure 78: Maintenance schedules of the four mills as used in the simulation

SIMULATOR 2, ENERGY SIMULATOR and MEGAFLEX SIMULATOR

As discussed before, the main purpose of SIMULATOR 2 is to include the load shift inputs into the simulation. At this stage of the simulation, no load shift has been added, making any attempts to include the interface completely useless. Furthermore, as there are no load shift inputs, the ENERGY- and MEGAFLEX SIMULATORS are of no use at this stage in the simulation cycle. The following section provides the preliminary simulation results as they were determined by the simulators. A discussion of these results is also provided.

4.4 PRELIMINARY SIMULATION RESULTS

The primary results provided by the simulation model are the monthly silo levels. These may appear simple, but they are in fact very valuable as a quick reference tool to predict future stoppages on a specific mill. By using the actual milling tons and downtimes provided by the plant, the user of this simulation can quickly determine if a specific mill will experience a problem in the next month. The current inputs to the simulation provided earlier were used to simulate the following average silo levels:

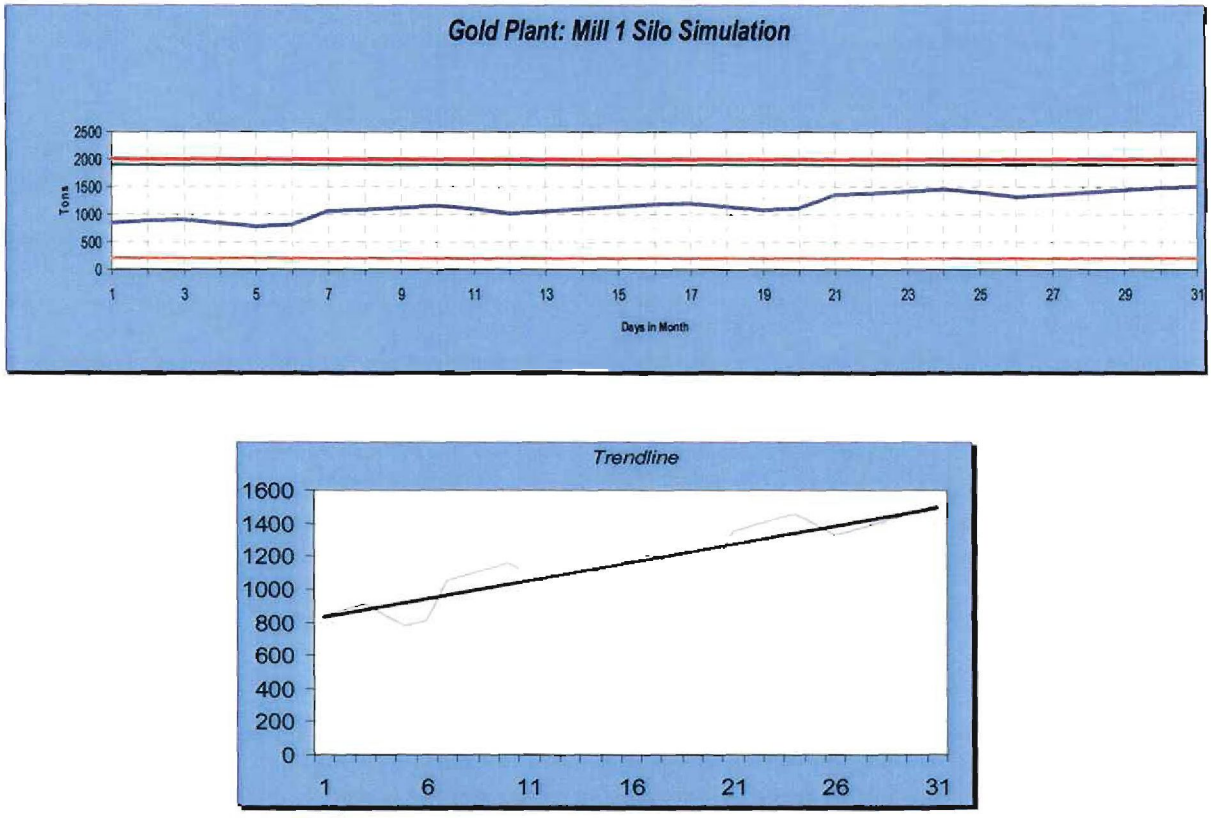


Figure 79: Silo level results for Mill 1

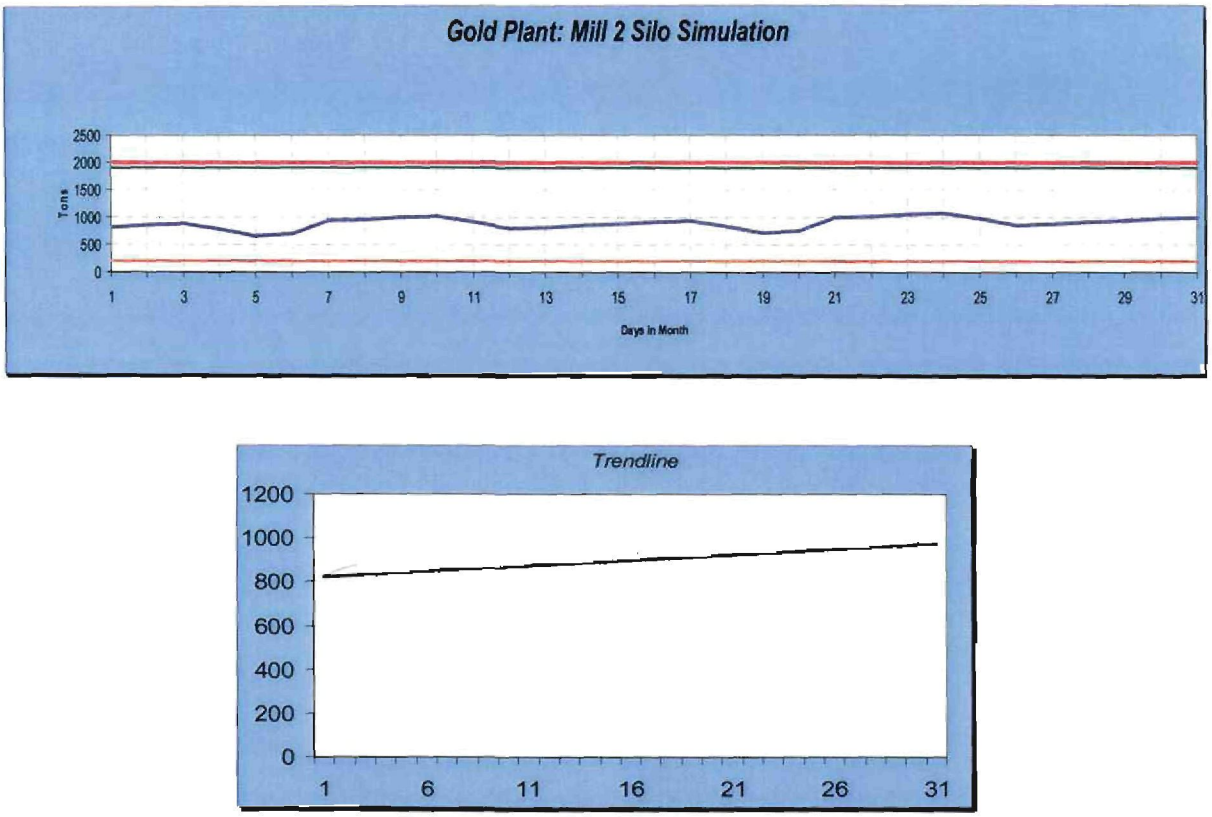


Figure 80: Silo level results for Mill 2

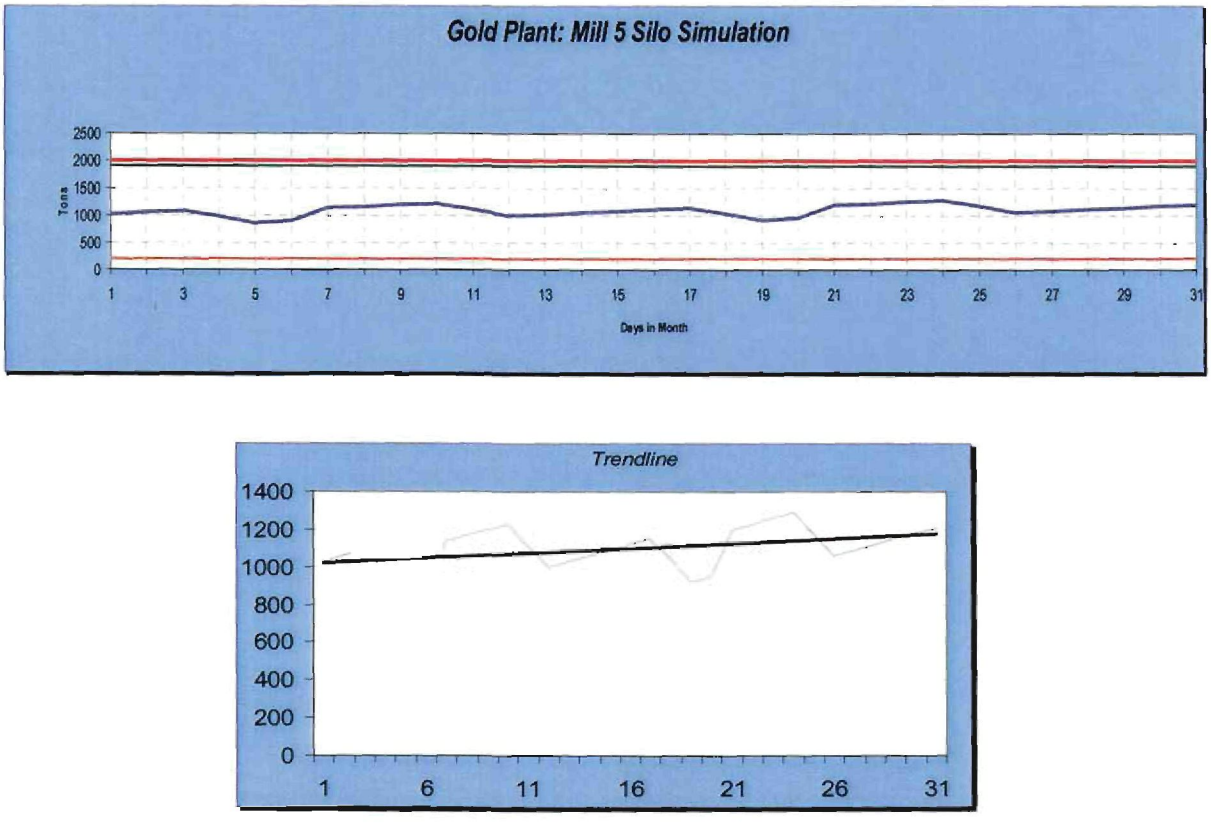


Figure 81: Silo level results for Mill 5

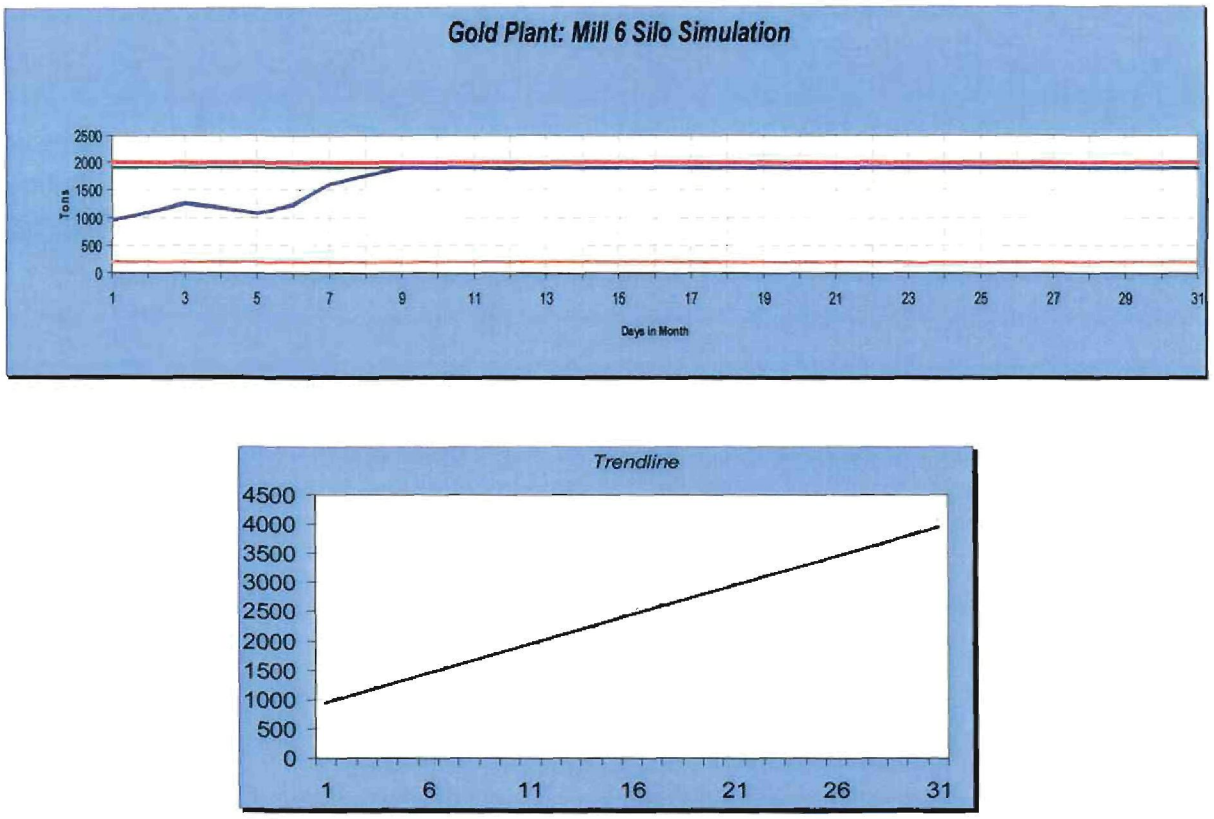


Figure 82: Silo level results for Mill 6

The above figures show the simulated silo levels for the mills, as well as the trend lines used to indicate any problems in the current production setup. The simulation is consistent with the current plant practice to try and keep the silo level constant. This is a result of trying to keep the plant going at a constant rate, and it is automatically controlled by the SCADA system. The trend line shows that the silo gets full after a few weeks. This is because the breakdowns of the mills allow the silos to get full.

In the current milling configuration without steel balls, the tonnage is lower than with steel balls. The constant breakdowns also hamper the milling circuit in getting back on track completely. If a mill breaks down, the ore transport to the mill also has to stop. Since the mill has stopped unplanned, no preparation could be made as to the mill charge necessary for start up. Starting the mill after a breakdown takes time, as the mill charge needs to be increased in a controlled fashion.

Meanwhile, the ore is still transported to the silos from the shaft, causing them to fill up. It is therefore of the utmost importance for a plant to be able to keep up with the shaft in terms of ore handling. On mills 1, 2 and 5, the plant operations were very successful, since the silo

levels are mostly horizontal. However, on mill 6 it can be seen that the silo gets full very quickly. This is expected, since that mill had plenty of breakdowns during the months when the data was gathered. It can be seen that the average breakdowns on this mill comprises nearly 7 hours per day. This is too much for the mill to handle in the current configuration.

4.5 VERIFYING THE SIMULATION RESULTS

In order to verify the simulation results provided in the previous section, the current system constraints were used to simulate the current situation at the plant. The resulting simulated production and performance indicators were compared to the actual indicators in order to test the accuracy of the simulation. The following table provides a summary of these results:

	Mill 1	Mill 2	Mill 5	Mill 6
Actual downtime	3 h/d	4 h/d	4 h/d	7 h/d
Actual Mill dry tons	35 t/h	36 t/h	36 t/h	35 t/h
Actual Availability	90%	86%	85%	77%
Simulated Downtime	3 h/d	3.5 h/d	4 h/d	7.5 h/d
Simulated Mill dry tons	34 t/h	35.5 t/h	36 t/h	37 t/h
Simulated Availability	89%	88%	86%	75%

Table 34: Comparison between actual and simulated results on the plant

From this table it can be seen that the simulate results are very close to the actual results. Graphical comparisons have also been made from the different results. These are shown in the following figures:

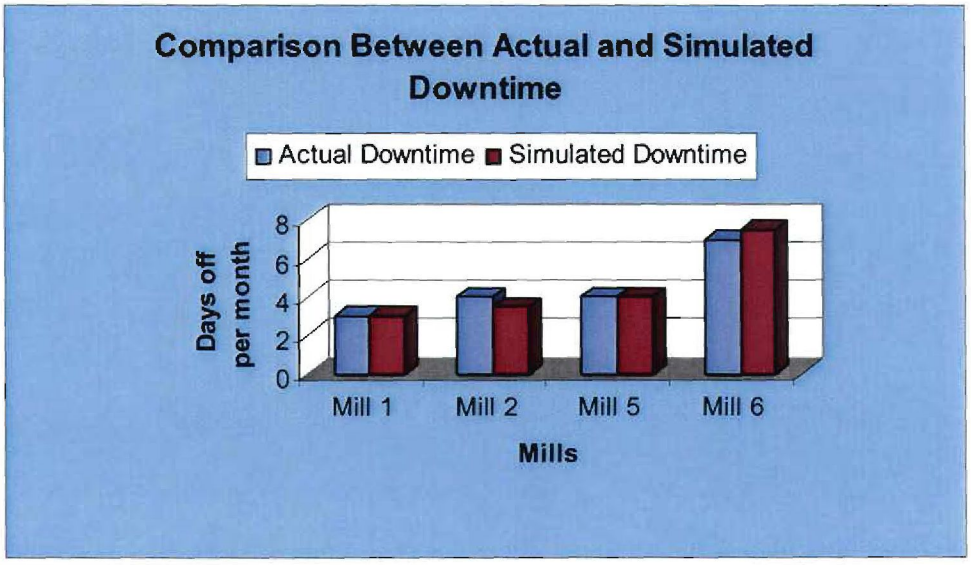


Figure 83: Comparison between actual and simulated downtime

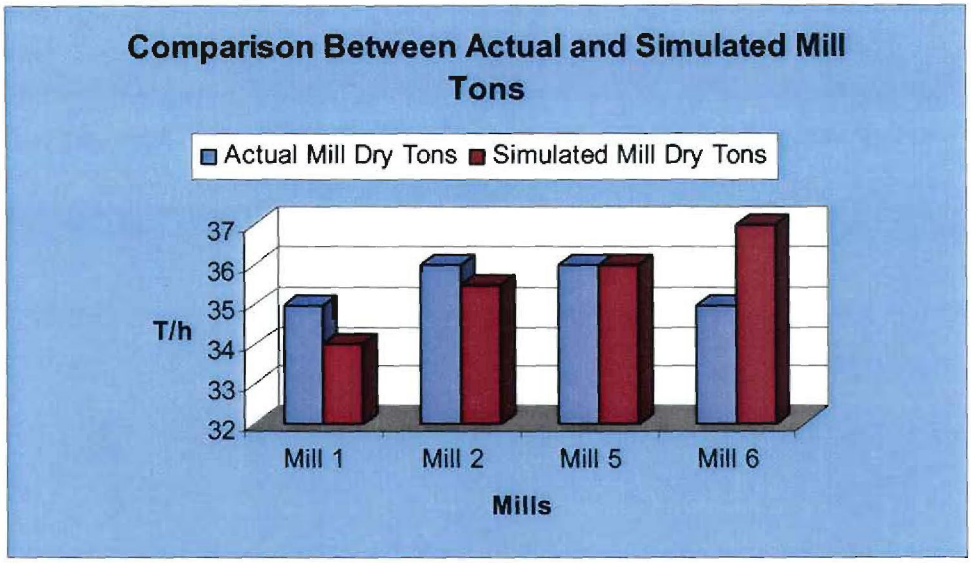


Figure 84: Comparison between actual and simulated mill tons

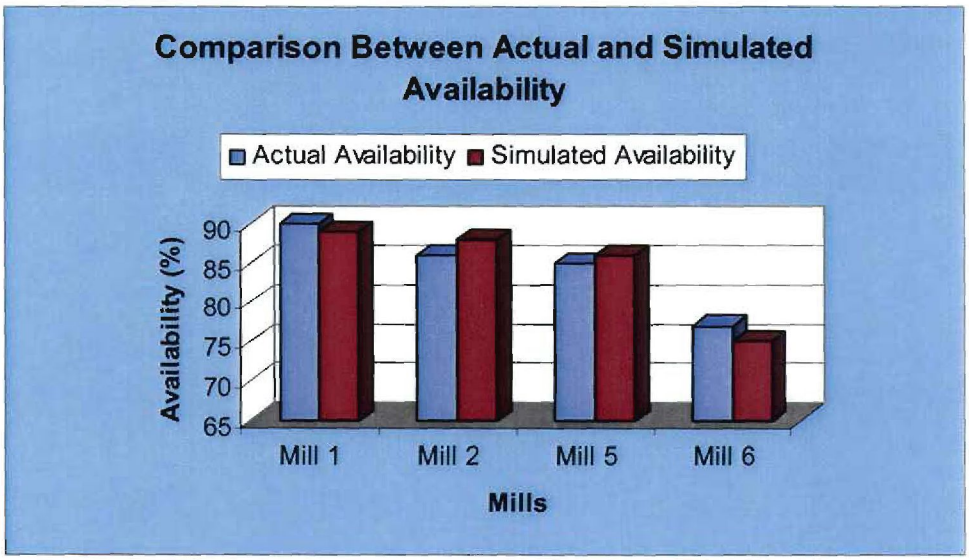


Figure 85: Comparison between actual and simulated mill availability

The accuracy of the simulation results compared to the actual values has been calculated from the results. This has been summarised in the following table:

Accuracy of Results	Mill 1	Mill 2	Mill 5	Mill 6
Daily Downtime	100%	88%	100%	93%
Mill Dry Tons	97%	99%	100%	95%
Availability	99%	98%	99%	97%

Table 35: Summary of the accuracy of the various simulation results

From this table it can be clearly seen that the simulated values are very close to the actual values of the current milling setup. The largest error is 12%, while most other errors are in the

order of 0% to 5%. The reason for this difference is because the simulation is based on the planned tons and average unplanned stops. This allows inaccuracies to occur when the mills have longer than average breakdowns. This is proof that the simulation model is accurate enough to use as a tool to simulate the milling circuit of a gold plant.

Another test to prove the accuracy of the simulation is to compare the simulated silo levels to the actual silo levels. Unfortunately, on this specific plant, no historic data could be found for the silo levels. In order to overcome that problem, the simulation model was used on another plant in the Carletonville area. The purpose of this simulation was to prove that the simulation accurately simulates the silo levels on the plant. For this reason, only the silo level results are provided here.

This plant has three reef mills, namely Mills A, B and C. The capacity for each silo is 4000 tons. The silo level comparison has been prepared in a fashion similar to the results provided by the simulation, namely a silo level graph for a month period. The comparisons for the three mills are shown in the following figures:

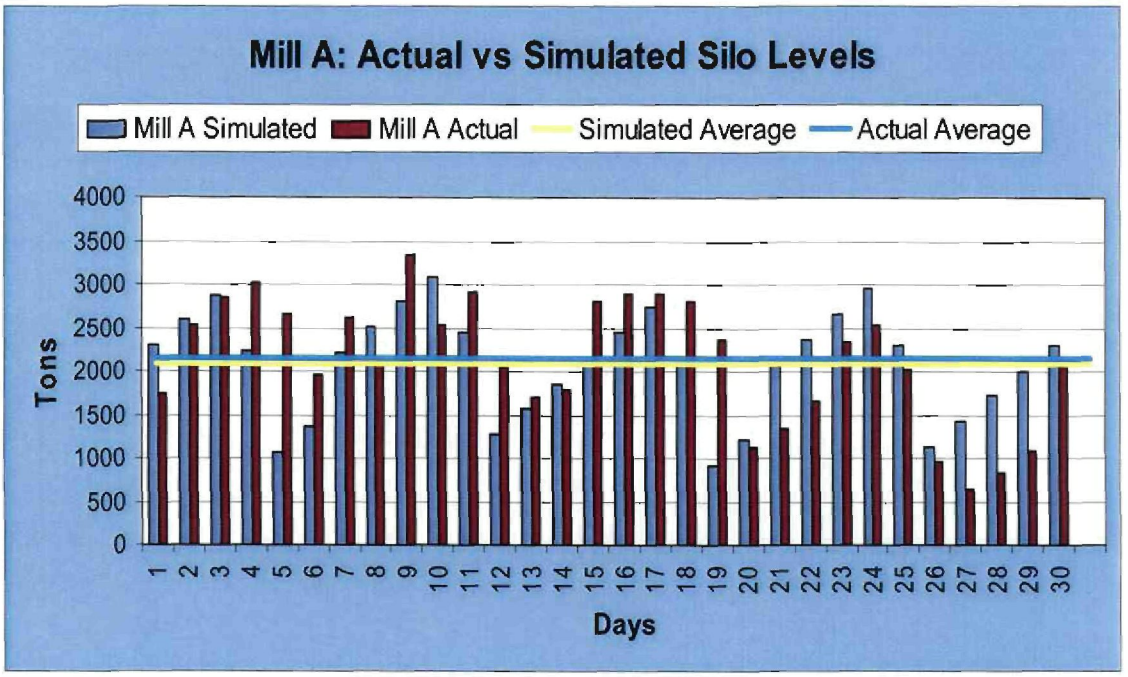


Figure 86: Simulated vs actual silo levels for Mill A

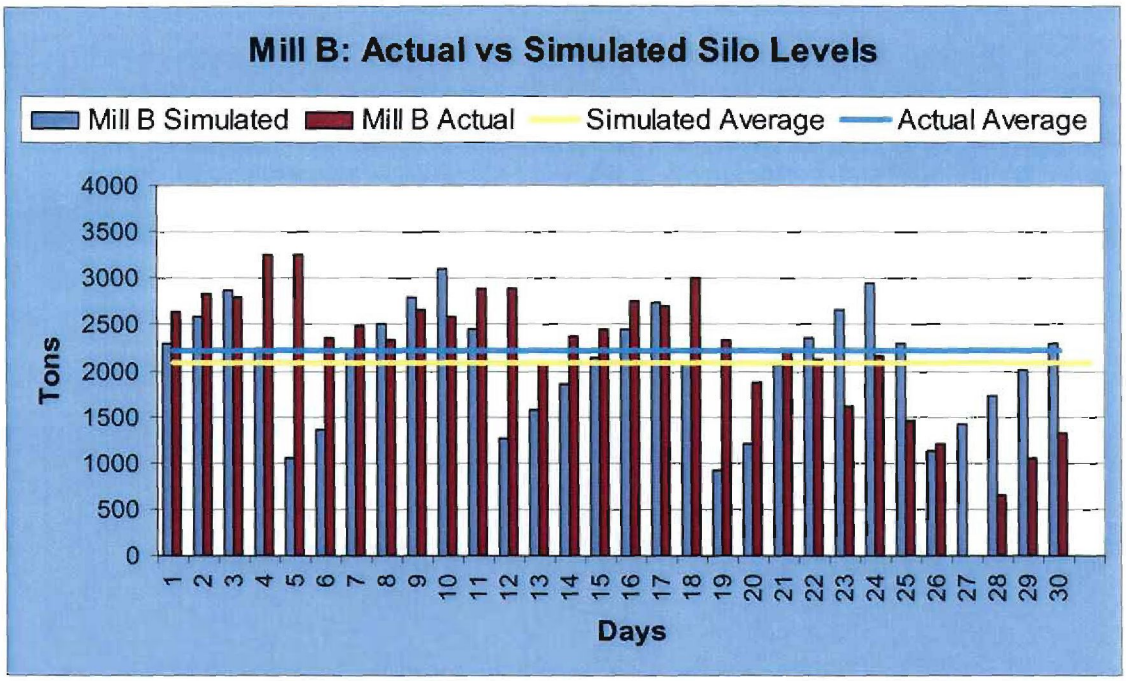


Figure 87: Simulated vs actual silo levels for Mill B

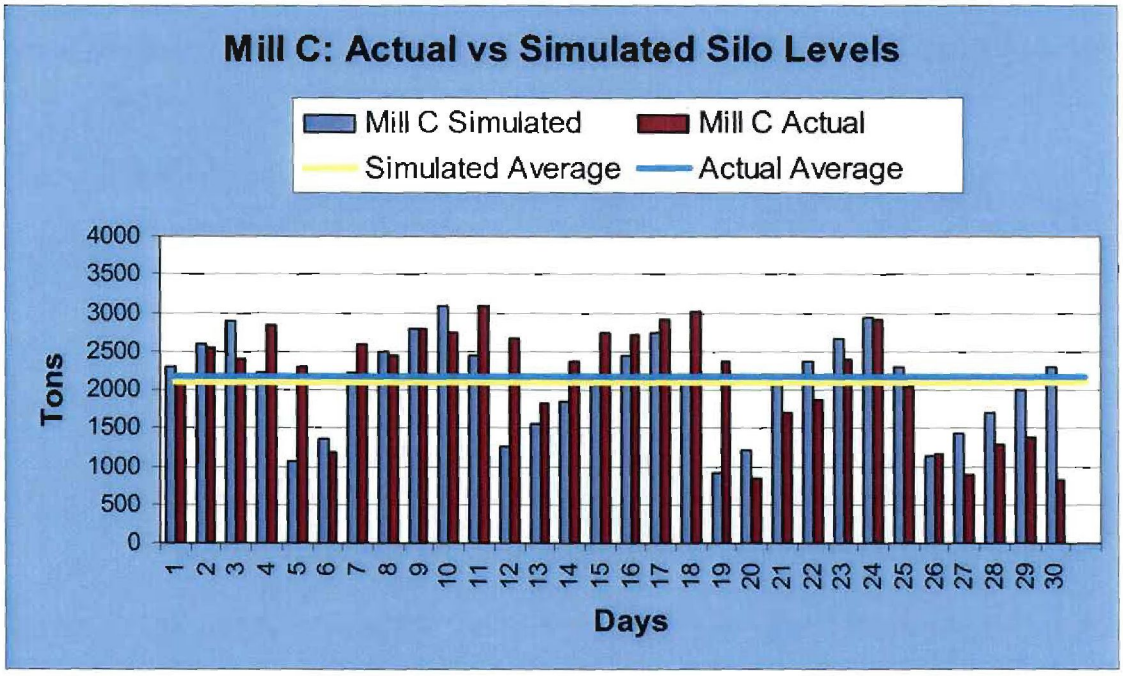


Figure 88: Simulated vs actual silo levels for Mill C

It is clear from these figures that the simulated silo levels are very close to the actual silo levels. The reason why the simulated levels are not exactly the same as the actual levels, is because the simulation model use average tons and unplanned stops to predict the future silo levels. Unexpected breakdowns cannot be accounted for in such a model. In order to

demonstrate just how accurate the simulation is, a mathematical comparison was made between the actual and simulated tons milled.

	Mill A	Mill B	Mill C
Total tons milled (Actual)	64,189	66,331	64,996
Total tons milled (Simulated)	62,599	62,599	62,599
Difference between results	2%	6%	4%

Table 36: Comparison between the total simulated and actual tons milled

Another comparison can be made between the actual and simulated average silo tons. If the figures above are examined it can be seen that they are very close together. The actual comparison of the averages results in the following:

	Mill A	Mill B	Mill C
Actual Average	2,087	2,087	2,087
Simulated Average	2,140	2,211	2,167
Difference between results	2%	6%	4%

Table 37: Comparison between actual and simulated average silo levels

By comparing the simulated results with the actual values, it can be seen that the differences are very small, as shown in *tables 36* and 37. This proves that the simulation is accurate enough to be used in simulating the milling circuit of a CIP gold plant. Before the following step of proving that load shift can be successfully simulated using this model, some time needs to be allocated to discuss the problems encountered during audits and simulations on the various gold plants. This is to demonstrate where gaps exist in the existing procedures and simulation results developed during this research.

4.6 PROBLEMS ENCOUNTERED

In order to discuss the problems encountered in the development of this simulation model, the focus needs to be first divided into the information gathering stage, and the actual simulation stage of the investigation.

4.6.1 INFORMATION GATHERING STAGE

During this stage of the research, visits have been made to 10 gold plants all over South Africa. In the interest of standardization, the information gathering procedures was kept as similar as possible for each plant. This includes actions like meeting with the plant management to

discuss the purpose of the research, performing a walkthrough audit of the plants and gathering historic plant information for the questionnaire. The following problems were encountered during this stage of the research:

- Sometimes it is difficult to convince people on a plant of the idea that it might be possible to stop the mills for load shifting. Usually the plant management looks at the proposal with interest, but usually artisans and plant operators react very sceptical to the idea.

- Some plants are very old, and make use of outdated filter technology. This is not the same as the modern CIP process where thickener tanks can be used as storage. Fortunately, these plants are few, and currently in the process of being phased out and therefore ignored for this research.

- Not all plants have historical records of their operational data. And when they do, it may be incomplete, or inaccurately done in by semi-skilled personnel, making it difficult to get an accurate picture of the plant operations.

- If data is available, it is not always easily accessible on a SCADA system, but often in daily handwritten log sheets that require extensive effort to transfer it into usable electronic form.

- Sometimes the management are not willing to share certain information, as these are considered to be too sensitive for public use. As such, only the most basic information was given in this thesis and names of plants have been omitted for security reasons.

4.6.2 SIMULATION STAGE

Since the simulation should be similar for all the plants, it must be expected that there would be very little problems at this stage. Unfortunately, this is not the case, since each plant still has its own distinct peculiarities that need to be accounted for in order to get an accurate simulation. The following problems have been encountered at this stage:

- Since the simulation is used to predict the future silo levels for a specific plant, it is necessary to use average values in all the simulations. Values affected in this way

include the tons milled per hour and the tons received from the shafts. This causes some inaccuracy in the simulation. However, it has been shown in the previous section that this is usually of little concern.

- Unplanned stops cannot be accurately predicted beforehand, therefore, an average daily value calculated from past results is used. This has proven to be a reliable way of performing the simulation.

- Unplanned stops have a negative effect on plant production. It is not always possible to accurately simulate major unexpected delays, due to the predictive nature of the simulation and the unexpectedness of these breakdowns.

- In some cases, a large amount of effort is needed to adapt the historical data into usable electronic form. This is often very time-consuming, for it must be done accurately to ensure accurate results.

4.7 LOAD SHIFT SIMULATION RESULTS

4.7.1 INTRODUCTION

Now that it has been proven that the simulation can accurately predict a current milling circuit at a gold plant, it is time to apply it to find any possible load shift on these plants. The load shift simulation is actually the next phase of the simulation, the first phase being the simulation of the current situation at the plant.

It has been discussed earlier that production plant personnel are only willing to shift load at times where most convenient and beneficial for the plant. In the case of a gold plant, it usually is the morning peak from 07:00 to 10:00. The morning peak is longer than the evening peak period, and in the mornings the artisans are available to perform maintenance, should this be necessary.

In order to test the idea of load shift on a real plant, a new milling strategy was proposed. This strategy includes the following:

- Try to perform load shift every weekday in the morning peaks.

- If possible, try to shift more load in other peak times.

- Try to move the planned maintenance every second week to these daily 3-4 hour periods.

- Increase the mill throughput by adding steel balls to the mills. This will ensure the tons produced to be the same as currently, even with the extra stops in the morning.

- Try to perform the load shift as diligently as possible, but refrain from it if production constraints are more important.

- This was done for a three month test period from April to June 2007.

- Since the mills will now stop for longer periods, the mill availability will be decreased. However, this should not affect the tons, since the steel balls will ensure the same production rate.

The following section shows the results obtained by performing tests on the gold plant from the previous chapter.

4.7.2 RESULTS OF LOAD SHIFT TESTS ON THE GOLD PLANT

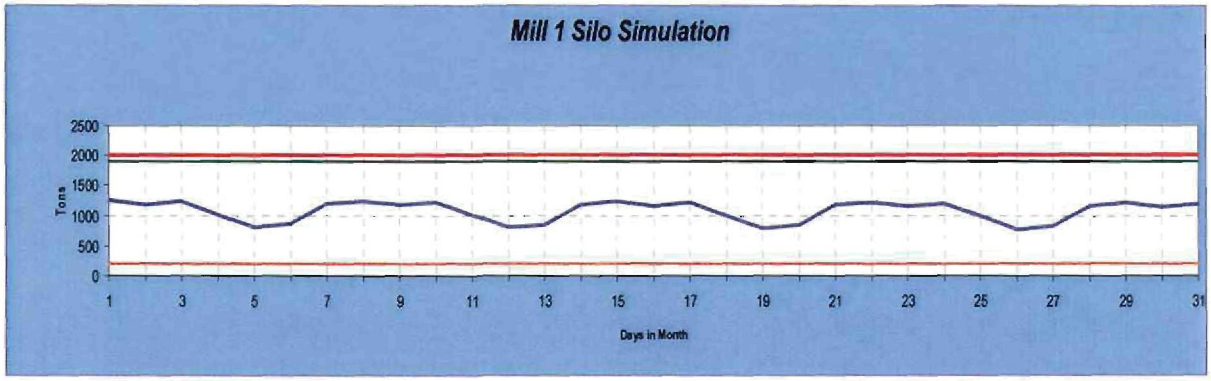
Once again, the same four mills (1,2,5 and 6) of the plant at Evander were used to perform these tests. Even though the mills may have somewhat different tonnages being milled, they are all of the same design. One of the aims of the simulation is to find a way in which all the mills can run efficiently with the same milling schedule. As such, the four mills were treated as equal in term of the simulation model. The following values were used as inputs to the simulation model; these values are in line with the suggested milling strategy in the previous section:

	Mill 1	Mill 2	Mill 5	Mill 6
Mill Dry tons	40 t/h	40 t/h	40 t/h	40 t/h
Ore into Silos (Weekdays)	750 t/d	750 t/d	750 t/d	750 t/d
Ore into Silos (Saturdays)	750 t/d	750 t/d	750 t/d	750 t/d
Ore into Silos (Sundays)	750 t/d	750 t/d	750 t/d	750 t/d
Running hours on Saturdays	24 hr	24 hr	24 hr	24 hr
Running hours on Sundays	24 hr	24 hr	24 hr	24 hr
Planned Maintenance	3.5 h/d	3.5 h/d	3.5 h/d	3.5 h/d
Load Shift	3 hours every second weekday	3 hours every second weekday	3 hours every second weekday	3 hours every second weekday
Availability	78%	78%	78%	78%

Table 38: Production details used as input to the simulation

It can be seen that the tons going through the mill has been increased to 40 t/h. This is possible if steel balls are added to the mills as grinding media. This will increase the throughput somewhat and allow stoppages for load shift. Once again, the focus of the simulation was to keep the silo level relatively constant. This ensures that there will always be ore available in the silo should the mills need it. It also ensures a relatively constant process where the mill will not have to perform unnecessary stops due to empty silos.

If the silo level is under control, the shaft will not have to wait for the mills to catch up. By using the load shift in *Table 38,* the simulation was done for all four of the mills. The following figures show the simulated silo levels for these mills. It can be seen that the silo levels are still within the minimum and maximum levels as defined by the plant:



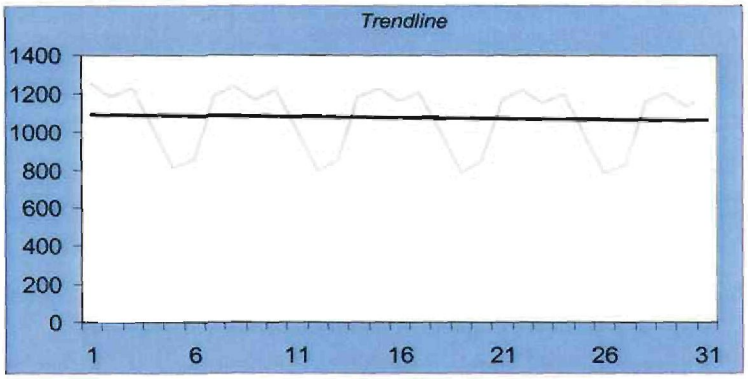
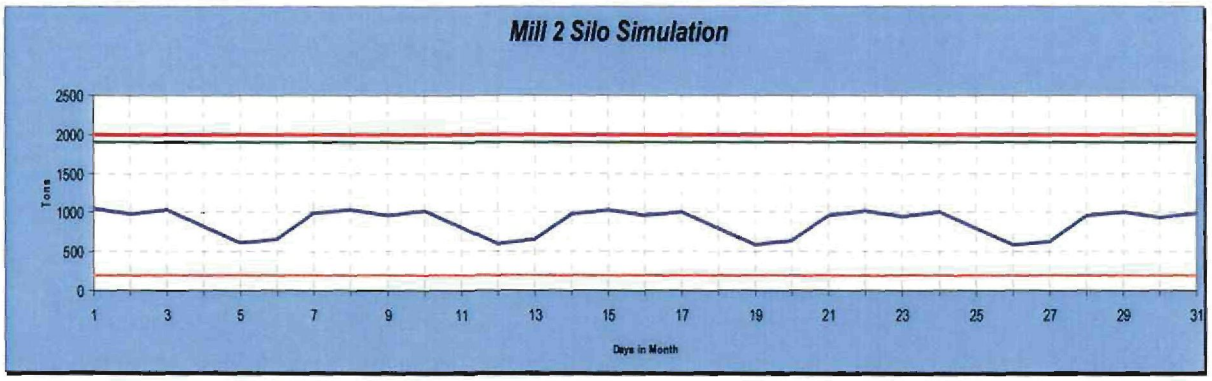


Figure 89: Silo level simulation results for Mill 1



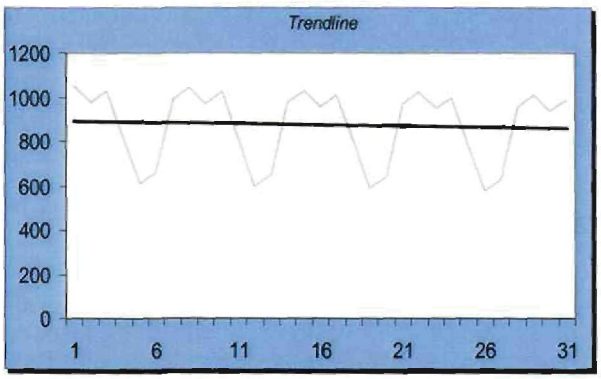
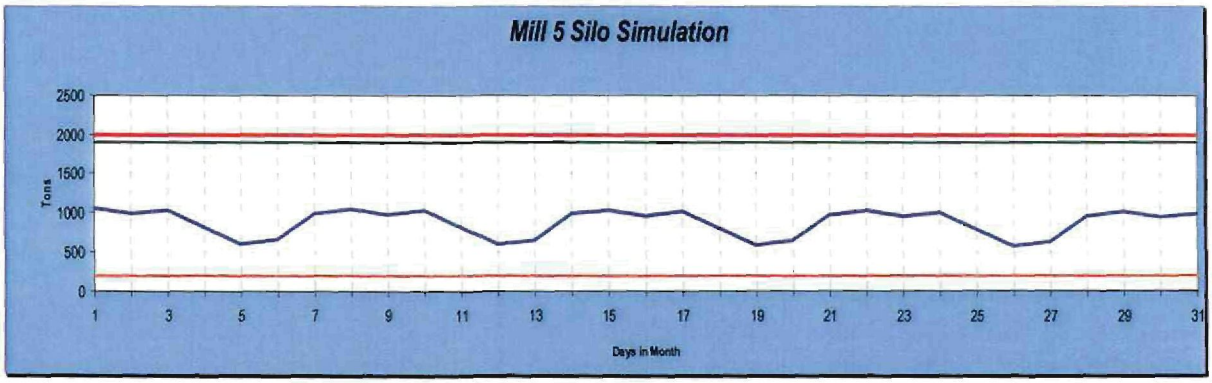


Figure 90: Silo level simulation results for Mill 2



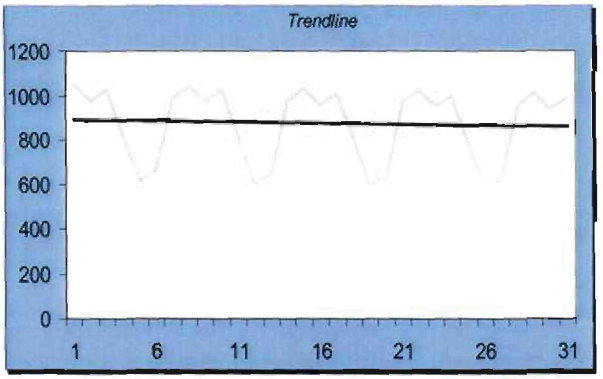
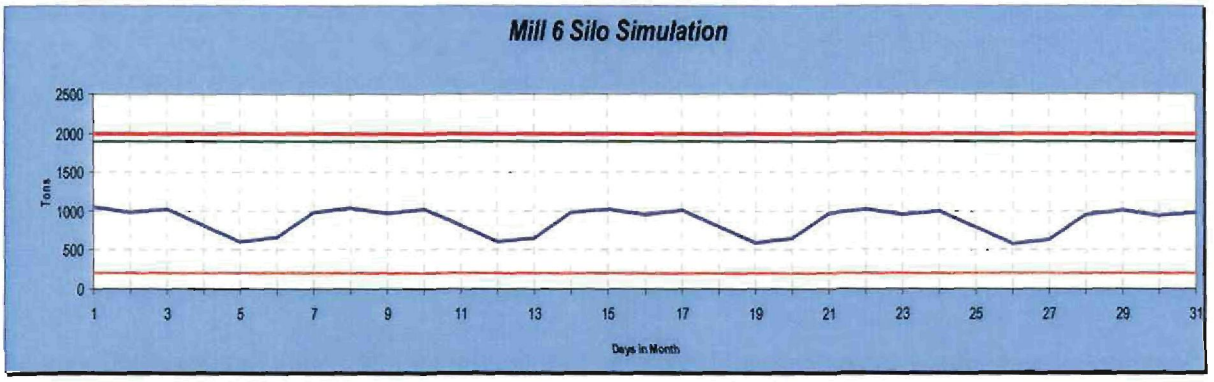


Figure 91: Silo level simulation results for Mill 5



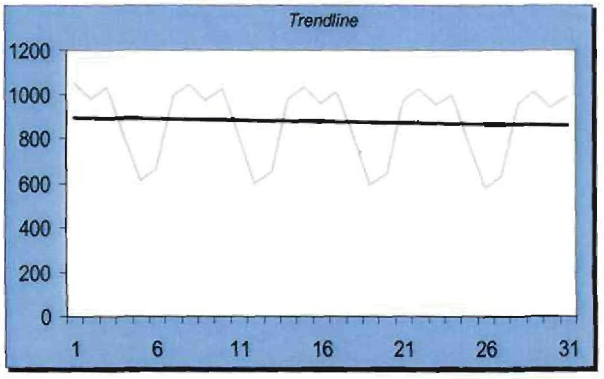


Figure 92: Silo level simulation results for Mill 6

These simulation results show that it should definitely be possible to achieve load shift on this plant without affecting the silo levels negatively. In order to verify this, a test was done on the plant. The MILLING SCHEDULE SIMULATOR produced the following optimised milling schedule:

Weekday		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
3	01	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	03	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	04	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	05	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	06	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	07	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	08	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	09	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	10	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	13	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	14	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	15	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	17	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	20	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	21	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	22	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	24	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	27	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	28	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	29	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	31	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 39: Optimised milling schedule for the plant as created by the MILLING SCHEDULE SIMULATOR

The plant followed the milling schedule guidelines provided in the previous section for three months on the same mills used previously (1,2,5 and 6). The results from these tests were reduced to determine the baselines with load shift in the morning peak. These baselines are provided in the following figures:

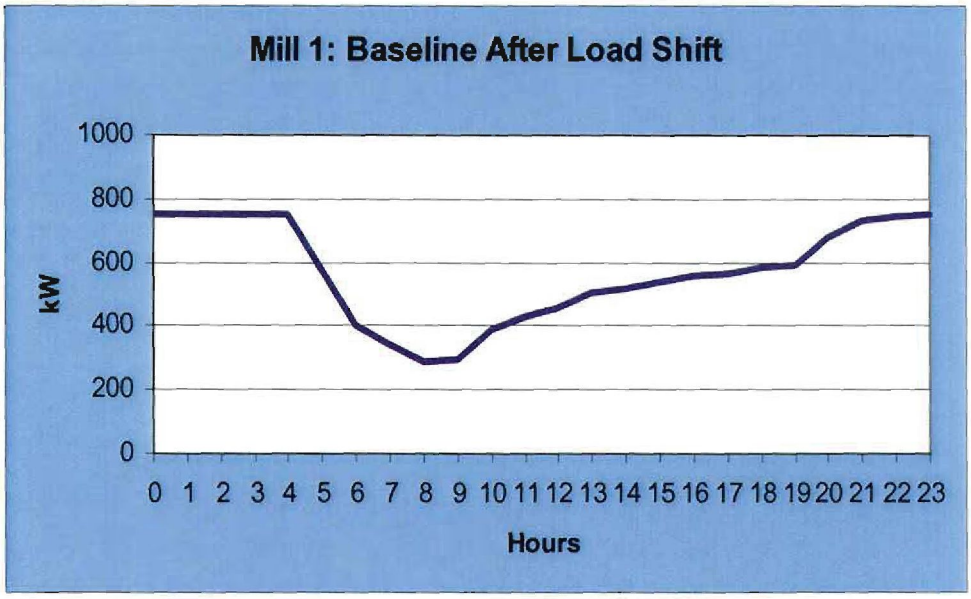


Figure 93: Mill 1 Baseline after load shift

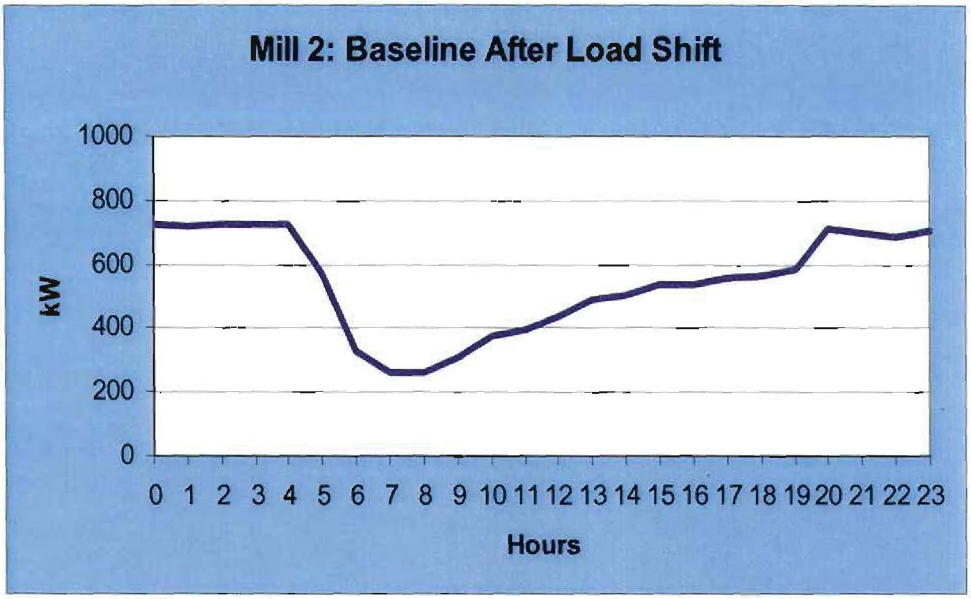


Figure 94: Mill 2 Baseline after load shift

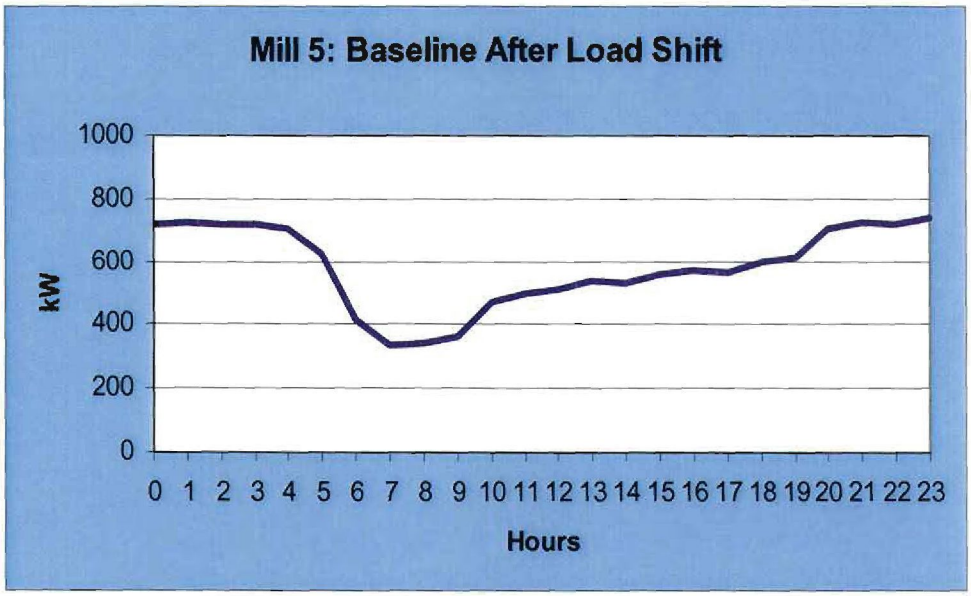


Figure 95: Mill 5 baseline after load shift

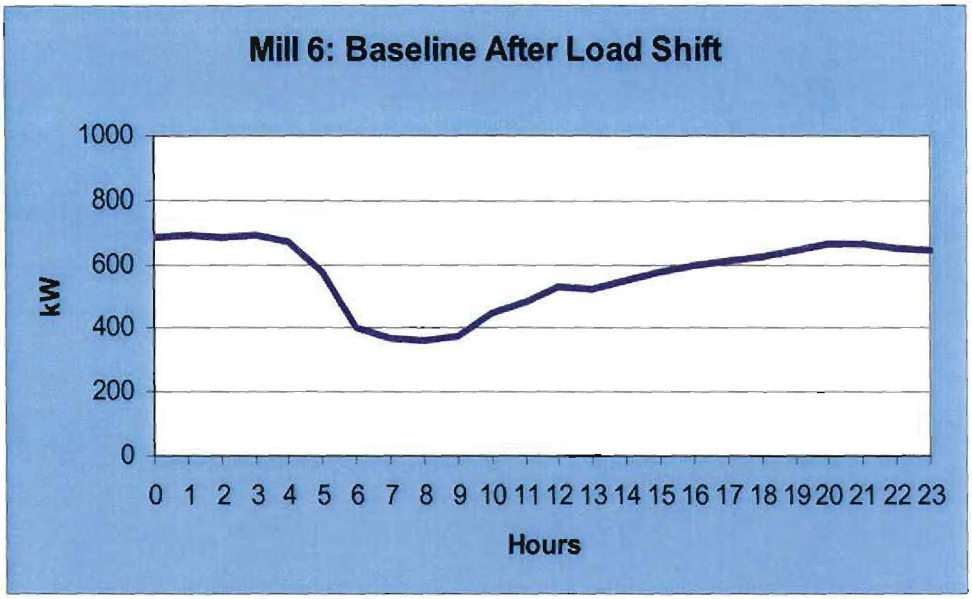


Figure 96: Mill 6 Baseline after load shift

From these figures, it can be clearly seen that load shift has been performed successfully for a period of three months on all the mills. The baselines seem to show that the mills were not switched off completely during the morning peaks. This is because there were days when load shift could not be performed due to operational constraints. This was expected since it was simulated beforehand with the simulation model. The baselines are the average values taken during the test period, resulting in the reduced load shift shown in the figures.

4.7.3 RESULT COMPARISON

In order to verify the simulation model, the actual results were compared with the simulation results. These are shown in the following figures:

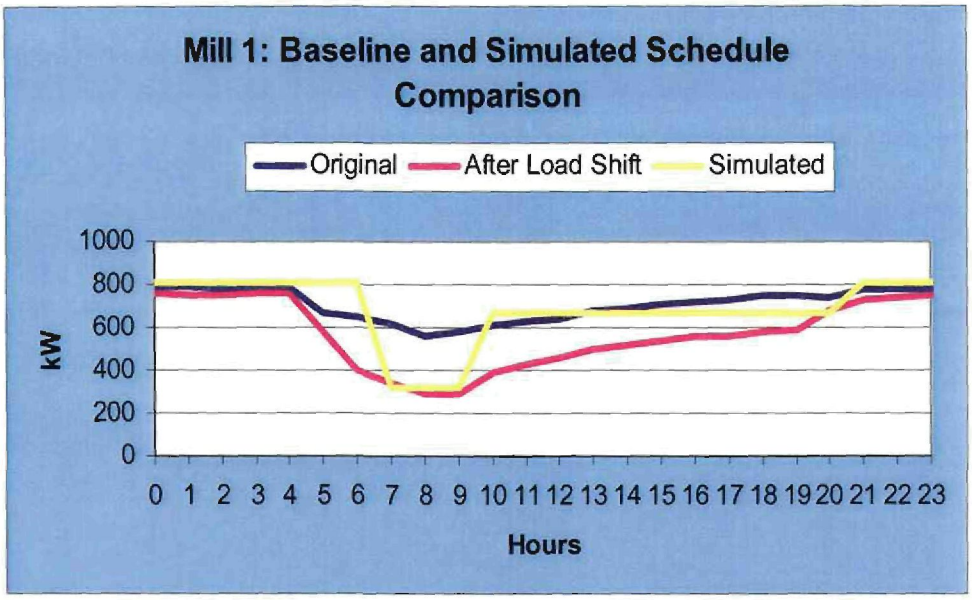


Figure 97: Mill 1 Baseline comparisons

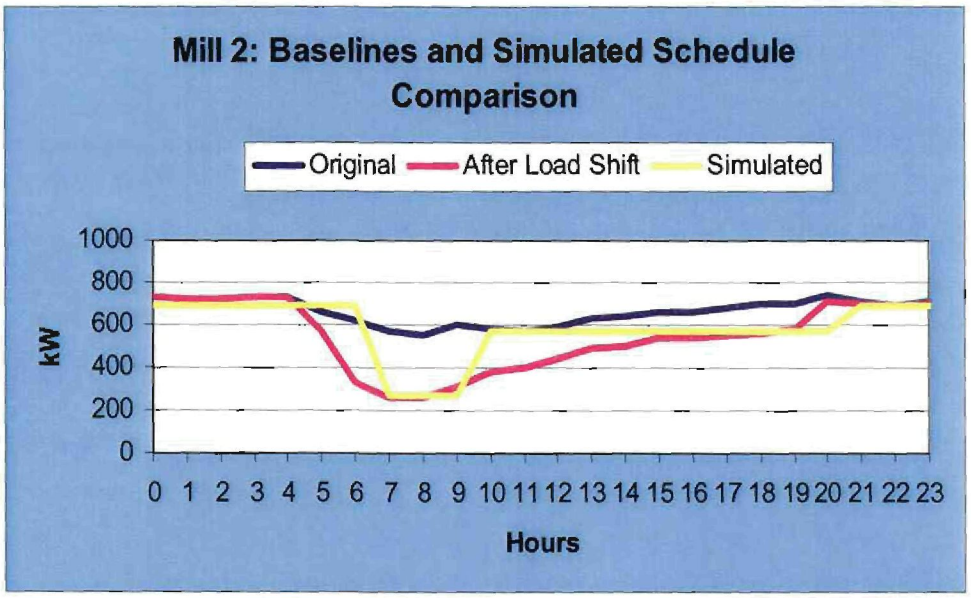


Figure 98: Mill 2: Baseline comparisons

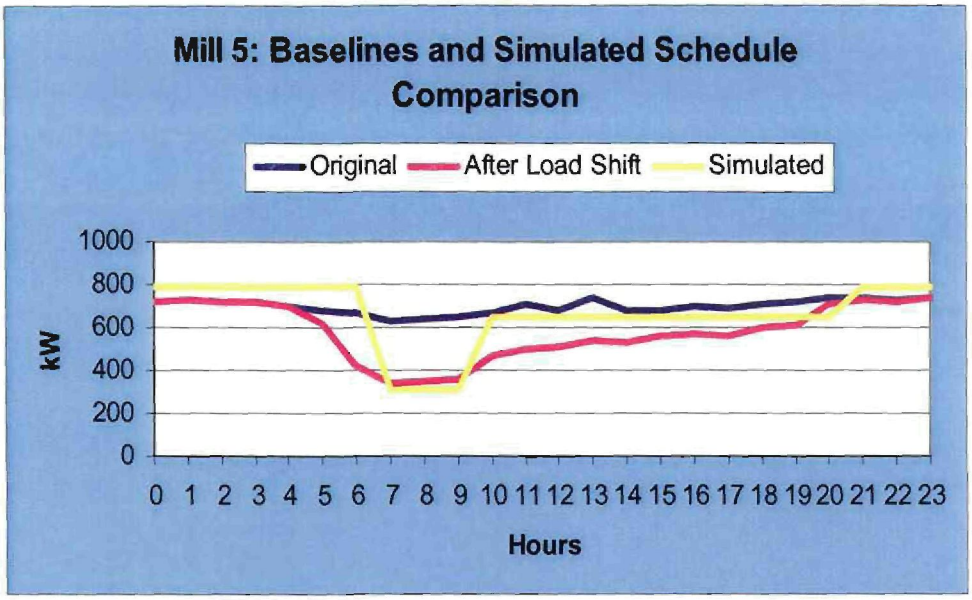


Figure 99: Mill 5 Baseline comparisons

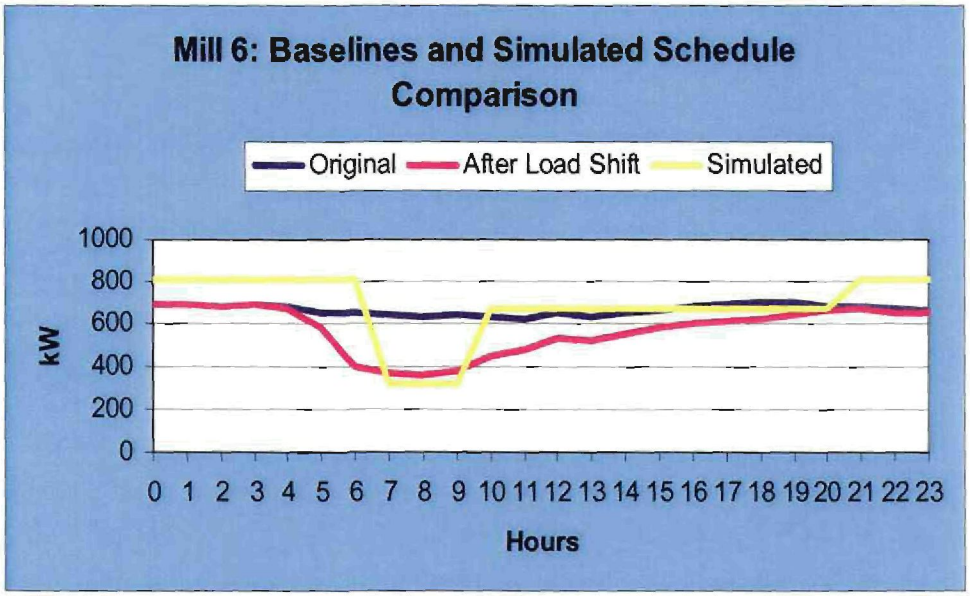


Figure 100: Mill 6 Baseline comparisons

The comparisons clearly show that the simulated load shift is close to the actual values attained for all the mills. There are some differences between the actual and simulated graphs. This is especially evident just before and after the load shift period in the mornings. This is explained in section 4.8 (EXPLANATION OF DISCREPANCIES).

The possible load shift savings for this setup has been calculated by the simulator. These were compared to the actual savings to determine the accuracy of the simulation. The results are summarised in the following table:

	Mill 1	Mill 2	Mill 5	Mill 6
Simulated Load Shift	273 kW	304 kW	334 kW	319 kW
Actual Load Shift	280 kW	295 kW	292 kW	264 kW
Difference between results	7 kW	9 kW	42 kW	55 kW

Table 40: Accuracy comparison between actual and simulated load shift

From these results it can once again be seen that the simulation is accurate in determining the load shift possibilities for a plant. The largest difference between the results is 55 kW. This is not large when viewed in terms of the total load shift of 1,131 kW. It can therefore be said that this section has shown that the simulation model is accurate in determining the possible load shift on a gold plant milling circuit. The actual tests performed on the plant resulted in very similar answers, except for a few exceptions. These are discussed in the following section.

4.8 EXPLANATION OF DISCREPANCIES

The following discrepancies were found between the simulated and actual load shift results:

- *Discrepancy:* The values used in the simulations are not always the same as in the actual situation. This is especially true for the tons milled and the tons received.

  Explanation: The simulation must make use of historical averages to simulate the results. These are sometimes far removed from the average values.

- *Discrepancy:* Unplanned stops used in the simulations differ from the actual unplanned stops.

  Explanation: Unplanned stops in the simulations were once again average values calculated from historical data. Unplanned stops cannot be determined beforehand and the values may differ greatly from those in the simulation.

- *Discrepancy:* The simulation shows that the mills can be stopped and started instantaneously, while the actual results show this to be inaccurate.

  Explanation: When an actual mill is stopped, the whole batch of material in the mill is slowly reduced in order to have as little as possible disturbance in the rest of the system. This empties the mills during the peak times. When the mill is started up again,

it takes some time to fill the batch to the correct size and RD for effective gold extraction. This explains the slowly increasing power draw after the morning peak stops.

- *Discrepancy:* The maximum load shift has not been achieved by either the simulation or the actual test.

  Explanation: The setup of the specific system does not allow for the maximum load shift schedule of stopping the mill everyday. In order to keep the planned production schedule of the plant, the load shift had to be reduced to accommodate milling time.

4.9 CONCLUSION

In this chapter, the simulation model developed in Chapter 3 was tested on a real gold plant in order to verify the accuracy. These tests were done in two sections: In the first section, the current mill setup of the plant was simulated using their actual production details. The simulated results were compared to the actual values obtained from the plant. The results were very close, proving the accuracy of the simulation in this regard.

In the second section, load shift on the mills were simulated using the simulation model. In order to verify the accuracy of the simulation in this regard, actual load shift was performed on the plant during the morning peak period. The planned maintenance has been moved to a daily schedule for this setup. Load shift proved to be very successful during the morning peak, and the actual load shift correlated well with the simulation results.

As such, it can be concluded that the simulation model is accurate and successful in predicting possible load shift on the milling circuit of a gold plant.

CHAPTER 5

APPLICATION OF THE NEW METHODOLOGY AND SIMULATION MODEL

5.1 INTRODUCTION

Now that the simulation model has been developed and tested on an actual gold plant, it is good practice to expand the application of the new simulation method to facilities of similar type and layout. The repeated application of the methodology on different facilities has the benefit of gaining additional insight into the dynamics affecting the specific facility. This in turn will allow the user of the simulation to determine the probability of load shift on the specific facility, if any.

As such, the following sections include the results of the application of the simulation methodology on five different gold plants from all over South Africa. After application, the results will be compared to see which of these gold plants have the capability to shift load from their milling circuits without affecting the production in a negative way.

5.2 GOLD PLANT 1

5.2.1 INTRODUCTION

Gold Plant 1 is situated near the town of Orkney in the North West province of South Africa. It is a plant from the Vaal River operations of the AngloGold Ashanti group. Currently, this plant receives both reef and waste material from two nearby shafts.

5.5.2 ELECTRICAL CAPACITIES OF THE MILLS

The plant has a total of six installed ROM mills. Each of these mills has an installed motor capacity of 3.1 MW, the running capacity of each mill is approximately 2.6 MW. From discussions with plant personnel, it was determined that two of these mills are dedicated to the milling of waste material. This means that four of the mills can be considered as being used for reef material.

The focus of this study will be on the reef mills. The following table shows the possible maximum load shift potential for Gold Plant 1:

Gold Plant 1		
Mill	Installed Capacity (kW)	Running Capacity (kW)
Mill 1	3,100	2,600
Mill 2	3,100	2,600
Mill 3	3,100	2,600
Mill 4	3,100	2,600
TOTAL	**12,400**	**10,400**

Table 41: Electrical capacities of Gold Plant 1 mills.

From this table it can be concluded that the maximum possible saving that can be achieved at Gold Plant 1, is 10.4 MW under any circumstances. This is the sum of the total running capacities of each mill.

5.2.3 ELECTRICAL BASELINE OF A TYPICAL MILL

Specific baseline data for each mill at this plant was not available at the time of the audit. However, data from the electrical incomer that feeds all the mills could be retrieved from the control room. This data was used to calculate the baseline for a typical mill found on this plant. As such, the simulation was only done on one mill, as no proof to the contrary could be found; it was assumed that the other mills would be similar. This baseline is shown in the following figure:

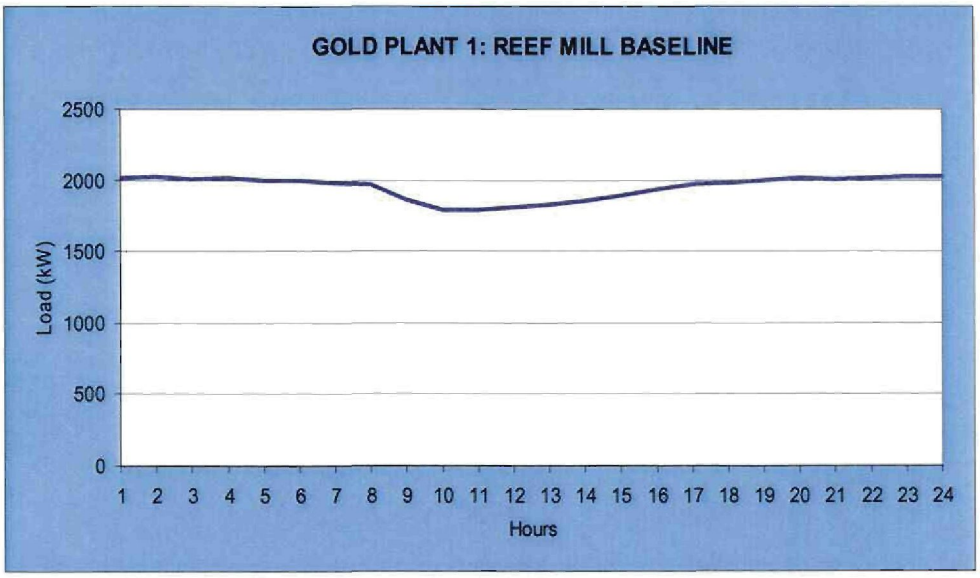


Figure 101: Baseline of a typical reef mill at Gold Plant 1.

The baseline is once again lower than the running capacities provided by the plant. This is due to the unplanned stops that reduce the average baseline if calculated over a period of time.

5.2.4 PRODUCTION DETAILS OF THE MILLING CIRCUIT

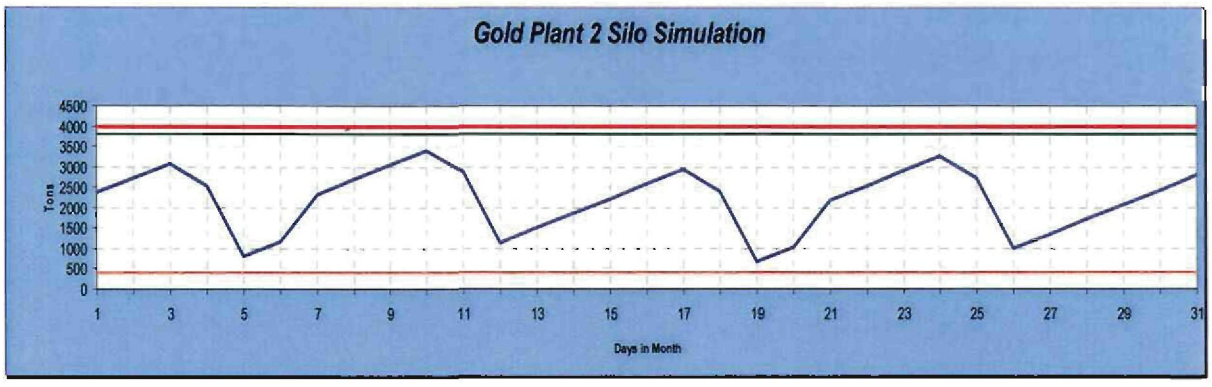
As discussed in a previous chapter, a ROM mill works best at a specific power setting. This power setting is determined by the size of the mill and the hardness of the material being milled at the specific time. For Gold Plant 1, as for any other gold plant, a balancing act is required between, supply of ore, silo capacity, mill production capacity and mill availability. The following table provides the production details of a typical mill at Gold Plant 1:

Gold Plant 1: Production Details	
Mill Production	100 t/h
Silo Capacity	4,000 t
Ore Reception on Weekdays	2,459 t/d
Ore Reception on Weekends	667 t/d
Planned Maintenance	8 Hours every second weekday
Average Daily Breakdowns	1 h/d
Running Hours on Saturdays	12 h
Running Hours on Sundays	24 h

Table 42: Gold Plant 1 plant production details.

5.2.5 RESULTS OF SILO LEVEL SIMULATION

The production details in *Table 42* were used to simulate the possible load shift in the milling circuit of Gold Plant 1. The main aim of the simulation is once again to try and keep the silo level as constant as possible between the minimum and maximum levels set by the plant personnel. The following figure shows the simulated silo level:



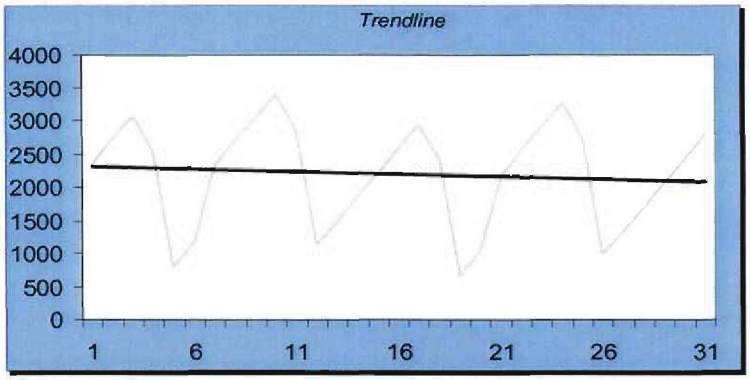


Figure 102: Simulated silo level results

From the above figures it can be seen that the silo level is kept as constant as possible throughout the whole month. The average trend line is almost horizontal as confirmation. The above results were achieved by performing two hours of load shift every weekday in the evening peak. The following section provides the savings results simulated for the plant.

5.2.6 LOAD SHIFT AND ENERGY COST SAVING RESULTS

The optimised silo level shown in the previous section resulted in an optimised milling schedule for Gold Plant 1. The following figure shows this optimised milling schedule superimposed on the current baseline:

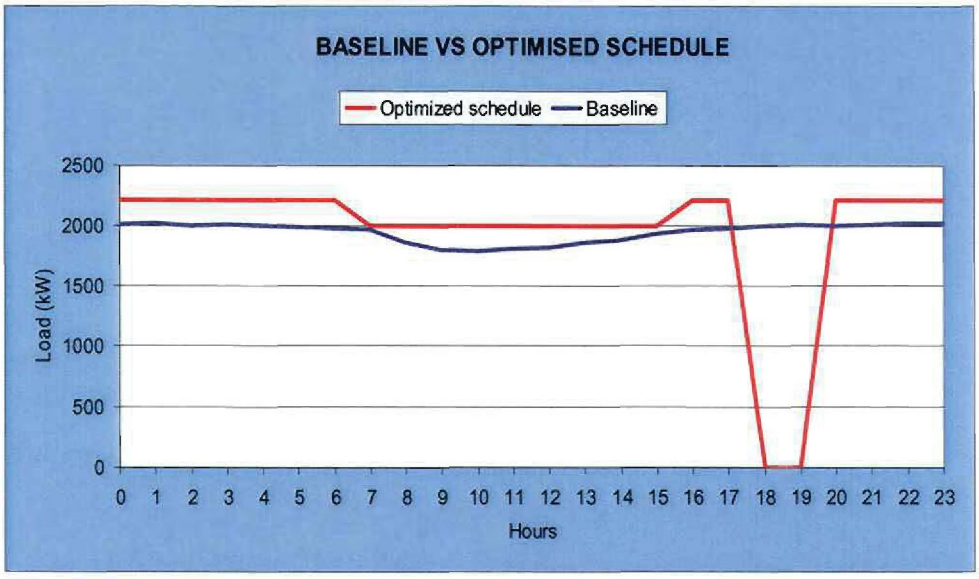


Figure 103: Baseline versus Optimised milling schedule for Gold Plant 1.

From the above figure, the two hours of load shift can be clearly seen between 18:00 and 20:00. Since there are four similar mills at the plant, it was accepted that all four mills will have the same results. The following table provides the saving results for the four reef mills:

Mill	Morning Load Shift (kW)	Evening Load Shift (kW)	Electricity Cost Saving (R/annum)
Mill 1	0	1,877	R 169,262
Mill 2	0	1,877	R 169,262
Mill 3	0	1,877	R 169,262
Mill 4		1,877	R 169,262
Total	**0**	**7,508**	**R 677,048**

Table 43: Summary of savings for all the mills

5.2.7 DISCUSSION OF RESULTS

The conclusion that can be made from the results of Gold Plant 1, is that load shift should be possible on this plant. The mills have such a large overtaking capacity over the current production tons coming from the shafts, that it should be easy to incorporate load shift into the schedule. However, it should be noted that should the production of this plant increase in future, the mills might not be able to keep up with the demand, and the load shift might have to be stopped to make way for increased production.

A possible solution to this problem is to increase the storage capacity at the plant. This will most probably take the form of another silo or perhaps a stockpile. This will allow the mills to be stopped during peak times, even though the production from the shafts is increased.

5.3 GOLD PLANT 2

5.3.1 INTRODUCTION

Gold Plant 2 is situated near the N12 between Potchefstroom and Johannesburg in South Africa. It is one of the plants of the Wes Wits operations of the AngloGold Ashanti group. Currently, this plant receives reef material from a shaft nearby.

5.3.2 ELECTRICAL CAPACITIES OF THE MILLS

The plant has a total of three ROM mills installed. Each of these mills has an installed motor capacity of 3.1 MW, the running capacity of each mill is approximately 2.6 MW. The following table shows the possibl

e maximum load shift potential for Gold Plant 2:

Gold Plant 2		
Mill	Installed Capacity (kW)	Running Capacity (kW)
Mill 1	3,100	2,600
Mill 2	3,100	2,600
Mill 3	3,100	2,600
TOTAL	**9,300**	**7,800**

Table 44: Electrical capacities of Gold Plant 2 mills.

From this table it can be concluded that the maximum possible saving that can be achieved at Gold Plant 2 is 7.8 MW under any circumstances. This is the sum of the total running capacities of each mill. This value should be kept in mind when calculating the load shift of a particular mill.

5.3.3 ELECTRICAL BASELINE OF A TYPICAL MILL

Actual historical electrical data for Gold Plant 2 was used to determine the electrical baseline. The following figure shows the baseline for a typical reef mill:

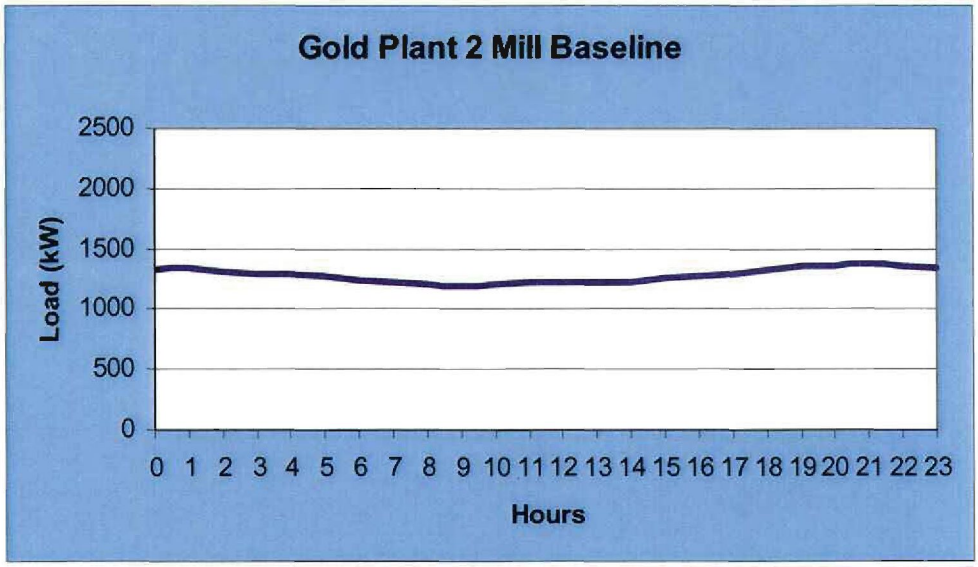


Figure 104: Baseline of a typical reef mill at Gold Plant 2.

5.3.4 PRODUCTION DETAILS OF THE MILLING CIRCUIT

In order to create a starting point for the simulation, the current production details were used as inputs to the simulation. The following table provides the production details of a typical mill at Gold Plant 2:

Gold Plant 2: Production Details	
Mill Production	90 t/h
Silo Capacity	4,000 t
Ore Reception on Weekdays	1,889 t/d
Ore Reception on Weekends	1,889 t/d
Planned Maintenance	8 Hours every second week
Average Daily Breakdowns	1 h/d
Running Hours on Saturdays	24 h
Running Hours on Sundays	24 h

Table 45: Gold Plant 2 production details

5.3.5 RESULTS OF SILO LEVEL SIMULATION

The production details in *Table 45* were used to simulate the possible load shift in the milling circuit of Gold Plant 2. The main aim of the simulation is once again to try and keep the silo level as constant as possible between the minimum and maximum levels set by the plant personnel. The following figure shows the simulated silo level:

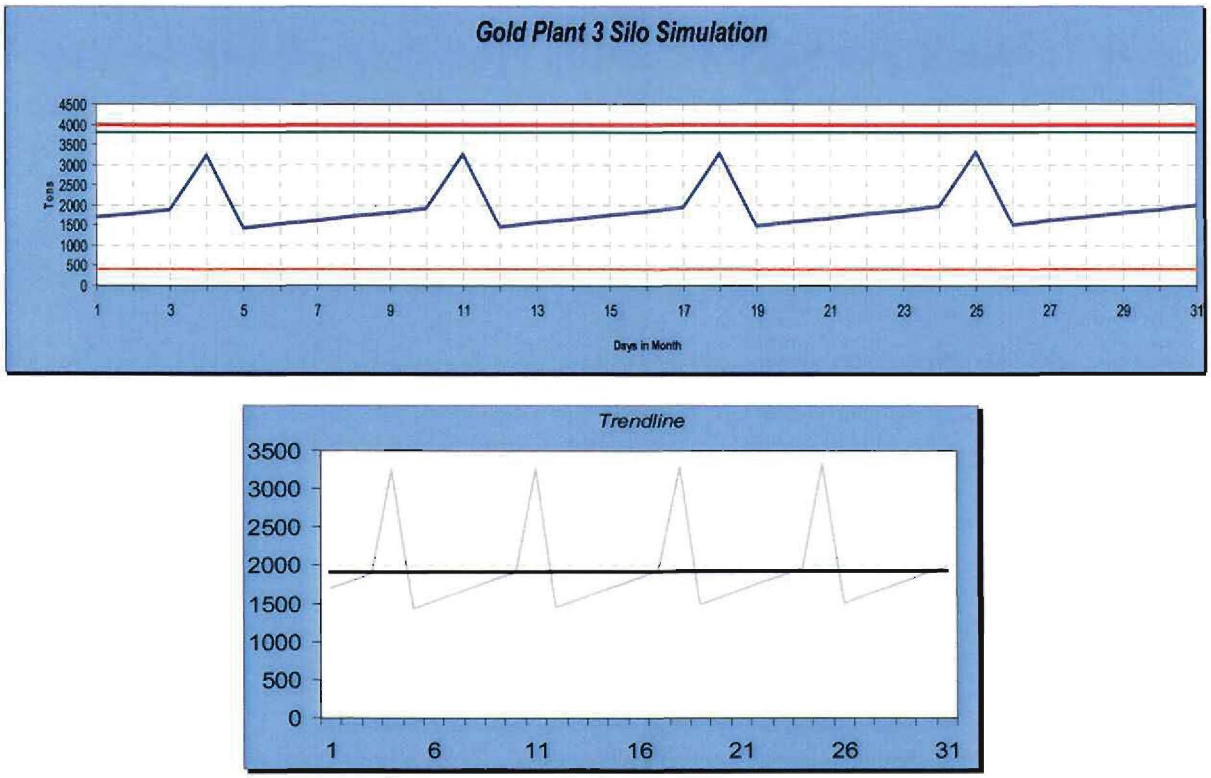


Figure 105: Simulated silo level results for Gold Plant 2

From the above figures it can be seen that the silo level is kept as level as possible throughout the whole month. As confirmation, the average trend line is almost horizontal.

5.3.6 LOAD SHIFT AND ENERGY COST SAVING RESULTS

According to the management, this plant is already very close to maximum production due to increased demand of higher production. It was said that load shift should not be possible on this plant because of these constraints. The simulation proved them right: No opportunity for load shift exists at this plant. The simulated optimised schedule is shown in the following figure:

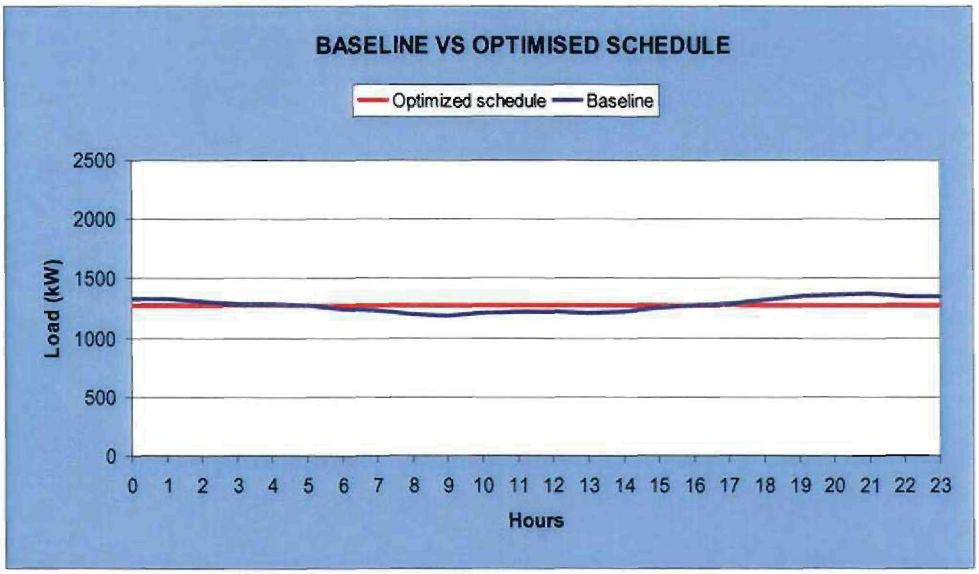


Figure 106: Baseline versus Optimised milling schedule for Gold Plant 2

These results show that the silo levels can be kept constant only if load shift is not performed on the mills.

5.3.7 DISCUSSION OF RESULTS

The study on this plant revealed that it is impossible to perform load shift on the mills without compromising the production figures. This is consistent with what the plant personnel revealed during the preliminary visit, showing once again that the simulation is accurate in predicting the possible load shift on a gold plant milling circuit.

5.4 GOLD PLANT 3

5.4.1 INTRODUCTION

Gold Plant 3 gold plant is situated in the town of Virgina near Welkom in the Free State province of South Africa. It is a plant from the Harmony Gold group. Currently this plant receives reef only by road and rail from four shafts in the area.

5.4.2 ELECTRICAL CAPACITIES OF THE MILLS

The plant has a total of two ROM mills installed. Each of these mills has an installed motor capacity of 3.9 MW the running capacity of each mill is approximately 2.5 MW. The following table shows the possible maximum load shift potential for Gold Plant 3:

Gold Plant 3		
Mill	Installed Capacity (kW)	Running Capacity (kW)
Mill 1	3,900	2,500
Mill 2	3,900	2,500
TOTAL	**7,800**	**5,000**

Table 46: Electrical capacities of Gold Plant 4 mills.

From this table it can be concluded that the maximum possible saving that can be achieved at Gold Plant 3, is 5.0 MW under any circumstances. This is the sum of the total running capacities of each mill. This value should be kept in mind when calculating the load shift of a particular mill.

5.4.3 ELECTRICAL BASELINE OF A TYPICAL MILL

Actual historical electrical data for the mills at Gold Plant 3 was not available. As such, the silo simulations were done first to determine whether it is possible to perform load shift on the mills. If not, a baseline is not necessary. If it is possible, a more detailed effort can be made to determine a baseline by means of actual measurements of current in the instrumentation panel. But for now, the baseline was kept out of the equation.

5.4.4 PRODUCTION DETAILS OF THE MILLING CIRCUIT

In order to create a starting point for the simulation, the current production details were used as inputs to the simulation. The following table provides the production details of the two mills at Gold Plant 3:

Gold Plant 3: Production Details	
Mill 1 Production	125 t/h
Silo Capacity	4,500 t
Ore Reception on Weekdays	2,859 t/d
Ore Reception on Saturdays	2,979 t/d
Ore Reception on Sundays	3,260 t/d
Planned Maintenance	6 Hours every second week
Average Daily Breakdowns	2.5 h/d
Running Hours on Saturdays	24 h
Running Hours on Sundays	24 h

Table 47: Production details for Mill 1 at Gold Plant 3

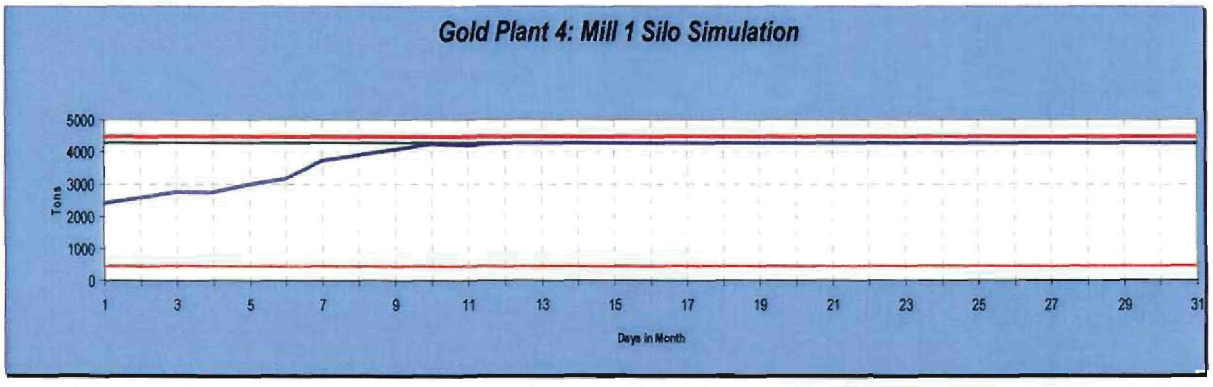
Gold Plant 3: Production Details	
Mill 2 Production	133 t/h
Silo Capacity	4,500 t
Ore Reception on Weekdays	2,859 t/d
Ore Reception on Saturdays	2,979 t/d
Ore Reception on Sundays	3,260 t/d
Planned Maintenance	6 Hours every second week
Average Daily Breakdowns	1.5 h/d
Running Hours on Saturdays	24 h
Running Hours on Sundays	24 h

Table 48: Production details for Mil 2 at Gold Plant 3

5.4.5 RESULTS OF SILO LEVEL SIMULATION

On this plant, the management insisted that any possible load shift be performed during the morning peak to fit in with their current maintenance schedule. Even though this is not particularly helpful to Eskom, given their problem in the evening peak, it still goes a long way towards helping to reduce the morning peaks.

Once again the simulation was performed on this plant. Since detailed information was available on both mills, the simulation model was performed on both mills. The following figures show the silo level simulation results:



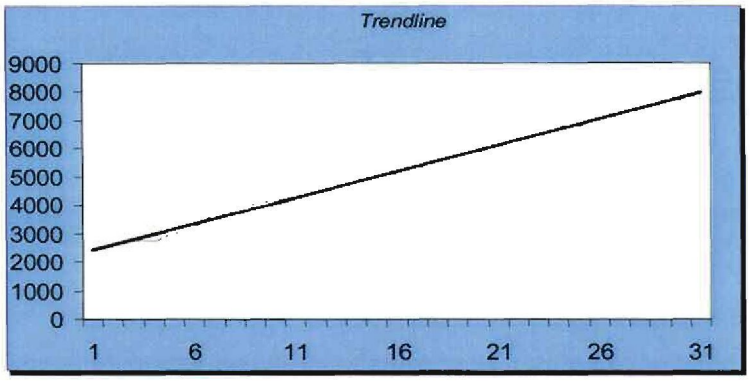


Figure 107: Silo level simulation results for Mill 1at Gold Plant 3

For Mill 2, the following results were obtained:

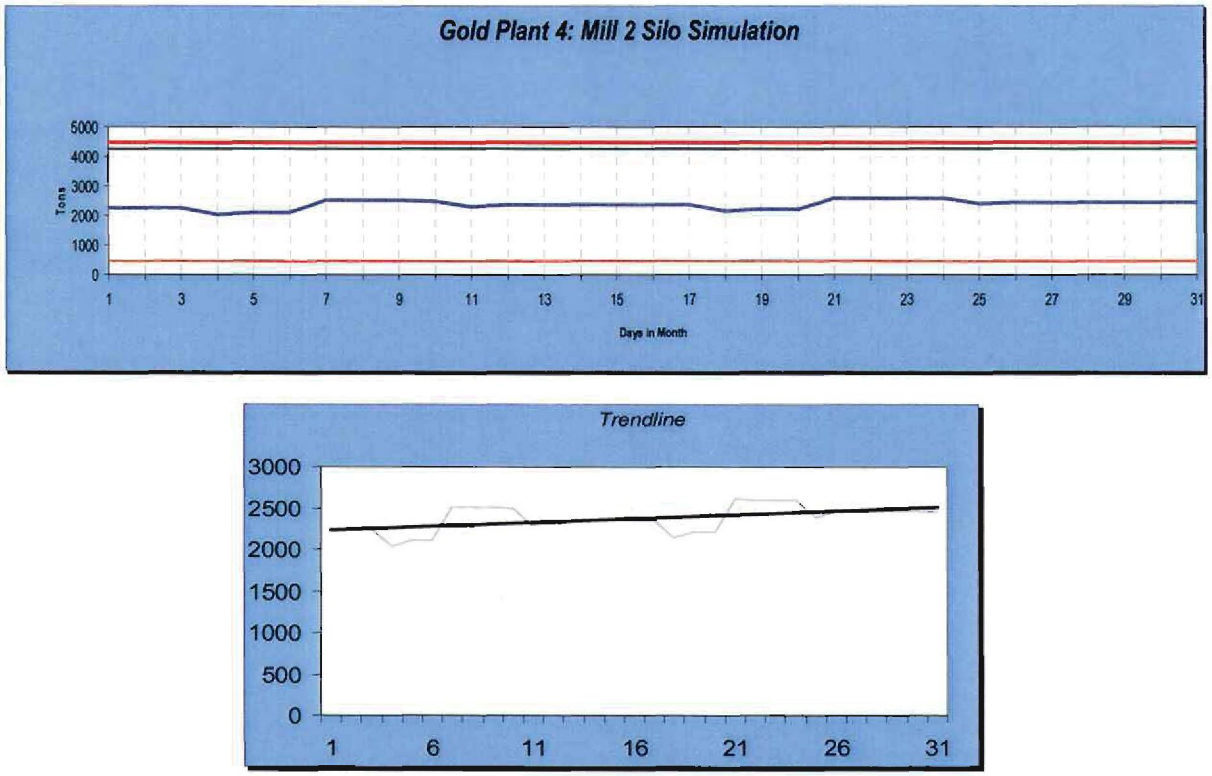


Figure 108: Silo level simulation results for Mill 2 at Gold Plant 3

The results for Mill 1 show that the silo gets full after a few days, and it is not possible to keep the silo level constant. This is due to a recent increase in the tons coming from the shaft, as well as some unexpected breakdowns on the mill. In order to give the mill time to catch up, the shaft throws the ore on a stockpile next to the silo in order to keep the shaft running.

The results for Mill 2 show that it was possible to keep the silo level relatively constant. It was even possible to perform some load shift on this mill. The reason why it is possible to perform

load shift on this mill, is because it has a higher throughput than Mill 1, as well as a higher reliability. The following section provides the load shift results.

5.4.6 LOAD SHIFT AND ENERGY COST SAVING RESULTS

The simulations determined that it is not possible to shift load on Mill 1 with the current production and breakdown figures. The following figure shows the optimised milling schedule without the load shift:

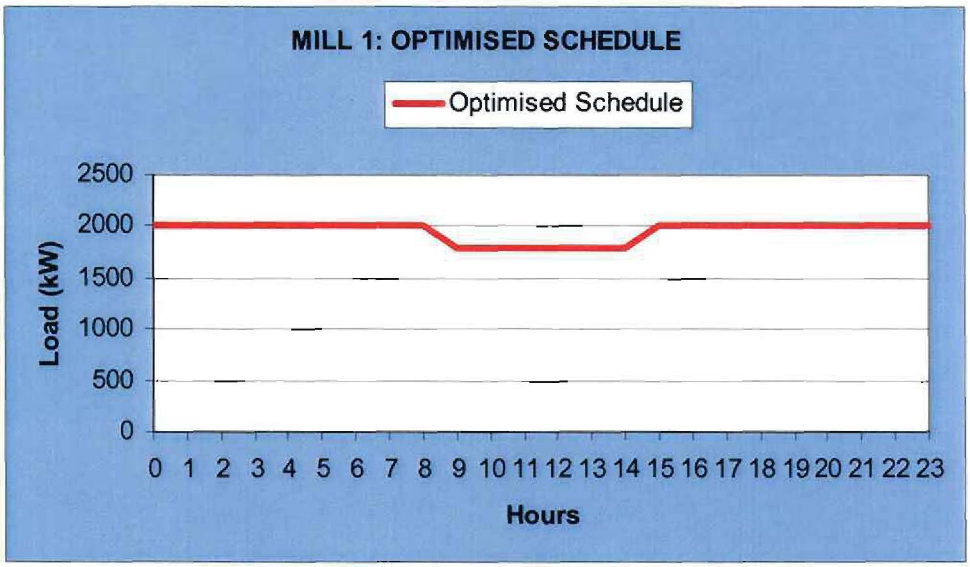


Figure 109: Simulated optimised milling schedule for Mill 1 at Gold Plant 3

According to the simulation for Mill 2, it is possible to perform one hour of load shift on this mill during most weekdays. The only exceptions are the days when planned maintenance is performed. This is shown in the following milling schedule simulation:

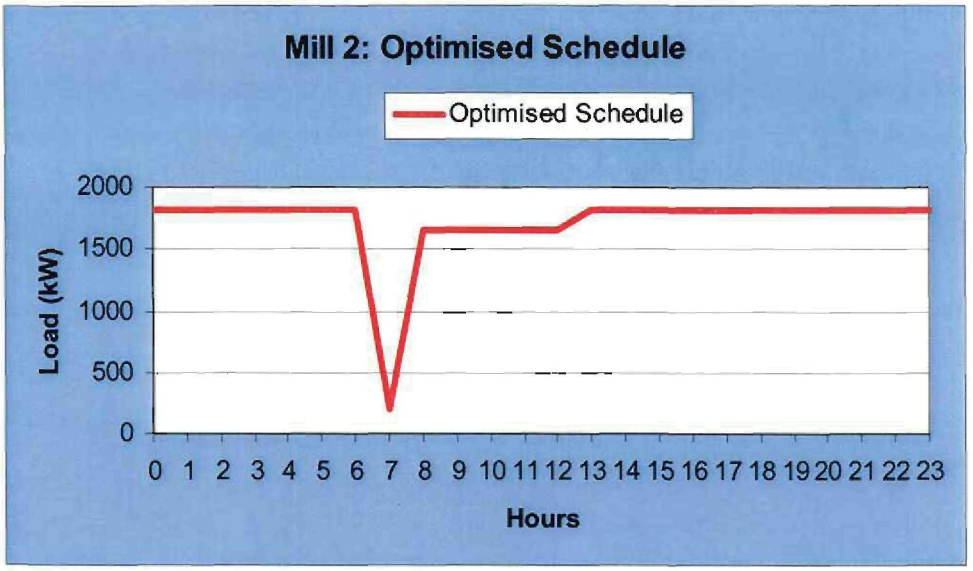


Figure 110: Optimised milling schedule for Mill 2 at Gold Plant 3

No baseline could be calculated for this mill, either due to a lack of historic plant data. As such, only the optimised milling schedule is shown in *Figure 110*.

5.4.7 DISCUSSION OF RESULTS

Gold Plant 3 shows that even though two mills may seem to be of the same design, each mill may have unique peculiarities that may turn a possible load shift candidate into one on which no load shift is possible. It may therefore be necessary to examine each mill on its own merit.

5.5 GOLD PLANT 4

5.5.1 INTRODUCTION

Gold Plant 4 is situated near the town of Welkom in the Free State province of South Africa. It is a plant from the Harmony Gold group. This plant has six mills and is one of the largest gold plants in South Africa. Currently this plant receives reef from seven shafts in the Welkom area.

5.5.2 ELECTRICAL CAPACITIES OF THE MILLS

The plant has a total of six mills installed. Each of these mills has an installed motor capacity of 3.3 MW. The running capacities are approximately 1.98 MW per mill. The following table shows the possible maximum load shift potential for Gold Plant 4:

Gold Plant 4		
Mill	Installed Capacity (kW)	Running Capacity (kW)
Mill 1	3,300	1,980
Mill 2	3,300	1,980
Mill 3	3,300	1,980
Mill 4	3,300	1,980
Mill 5	3,300	1,980
Mill 6	3,300	1,980
TOTAL	**19,800**	**11,880**

Table 49: Installed vs running capacities of the mills at Gold Plant 4

From this table it can be concluded that the maximum possible saving that can be achieved at Gold Plant 4 is 11,88 MW under any circumstances. This is the sum of the total running capacities of the six mills. This value should be kept in mind when calculating the load shift for the mills.

5.5.3 ELECTRICAL BASELINE OF THE MILLS

During the visit to this plant, it was possible to retrieve historical data from the SCADA system. This plant has a very sophisticated control room from which the whole process can be controlled very accurately. Three months worth of historical data was gathered and the baselines were calculated for each mill. It was expected that the usage of this plant would be very high due to the large amount of ore being sent to it for processing from the seven shafts. The historical data proved this to be correct, and it can be seen in the baselines shown in the following figures:

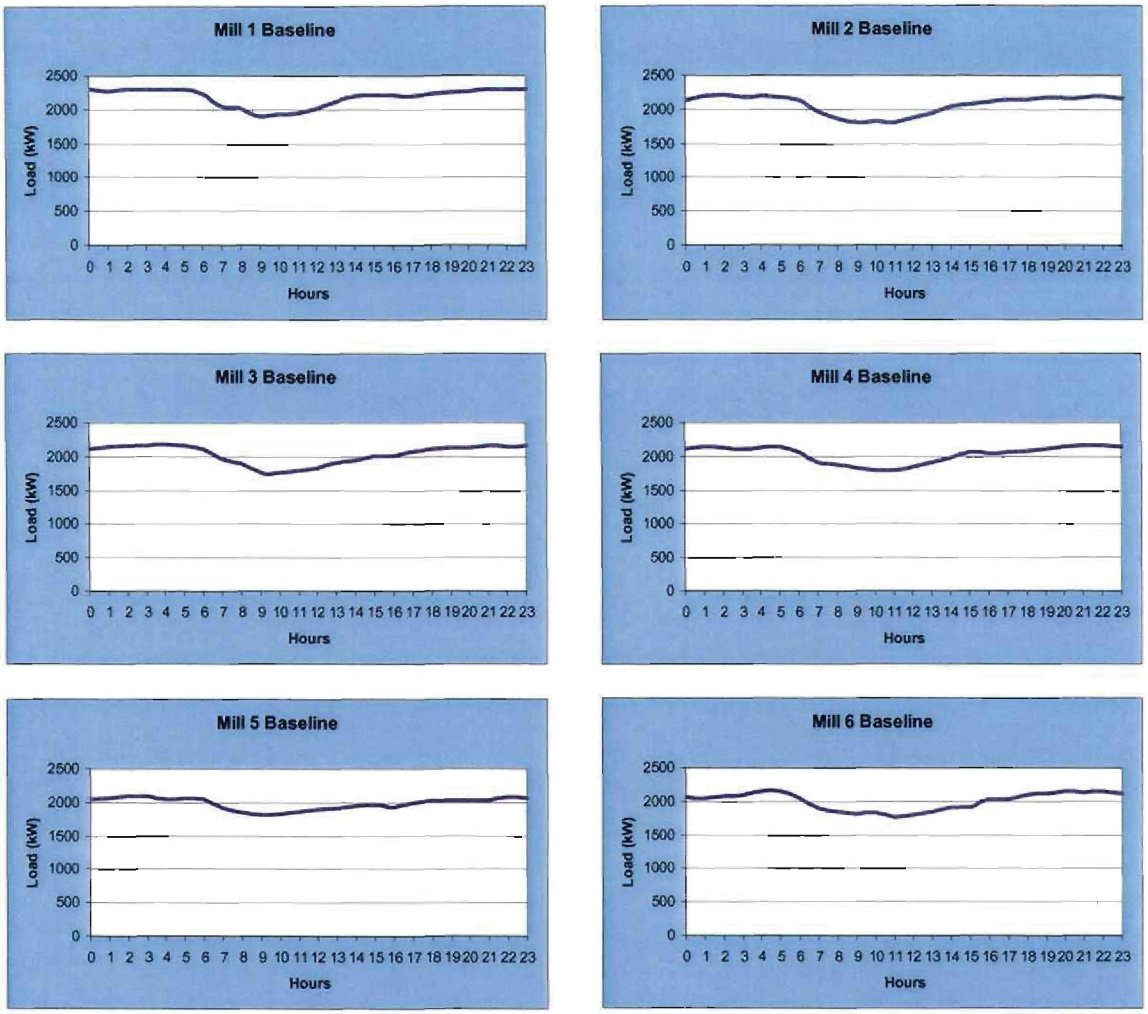


Figure 111: Baselines of the six mills at Gold Plant 4

The simulation model was run on all six of the mills, and the results are provided in the following sections.

5.5.4 PRODUCTION DETAILS OF THE MILLING CIRCUIT

In order to create a starting point for the simulation, the current production details were used as inputs to the simulation. The following table provides the production details of the typical mill at Gold Plant 4:

Gold Plant 4: Production Details	
Mill Production	110 t/h
Silo Capacity	6,056 t
Ore Reception on Weekdays	2,595 t/d
Ore Reception on Saturdays	2,264 t/d
Ore Reception on Sundays	1,805 t/d
Planned Maintenance	6 Hours once a month
Average Daily Breakdowns	1 h
Running Hours on Saturday	23 h
Running Hours on Sunday	23 h

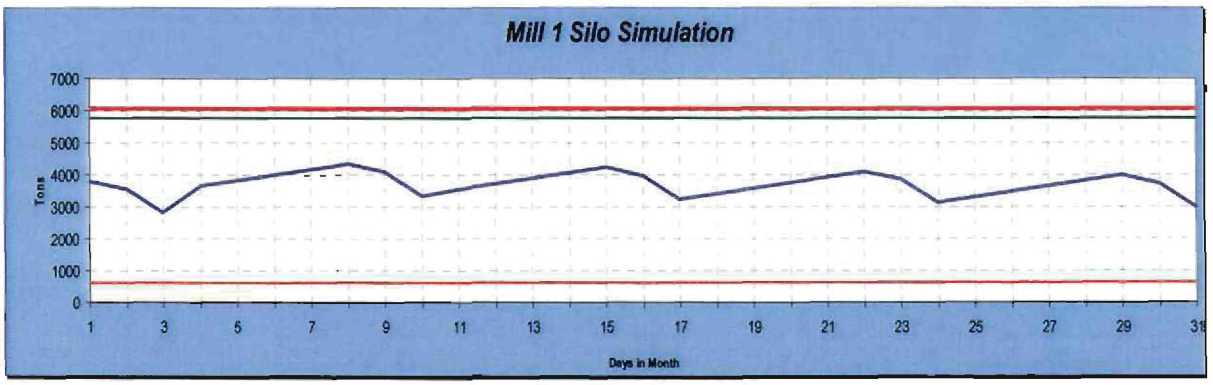
Table 50: Production details for Gold Plant 4

5.5.5 RESULTS OF THE SILO LEVEL SIMULATION

The above production details were used to simulate the load shift on all the mills at the plant. On this plant, the simulation was done a bit differently - the load shift was simulated to be in the evening peak period, instead of the morning peak. This is to satisfy the needs of Eskom DSM in terms of their problem with high demand in the evening peak.

During the visit to this plant, it was found that the ore from the shafts are distributed evenly among all the mills. The set points are the same for all the mills and the motor capacities are all the same. In order to simplify the milling process, the plant controls all the mills in a similar fashion. Since none of the mills have specific ailments that constantly plague them, this control strategy results in very similar production and electricity usage profiles. The baselines in *Figure 107* show the similarities between the six mills.

Because of the similar simulation inputs for all the mills, it can be expected that the simulation results will be similar for all the mills. As such only one set of silo level simulation results are given here. Once again, the simulation was set up in such a way as to try and keep the silo levels constant. The following silo level results were simulated for the mills:



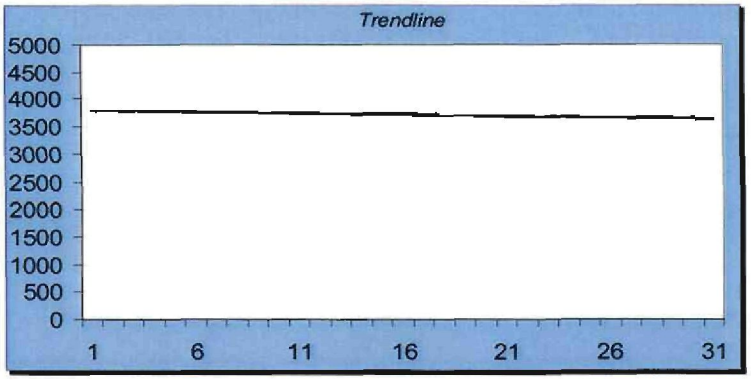


Figure 112: Silo level simulation results for Mill 1 at Gold Plant 4

As can be seen from the above figures, the simulation shows that the silo levels should stay constant with the implementation of load shift on the mills. The most prominent differences between the mills are evident when the optimised milling schedules are compared to the baselines of each mill. The following section is devoted to providing and describing the load shift that resulted from the different simulations.

5.5.6 LOAD SHIFT AND ENERGY COST SAVING RESULTS

Due to the high production figures that need to be maintained by the plant, the scope for load shift on the mills is reduced. In order to keep the silo levels as constant as possible, it was only possible to perform one hour of load shift per mill each weekday. This reduces the savings considerably in terms of DSM. It also means that should a situation arise where one of the mills has a somewhat prolonged breakdown, the load shift will not be possible on that mill. The following figures show the optimised profiles compared to the baselines for each mill:

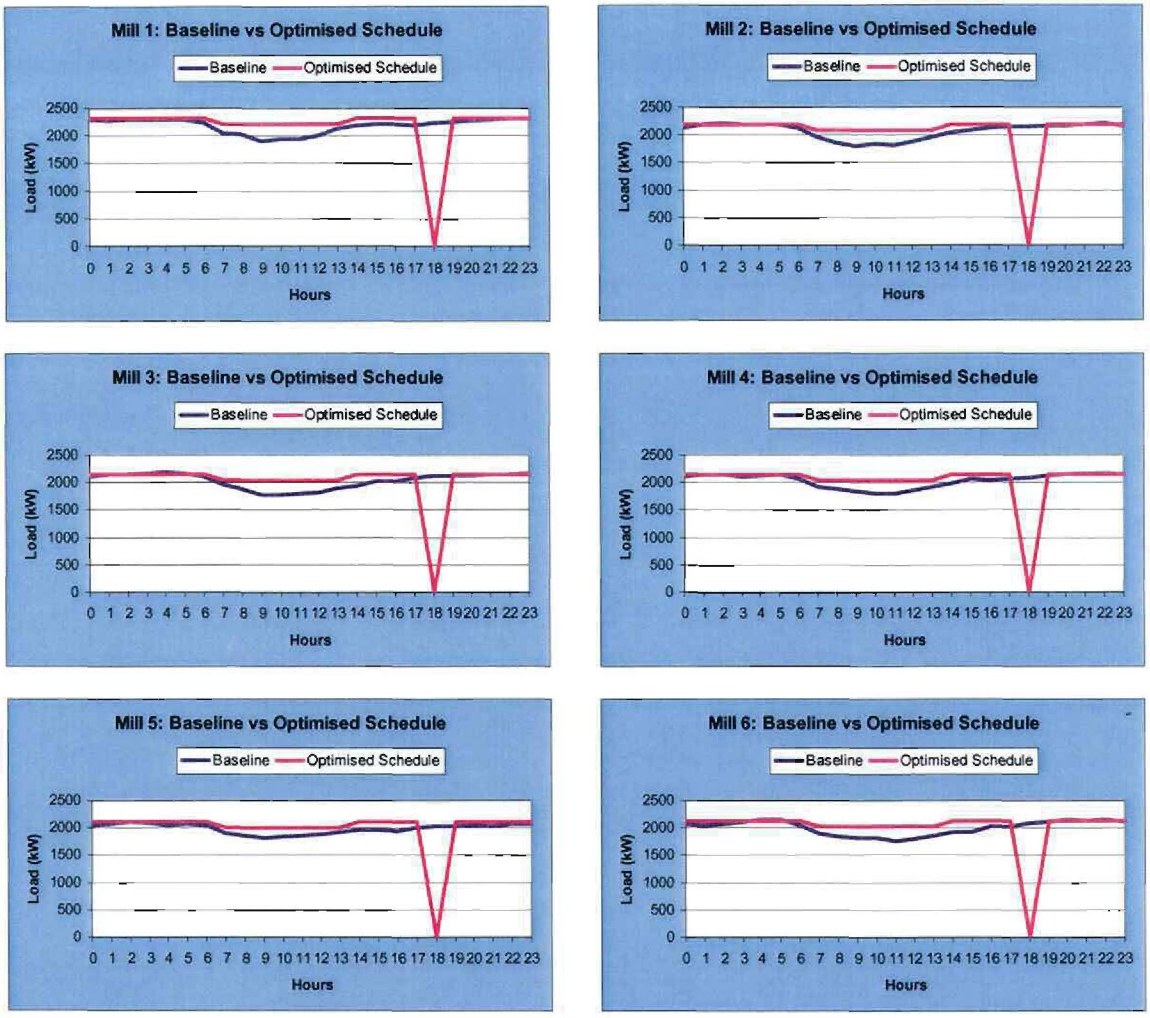


Figure 113: Baselines vs optimised milling schedules for the six mills at Gold Plant 4

It can be seen from the above figures that only one hour of load shift is possible per mill per day. This hour was simulated to be in the evening peak. The savings resulting from this plant are summarised in the following table:

Mill	Morning Load Shift (kW)	Evening Load Shift (kW)	Electricity Cost Saving (R/annum)
Mill 1	0	1,085	R 64,776
Mill 2	0	1,064	R 62,940
Mill 3	0	1,045	R 64,212
Mill 4	0	1,025	R 65,236
Mill 5	0	977	R 65,971
Mill 6	0	1,045	R 67,409
Total	**0**	**6,241**	**R 390,544**

Table 51: Summary of the savings obtained on the six mills of Gold Plant 4

5.5.7 DISCUSSION OF RESULTS

From the results of this plant it can be concluded that a plant with a high production figure to meet will have a reduced chance of performing load shift on the milling circuit. The reason for this is because the mills are needed almost continuously to process the ore from all seven shafts.

It can also be said that one hour of load shift is too small to be sustainable, since a small reduction in the availability of the mill will result in the load shift being removed from the daily milling schedule to make room for production. More load shift can possibly be achieved if larger mills are installed, or if the storage capacities are increased by adding another silo for example.

5.6 CONCLUSION

Since the accuracy of the simulation model has been proven in Chapter 4, this chapter has been devoted to implementing the simulation on some actual gold plants to determine if it is possible to perform load shift on the milling circuits. Four gold plants throughout South Africa were chosen and the following varying sets of results were obtained:

- Gold Plant 1: 2 Hours of load shift could be performed in the morning peaks
- Gold Plant 2: No load shift could be performed
- Gold Plant 3: No load shift on one mill, and limited load shift on the other mill
- Gold Plant 4: Limited to 1 hour of load shift during the evening peak

These varying results on the four different plants show that it is not safe to assume that load shift is possible on the mills of all plants. Sometimes there are issues on a specific plant that only plague some of the mills. Sometimes the production has been increased, leaving no space for load shift on a plant where plenty of spare time was available before. It might even be true that a mill which might be able to shift load under normal circumstances, might struggle to keep up in some months due to unexpected maintenance problems.

It can therefore be concluded from this chapter that each mill of each plant needs to be examined on its own merit in terms of load shift. It can also be concluded that the simulation is a valuable tool in determining which mills are suitable for load shift in a very short period of time. The simulation has passed the test in terms of usefulness during DSM audits on gold plants.

CHAPTER 6

APPLICATION OF THE NEW METHODOLOGY AND SIMULATION MODEL IN OTHER INDUSTRIES

6.1 INTRODUCTION

Chapters 3 and 4 have been devoted to developing and proving new simulation procedures for load shift on CIP gold plants. Chapter 5 has shown how the simulation model can be used to predict the viability of load shift on a particular gold plant. During the research for this thesis it became clear that the simulation model might be used in the same or slightly altered form to predict load shift on similar types of plants in other industries. Some research has been done to substantiate these claims.

6.2 OTHER INDUSTRIES THAT MIGHT BENEFIT FROM THE SIMULATION MODEL AND PROCEDURES

Typical industries that might benefit from the simulation procedures developed during this research would have plants of similar design to those used in gold extraction. There needs to be a milling circuit with suitable storage capacity as well. Two industries have been identified to that purpose, namely the cement and chrome industry. Both have a number of production plants in South Africa. The reasons why these plants might benefit from the research are the following:

- Both types of plants have large cylindrical mills.
- The general layout of the plants is similar but not identical to a gold plant.
- Both types of plants are energy intensive and use large amounts of electricity in their production cycles.
- There are storage facilities comprising of silos, which is a prerequisite for load shift.
- Principles and practices learned from gold plants can be helpful in performing load shift in these industries.

As part of this research the simulation model was slightly modified to make it useful for load shift predictions on cement plants and chrome pelletizers. The following sections are devoted to describing the expansion of the simulation models to include these plants. Some background information is provided on both industries, as well as the layouts of these plants. This is

followed by the application of the simulation model to identify possible load shift opportunities on these plants.

6.3 APPLICATION ON A CEMENT FACTORY

6.3.1 BACKGROUND ON THE INDUSTRY

There are currently 22 cement facilities in South Africa. 10 of these are production plants, while the remaining 12 are milling and blending units. All cement facilities in South Africa produce Portland cement and other blended products like CEM I, CEM II and CEM III. The typical ingredients of Portland cement are Dicalcium Silicate, Tricalcium Silicate, Tricalcium Aluminate and Tetracalcium Alumino-ferrite. Gypsum (Calcium Sulphate) is added to the cement to control the strength and hardening properties of the different types of cement [6.1]

At the time of writing there were four companies that dominated the South African cement industry. These are PPC, Holcim (formerly known as Alpha), Lafarge (formerly known as Blue Circle) and Natal Portland Cement (NPC). Historically, in 2003, the distribution of ownership was as follows [6.1]:

Company	Holding company*
PPC Cement	100% PPC Company (Pty) Ltd (of which 68% is Barloworld owned)
Lafarge SA (Pty) Ltd	100% Lafarge South Africa (Pty) Ltd (part of Lafarge International)
Alpha (Pty) Ltd	54% Holcim, 46% Aveng
Natal Portland Cement	98% Cimentos de Portugal (Cimpor), 2% Employees' Trust Fund
Ash Resources	50% Lafarge SA, 25% Alpha, 25% Roshcon (subsidiary of Eskom)
Slagment	33% Alpha, 33% Lafarge, 33% PPC Cement

Table 52: Breakdown of ownership of cement companies in South Africa

The cement industry in South Africa is currently experiencing a boom, as many civil engineering projects are being completed or planned for the near future. Typical projects completed or under construction include the N4 Bakwena platinum project, Baviaanspoort sewage works, Mohale dam, harbour projects in Durban, Richards Bay and Port Elizabeth, extentions to the Oliver Tambo International airport.

There is also the Gautrain project, which is expected to consume about 300,000 tons of cement between 2005 and 2009. This is in addition to the increased property boom of recent years, and the building of new stadiums for the 2010 soccer world cup. A good indication of the demand

for cement in recent years is that the 2005 per-capita consumption of cement in Gauteng province alone, was rivalled only by that of the European union [6.2][6.3].

6.3.2 PLANT LAYOUT

Before the simulation model is implemented on a cement plant, it might be prudent to first discuss the workings of a typical cement plant. The production process consists of nine basic steps which are discussed as follows:

QUARRYING

Here limestone is extracted from various deposits situated at different locations in the country. The quarry normally has a crushing and screening section that sizes the limestone to minus 19mm before being transported to the plant. The quarry is often situated away from the plant, necessitating the use of transport like trucks or trains. The following figure shows a picture of a quarry on a cement plant:

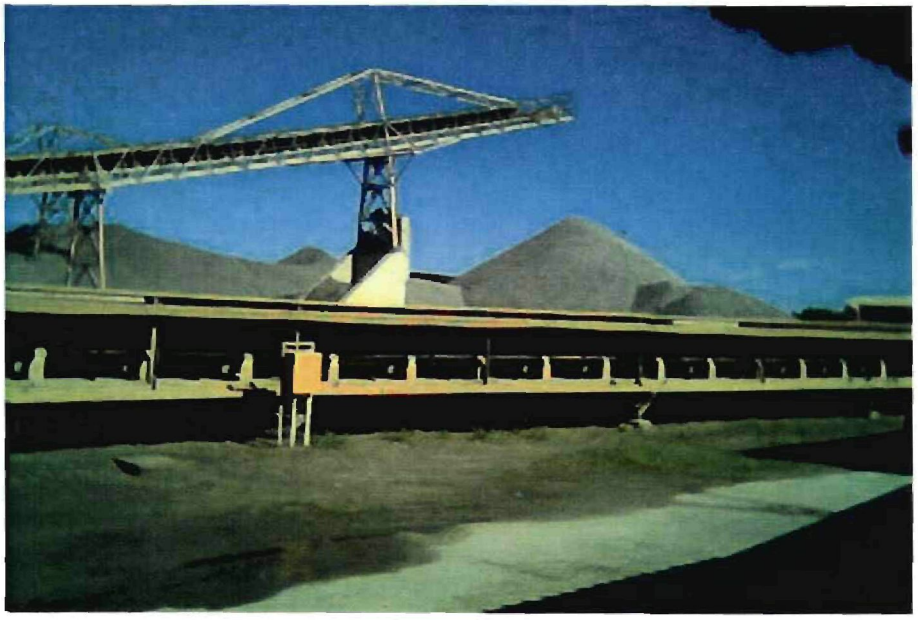


Figure 114: The quarry operations of a cement plant

RAW MILLING

This is the first stage at a production plant, where the raw material is milled to a fine power by means of horizontal mills similar to those on gold plants. Since the material is soft, steel balls are always used in the grinding process. The milling cycle is very similar to the one used on a gold plant, with the following exceptions:

- On a cement plant, the storage silo that needs to be kept within limits comes after the mill. This is different from a gold plant, where the silo is situated in front of the mill.
- Cement milling is a dry process, which means RD control will not be an issue. This allows the cement plant mills to be stopped and started more readily and easily.

The following picture shows a typical ball mill as found on a cement plant:



Figure 115: Typical raw mill on a cement plant showing the author for relative size

BLENDING

Even though the material is dry, it still needs to be blended with other materials in order to obtain the properties required by the specific end products. This blending is achieved automatically according to chemistry before transferring the material to the blending silo, also known as the raw mill silo. This is also the same silo that might be used for storage of material during a possible load shift application. A typical blending silo is shown in the following figure:

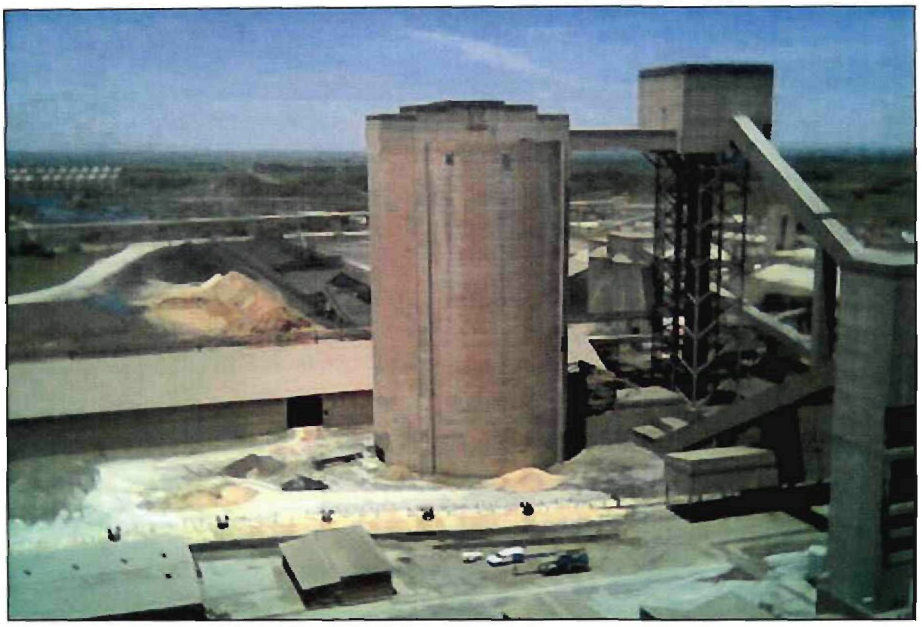


Figure 116: Typical silo found on a cement plant

CLINKER PRODUCTION

In this step, the material is transferred from the raw mill silo to the pre-heating tower. This heats the material to a temperature of approximately 900-1,000 °C before it enters the rotary kiln. The kiln consists of a long rotating cylinder set at an angle to allow the material to transfer.

A coal-fired flame is introduced at approximately 1,500 °C, at one end of the kiln. This added heat allows the powdered material inside the kilns to form clinker. This is the basic form of cement, and is usually easy to spot as they appear as hard, grey spherical nodules approximately 0.3 to 5 cm in diameter. A picture of the rotary kiln is shown in the following figure:



Figure 117: The rotary kiln as seen from the exit end

COOLING OF THE CLINKER

Different methods are used to cool the clinker as it exits from the kiln, of which the most popular methods employ grate coolers or planetary coolers on the older kilns. The clinker is typically red hot as it exits the kiln and it needs to be cooled down before it can be transported by special conveyor belts to the clinker silos. Proper cooling also preserves correct product qualities in the clinker. In the following figure, the planetary coolers can be seen as the small cylindrical shapes circumventing the kiln body at the top of the picture:

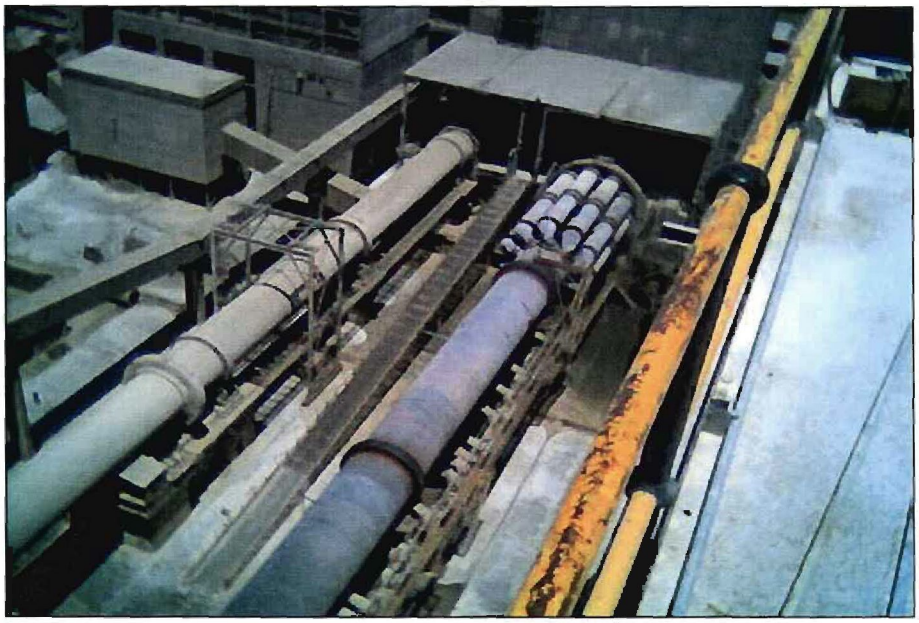


Figure 118: Planetary coolers on a rotary kiln

CLINKER STORAGE

Special clinker storage silos can be found on all cement facilities. As the clinker is the basic product from which cement is produced, plants normally store a few weeks worth of production in these silos. Some facilities don't have kilns and raw mills and they only use clinker from other facilities to make the final cement products. The following picture shows the clinker silos. They can be easily identified by their angled roofs:



Figure 119: Clinker silos on a cement plant

FINISH MILLING

This is one of the final stages in the cement making process. A mill is used, similar to the raw mill. The clinker is ground to a fine powder by this mill. The finishing mills are of the same design as the raw mills. As such, no picture of them is provided here.

ADVANCED BLENDING

Just before or after the finishing mill stage, various additives are added to the clinker powder to obtain various properties in the final cement product. The most prominent of these additives is gypsum, as it controls the initial reaction of the cement powder with water and controls the setting time for the cement [6.4]. This is how cement of different setting times can be obtained from the same clinker. The final cement product is transported from here to cement storage silos.

PACKING AND LOADING

Most cement facilities have a packing plant. This is usually highly mechanised and the cement from the cement storage silos is packed into the 50 kg bags, stacked on pallets and shrink wrapped with plastic, all with minimal human intervention. Bulk loading of cement into trucks is performed directly from the storage silos to the vehicles.

6.3.3 APPLYING THE SIMULATION

In order to apply the simulation on a cement plant, the differences between cement and gold plants had to be taken into account, and the simulation changed to reflect these differences. Since a cement plant production line has at least two mills in different sections of the plant, namely the raw mill and the finishing mill, it is necessary to decide which mill to use for load shift.

Some previous studies have been done on the viability of load shift on a cement plant [6.5]. The research done has shown that it is possible to perform load shift on the raw mill of a cement plant. The reason why the finishing mills were not included in the study was because stopping them had a direct impact on the production of the plant. The management of the plant was unwilling to perform load shift on the finishing mills in the current climate of high cement demand.

Since the main focus of this study was not the cement industry, it was decided that this chapter will also focus on the raw mills only in terms of load shift. Since some other research on cement plant DSM are currently under way using an adaptation of the simulation model developed by the author of this thesis, the main purpose is just to illustrate that the simulation model can easily be adapted to other industries.

In order to demonstrate the basic differences between gold and cement plants, a simple diagram has been created to illustrate the basic differences between the milling circuits of gold and cement plants. This is shown in the following figure:

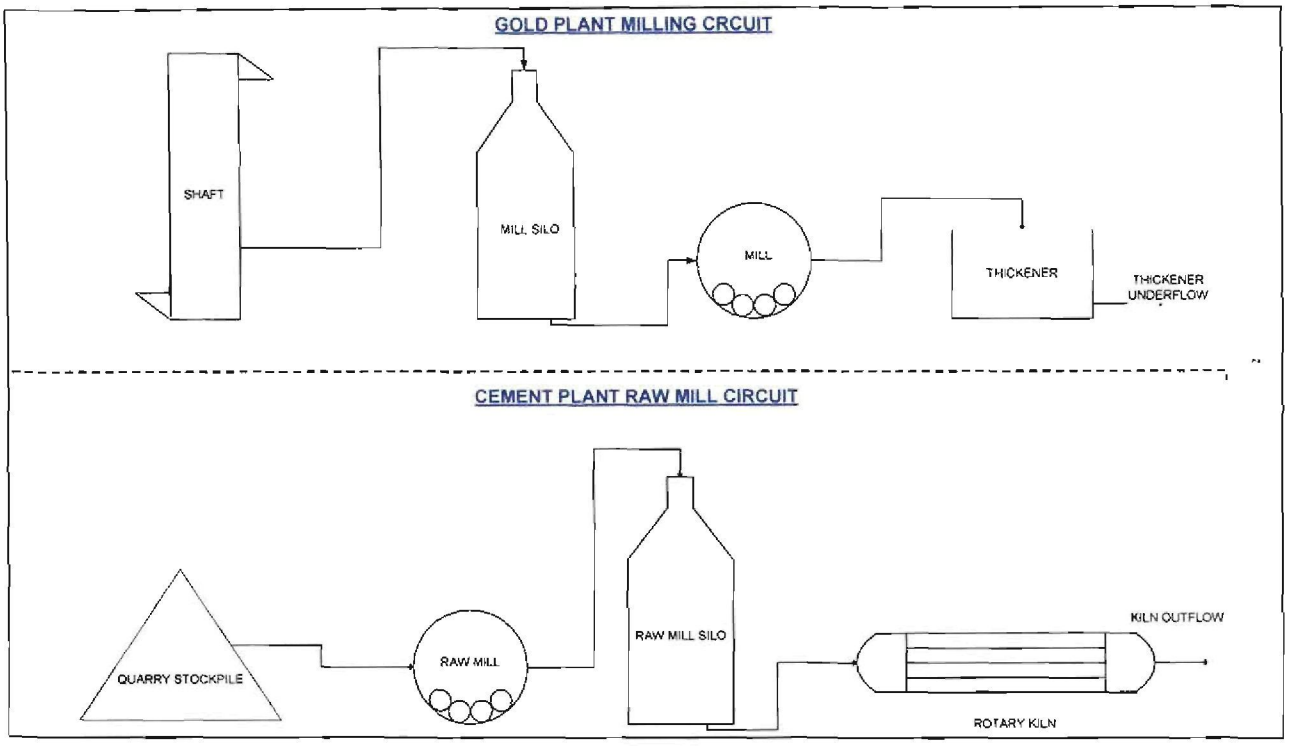


Figure 120: Basic differences between the milling circuits of a gold and cement plant

As can be seen from the figure, the two milling circuits are almost the same. The following differences will have an effect on the simulation model:

- Gold milling is a wet process, while cement milling is a dry process.
- On a gold plant, the mill comes after the silo, while on a cement plant; the mill comes before the silo.
- On a gold plant, a stopped mill will result in a full silo, while on a cement plant; a stopped mill will result in an empty mill.
- On a gold plant the cycle of tons received from the plant is important, while on a cement plant, the material is fed from the quarry in a continuous stream.
- On a gold plant, the thickener underflow can be changed to keep the RD constant. On the cement plant, the flow from the silo to the kiln is of a continuous nature.

Since the differences that affect the simulation model are minor, it should be easy to adapt the simulation to the raw mill circuit of a cement plant. The simulation was adapted in such a way as to show similar results as for a gold plant. A cement plant in the Limpopo province of South Africa was used to demonstrate the results. This plant has only one production line, and therefore only one raw mill. The results are discussed in the following section.

6.3.4 SIMULATION RESULTS

The following production details from the plant were used to simulate the load shift on the raw mill:

Cement Plant: Production Details	
Raw Mill Outflow	210 t/h
Kiln Inflow	160 t/h
Silo Capacity	20,000 t
Min Silo Level	60%
Max Silo Level	95%
Planned Maintenance	9 Hours every two weeks
Unplanned Stops	2 Hours per day
Running Hours on Saturday	11.5 h
Running Hours on Sunday	22 h
Availability	77%
Load Shift	2 Hours every weekday

Table 53: Production details for the cement plant

The following baseline was calculated from the historical data gathered from the ENERMAX system at the plant:

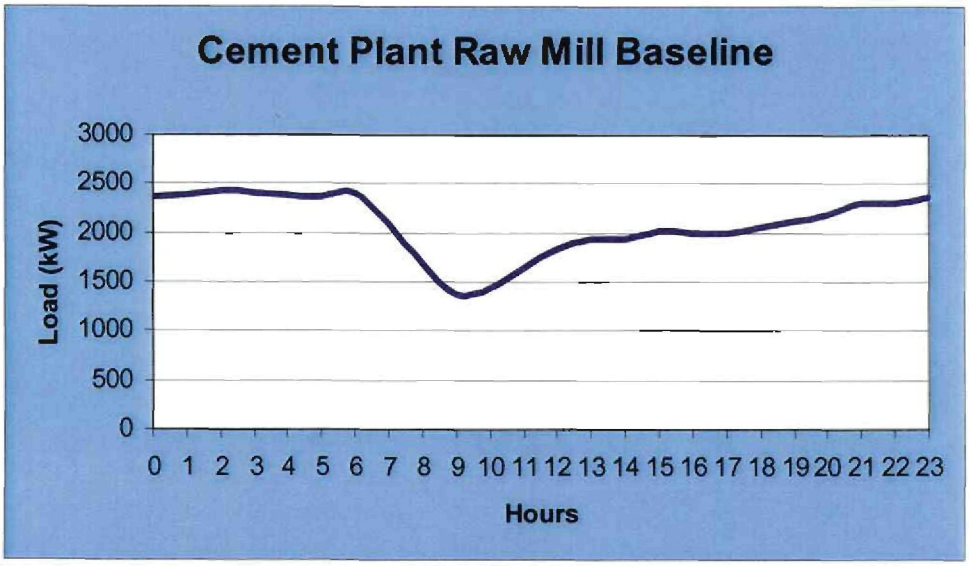


Figure 121: Baseline for the cement plant used in the simulation

The simulation model was implemented on the raw mill using the production details provided in *Table 53*. The simulation resulted in the following silo level results:

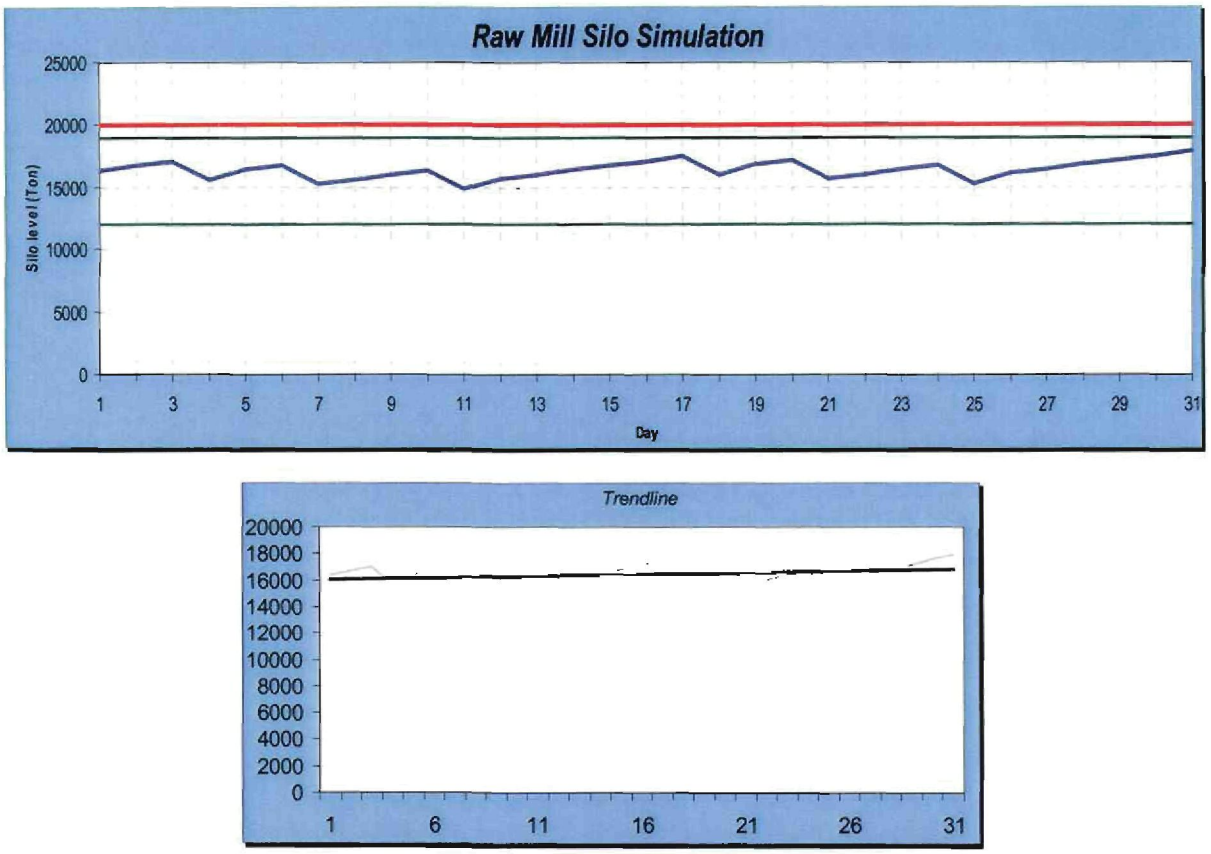


Figure 122: Silo level simulation results for the cement plant

Just as with the gold plant simulation, the purpose was also to try and keep the silo levels constant throughout the month. The results above prove the success of the simulation. In terms of load shift, the road most acceptable to Eskom was chosen for the simulation. This means that the load shift was once again simulated to be performed in the evening peak as in the previous chapter. The load shift was simulated and compared to the baseline to get an energy neutral profile. The results are shown in the following figure:

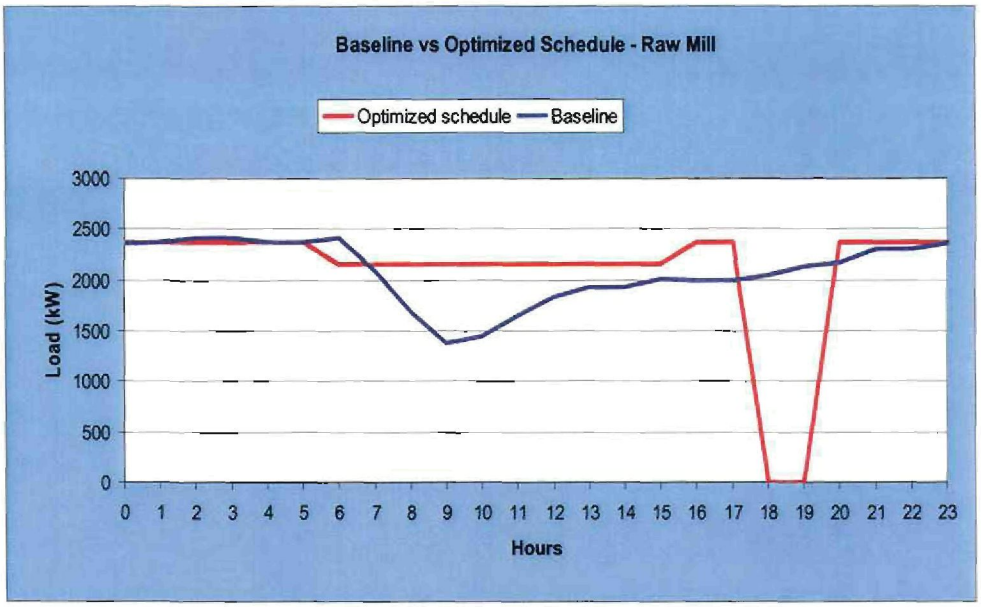


Figure 123: Baseline vs optimised milling schedule resulting from the simulation model

This resulted in the following savings calculated by using the MegaFlex tariff structure:

Mill	Morning Load Shift (kW)	Evening Load Shift (kW)	Electricity Cost Saving (R/annum)
RM 1	0	2,087	R 117,478 p.a.

Table 54: Summary of savings achieved on the cement plant

The results in *Table 54* show that the simulation model predicts a load shift of almost 2.1 MW from the evening peak. This is only on a single raw mill, and might be increased substantially if the production schedule of the plant allows the finishing mill to be put on a load shift schedule as well.

6.3.5 DISCUSSION OF RESULTS

The results obtained from this simulation shows that the simulation can also be used to predict the possible load shift on a cement plant by adapting the model slightly to reflect the milling circuit of a cement plant. Some further research into the use of the simulation model on cement plants may well yield many more load shift opportunities in this industry.

6.4 APPLICATION ON A CHROME PELLETIZER

6.4.1 BACKGROUND ON THE INDUSTRY

South Africa is estimated to hold 72% of the world's chromite reserves. The country is also the world's largest producer of chrome ore according to a 2005 survey [6.6]. The estimated amount is in the order of 5,000 million tons [6.7]. The most commonly utilised form of chrome is in alloy with iron, known as Ferrochrome (FeCr). This Alloy contains approximately 50% to 65% chrome, depending on the use.

Ferrochrome is most commonly used in the production of stainless steel (approximately 80% of the world's production). The Ferrochrome produced in South Africa is known as "Charge Chrome". It is produced from a chrome containing ore with low chrome content [6.8]. Charge chrome contains between 50% and 55% chromium, with approximately 7% taken up by carbon and 4% silicon [6.9]. Various Ferrochrome plants are situated in South Africa, mainly in what is known as the Bushveld complex. The following figure shows the distribution of the various Ferrochrome plants in this area:

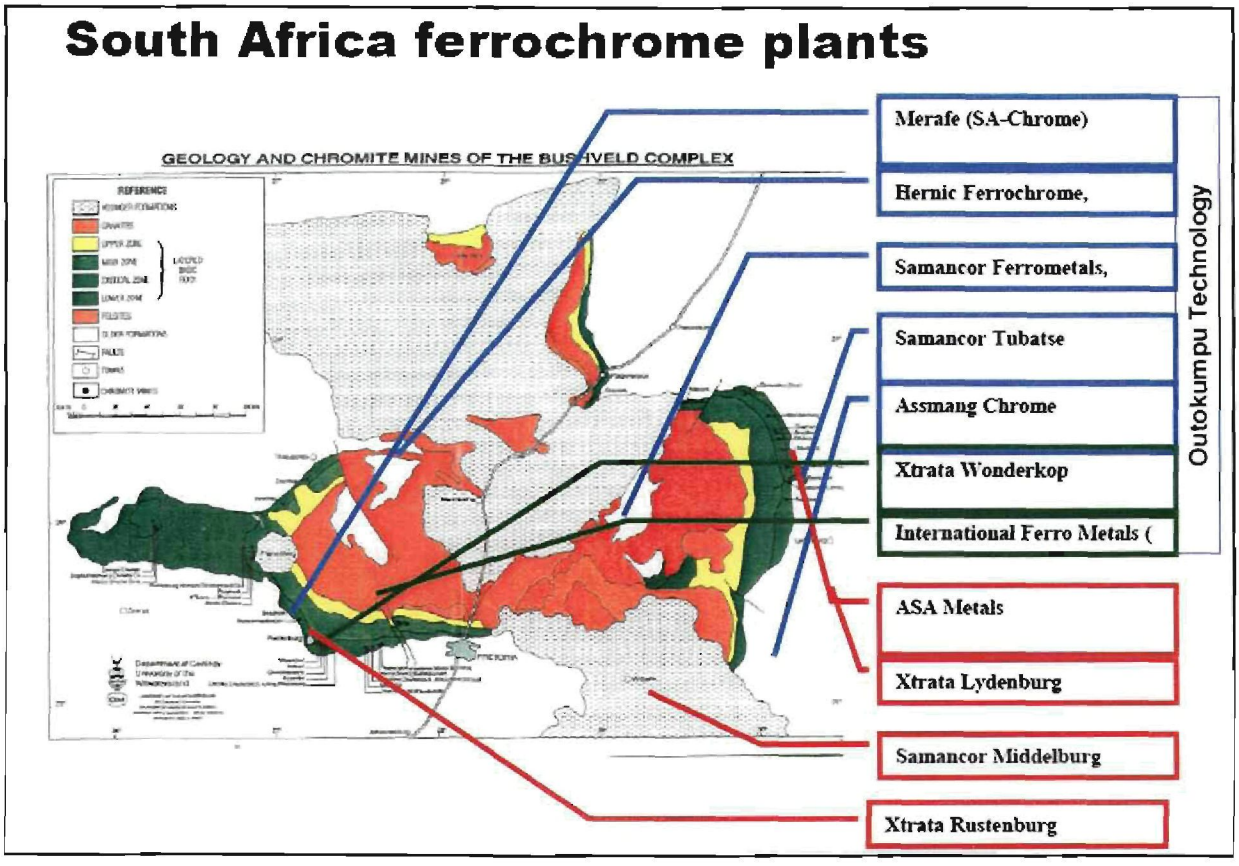


Figure 124: Placement of Chrome facilities in the bushveld complex

Mining of chrome ore in South Africa takes place in both open-cast and underground mines. Typical methods used include conventional scraper mining and mechanised trackless mining. Once the ore has reached the surface, it is crushed to size and beneficiated through dense-medium separation (DMS) plants, similar to those used on coal and diamond mines [6.9].

The separated chrome is now sent to a pelletizing plant. The purpose of this plant is to produce uniform coal pellets that can be sent to the chrome smelters which smelt down the pellets into a more usable form. A pelletizing plant has many similar equipment and layout to a cement plant. As such, the cement simulation model could be used in exactly the same manner on a pelletizing plant as described in the following sections

6.4.2 PELLETIZING PLANT LAYOUT

In order to test the simulation model, a chrome pelletizing plant in the town of Rustenburg was visited during the course of this study. The following figure shows a simplified layout of the pelletizing plant as explained during the visit:

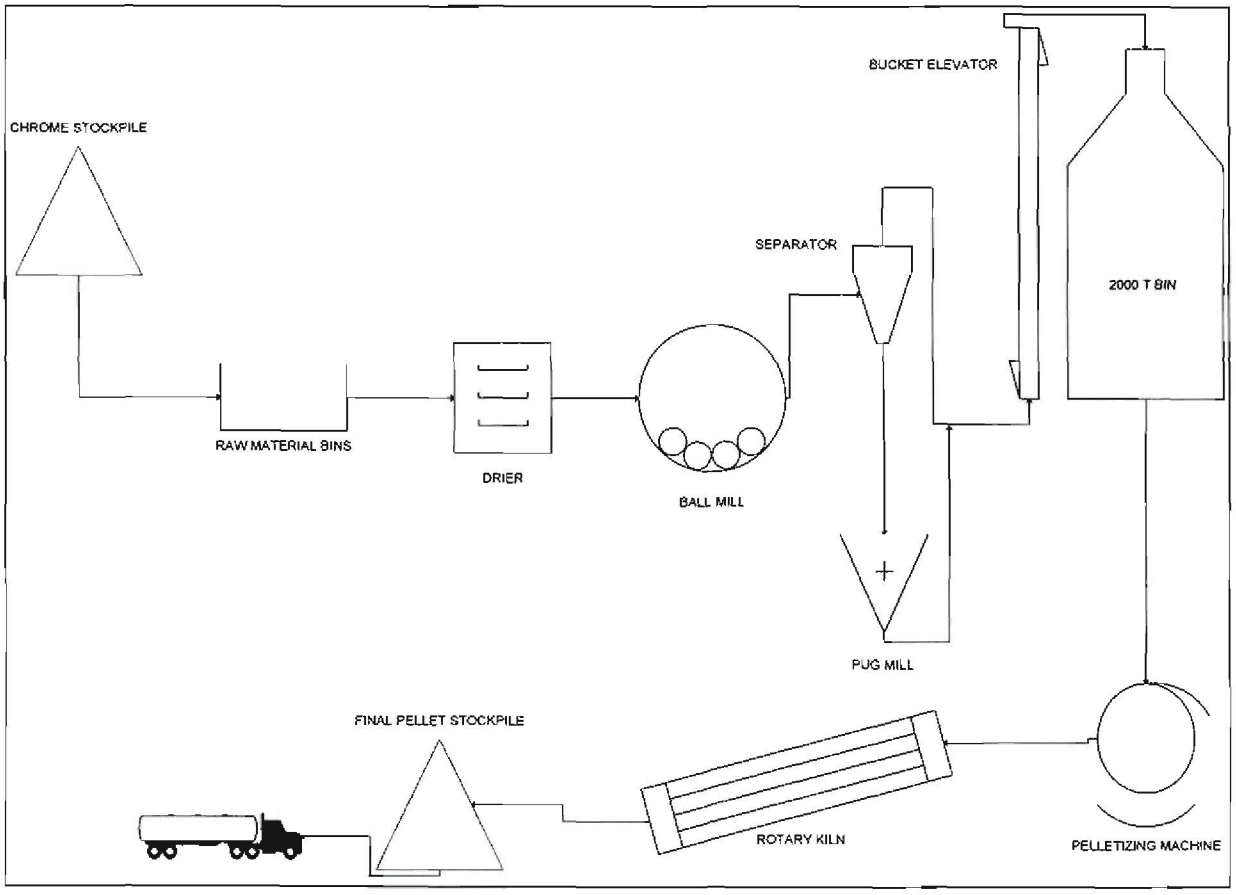


Figure 125: Basic layout of the pelletizing plant visited during the research

If *Figure 125* is studied, it can be seen that there are many similarities between the pelletizing plant and the gold and cement plants. The pelletizer has one or more mills of similar design as those used on the gold and cement plants. There is also a rotary kiln and a silo that can be used as buffer capacity in the event of possible load shift. The plant visited during the research has only one production line as shown above. In the interest of a more informed reader, the process of creating the pellets is described shortly below:

Raw material (Chrome ore) is first transported from the stockpiles by means of front-end loaders and loaded into the raw material bins. Here it is mixed with additives to give it the right composition. The following figure shows a picture of these stockpiles:



Figure 126: Chrome ore on the stockpile at the pelletizing plant

From the raw material bins, the material is sent to a dryer in order to remove any moisture that might have accumulated in the raw material due to mining processes and rain. The dryer operates by blowing the material with hot air created by means of a boiler and fans.

From here, the ore is sent to the ball mill to be ground to minus 75 microns. The milled material is separated according to size. The material of the right size is sent to a storage silo known as the 2000 ton bin on this specific plant. The following picture shows the ball mill at the plant:



Figure 127: Ball mill at the pelletizing plant

Any material that is too large to be sent to the silo is milled again in the pug mill before being sent to the silo. This is mainly a batch process that is run until the silo is full. This is possible because the mill has a large overtaking capacity over the process after the silo. When the silo is full, the mills are stopped until the silo level has dropped again.

From the silo onwards, the process is run on a 24 hour basis. The fine ore is taken from the silo on a continuous basis, it is mixed with water to make putty. Bentonite powder is added to serve as a binding material. This paste is now entered into the pelletizing section which consists of a rotating plate with small lifting fins, known as a pelletizing drum. In the drum the particles form small circular pellets due to the circular motion of the lifting plate. The pellets exiting the drum are screened to make sure they are the right size. Oversized pellets are crushed to be circulated through the milling section [6.9].

The pellets of the correct size are sent to a kiln to undergo a sintering process similar to the clinker forming in a cement plant. The following is a picture of the rotary kiln at the plant:

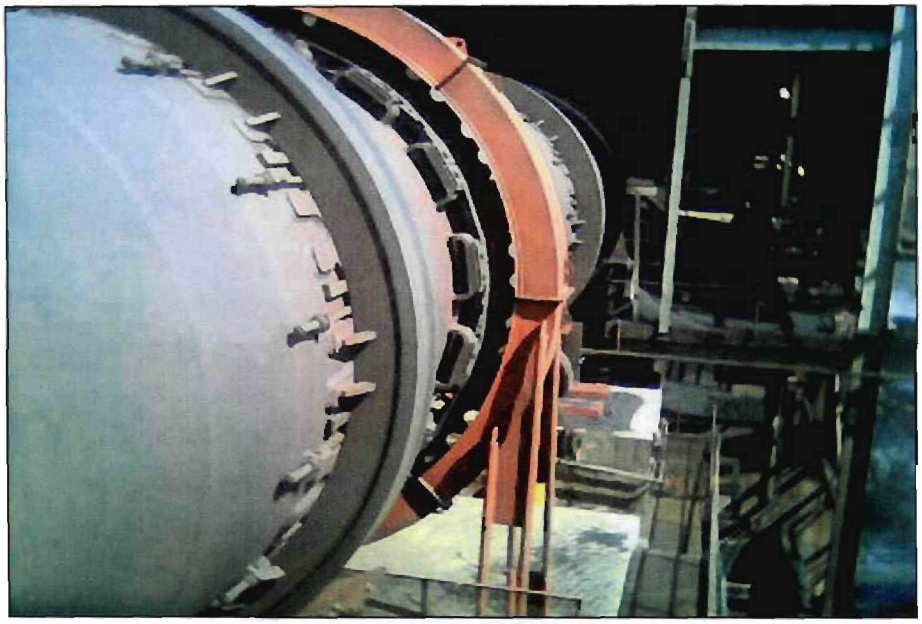


Figure 128: Rotary kiln at the pelletizing plant

These sintered pellets are stored in silos for direct use in smelting furnaces. The following figure shows typical pellets:

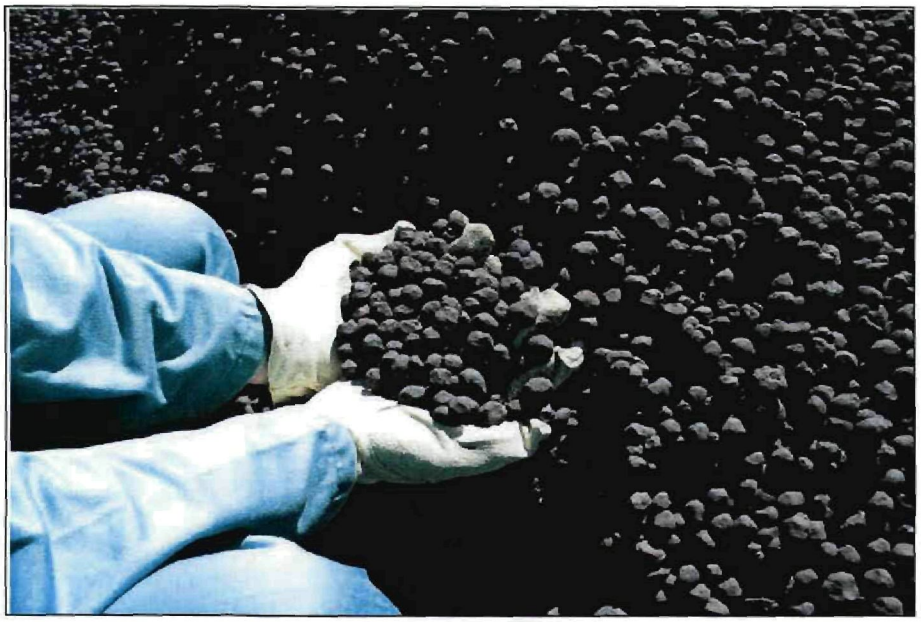


Figure 129: Picture of the chrome pellets as after exiting the kiln

These pellets are stored on a pellet stockpile. From here, they are transported to the smelter plant. In the case of this plant, the smelter plant was situated on the premises next door to minimise transport costs.

6.4.3 APPLYING THE SIMULATION

Considering load shift on the pelletizer plant, it should be straight forward to stop the mill during the peak times. This approach is expected to be very successful, since the mill has a large overtaking capacity over the rest of the plant. The silo can be used for buffer capacity during peak times. Since the plant has to stop in any case to wait for the silo to empty, the extra benefit of DSM savings can be achieved by planning the production schedules in such a way that the mill stops are made during the morning and evening peaks.

This approach should allow the silo level to stay relatively constant while performing load shift during both peak times. There might even be a requirement to stop the mill for more hours to allow the pelletizing section sufficient time to catch up with the mill. The simulation model was almost identical to the one used for the cement plant. This is because the plant layout is similar in terms of equipment. The following section describes how the simulation model was used to predict possible load shift on this plant.

6.4.4 SIMULATION RESULTS

Historical data was gathered from log sheets at the plant and the following baseline was determined for the mill:

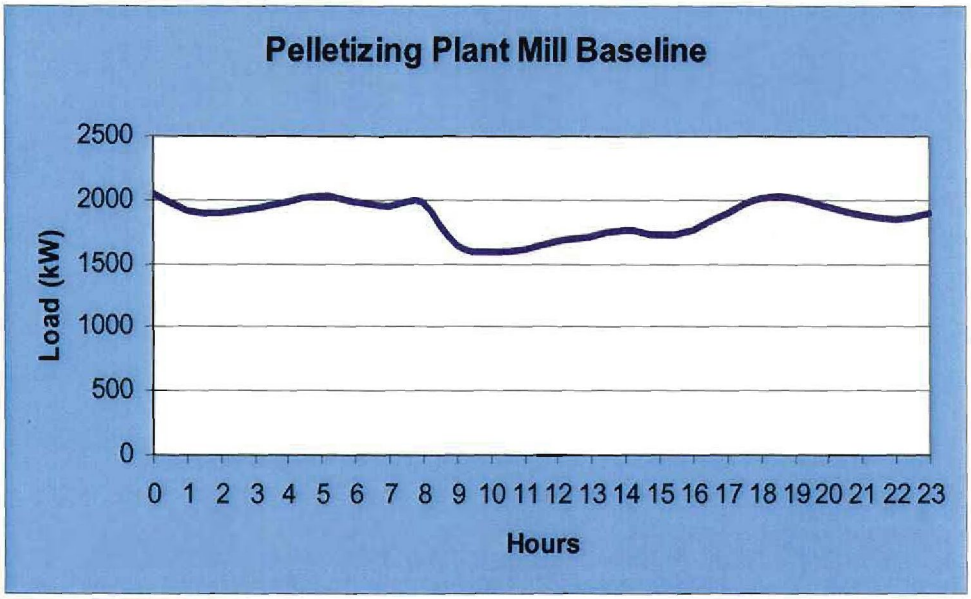


Figure 130: Baseline of the mill on the pelletizing plant

This baseline is quite similar to other baselines of similar mills. Because of this the same constraints were applied to this simulation as with the gold and cement plants. The following production details were used in the simulation:

Pelletizing Plant: Production Details	
Mill Outflow	66 t/h
Silo Outflow to Pelletizing Drum	41 t/h
Silo Capacity	2,000 t
Min Silo Level	30%
Max Silo Level	90%
Planned Maintenance	6 Hours every two weeks
Unplanned Stops	5 Hours per day
Running Hours on Saturday	19 h
Running Hours on Sunday	18.5 h
Availability	62%
Load Shift	5 Hours every weekday

Table 55: Production details of the pelletizing plant

These production details obtained from the simulation show that it should be possible to shift five hours of load every day, and still have five hours left in which to perform any maintenance due to breakdowns. This is because the mill has an overtaking capacity of 25 t/h over the rest of the plant. The following figure shows the silo level simulation results:

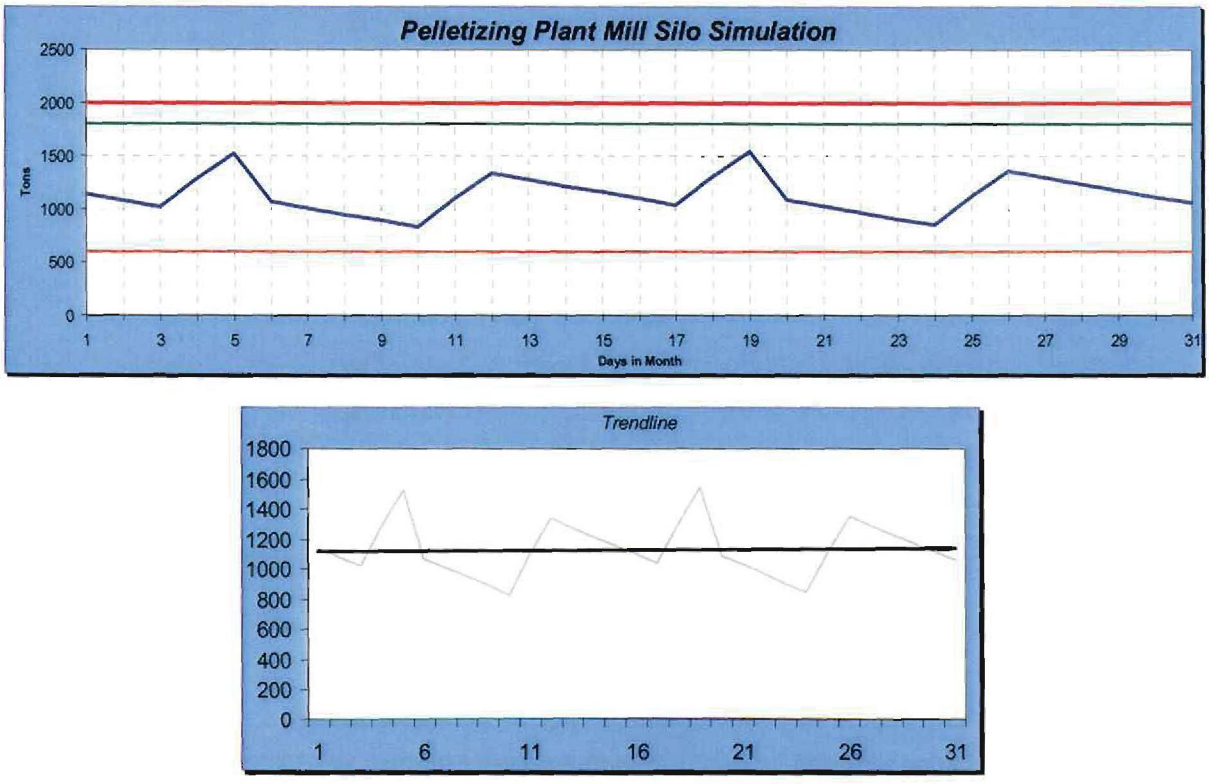


Figure 131: Silo level simulation results for the pelletizing plant

The results show that it should be easy to obtain the maximum load shift on this plant. It is clear that the silo levels are not even close to the constraints specified by the plant management. The following figure shows the optimised milling schedule compared to the baseline:

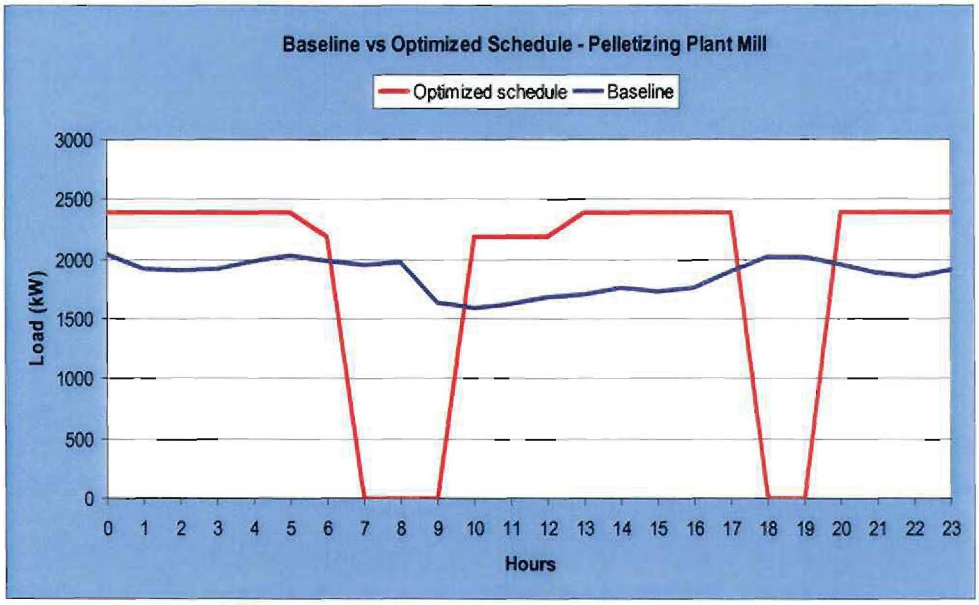


Figure 132: Baseline vs optimised milling schedule resulting from the simulation model

The Optimised schedule above resulted in the following savings:

Mill	Morning Load Shift (kW)	Evening Load Shift (kW)	Electricity Cost Saving (R/annum)
Mill 1	1,855	2,017	R 440,757

Table 56: Summary of the savings that can be achieved on the pelletizing plant

This plant provides a rare opportunity where load shift can be applied in both the morning and evening peak periods. The only concern would be the scheduling of the planned maintenance to fit in with the load shift schedule.

6.4.5 DISCUSSION OF RESULTS

The results obtained from the simulation show that it is definitely possible to perform load shift on a pelletizing plant. It also shows that the simulation is the perfect tool for examining these types of plants. Since this is the only plant visited during the whole duration of the research

that has the possibility of shifting the maximum load, a new discovery has been made in terms of DSM in processing facilities.

If all the pelletizing plants in South Africa have the potential to shift load from their milling circuits, a whole new field of research has been uncovered. Since the main focus of this research was placed on gold plants, this possibility has not been pursued any further than it already has up to this stage. However, it might be important for the DSM program in South Africa if these possibilities are pursued by ESCO's with the intention of performing load shift. The simulation model can be a very helpful tool in the process of evaluating the DSM potential of these plants in future.

6.5 CONCLUSION

By examining the results of this chapter, it can be clearly seen that the simulation model was implemented successfully on both the cement- and chrome pelletizing plant. It can be concluded that the ideas developed during the course of this research regarding DSM on a gold plant, can be expanded to include similar facilities in other industries. The simulation model developed for the mills on the gold plant can be adapted successfully with minor changes, for use on these new facilities.

The conclusion can therefore be made that the ideas and tools developed in this research has much more potential in terms of the DSM program in South Africa than previously realised.

6.6 REFERENCES

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[6.8] "Ferrochrome"; Website: http://www.wikipedia/wiki/Ferrochrome.

[6.9] M. Visser; "*An Overview of the History and Current Operational Facilities of Samancor Chrome*"; Southern African Pyrometallurgy 2006, Edited by R.T. Jones. South African Institute of Mining and Metallurgy, Johannesburg, March 2006.

CHAPTER 7

CONCLUSION

7.1 OVERVIEW AND CONCLUSIONS

The primary objective of this research was to find and develop new DSM opportunities in the precious metals industry. The target facilities were CIP gold plants and Platinum concentrators.

In terms of platinum concentrators, some background was provided on the operations in the different sections of the plant. Different sections that might have possible DSM applications were identified and discussed. DSM procedures were developed for these different sections. It was found that the most probable DSM application would be load shift.

Load shift procedures were developed and applied to the promising sections of the concentrator. It was found that there are unique problems that stand in the way of load shift on platinum concentrators. The largest of these problems were inherent to the design of the concentrator as well as oxidation of the material in question. These are problems that currently plague the operators of concentrators without a clear solution. As such, it can be concluded that load shift is not possible on platinum concentrators.

Because concentrators were found to be unsuitable for load shift, the focus of the research was shifted to CIP gold plants. Just as with the concentrators, the different sections were described in detail and examined in terms of load shift. Sections that showed the most promise are the elution boilers and the milling circuit. The elution boilers were examined in terms of load shift and energy efficiency.

Energy cost comparisons were made between different fuels for the boilers. After calculating the results and discussing the possible impact of the solutions, it was found that electrode boilers are the most energy efficient and cleanest option for use in the elution section. The plant on which the research was done already have these types of boilers installed, as such, they are already equipped for DSM in this regard.

Finally the focus was shifted to the milling circuit of a CIP gold plant. The main equipment that can be used for load shift is the mills. Gold plants typically have cylindrical mills known as SAG mills or ROM mills. Previous studies on DSM in gold plants also identified the milling circuit as the most obvious candidate for load shift. However, these studies never showed how to perform these actions.

This is where the uniqueness of this research plays a major part, since load shift procedures were developed for the mills. Possible savings were calculated and the effects of stopping the mills were examined in terms of the mill itself, as well as the thickeners. This preliminary research showed that it is definitely possible to perform load shift on the milling circuit of the gold plant.

In order to test these procedures, a simulation model was developed. The main purpose of this model was primarily to test the load shift procedures. It was also developed as a tool with which DSM audits can be done on different gold plants. It provides a relatively quick way to determine the viability and magnitude of any possible load shift projects on the milling circuit of a gold plant. The simulation model was tested extensively on an actual gold plant to verify if the results are within acceptable limits. It was found that the simulation model predicts both the normal milling operations, as well as future load shift on the mills within acceptable limits.

As a further use for the simulation model, it was tested by simulating possible future load shift on four other gold plants in South Africa. The results led to interesting conclusions regarding load shift on gold plant milling circuits. It was concluded that not all gold plants have load shift opportunities, even though they are of similar design.

This is also true for mills of the same type, on the same plant. It was also found that load shift on a milling circuit will only be feasible if the production levels are low enough to allow mill stoppages. The circuits might be able to absorb small increases in production without ill effect, but larger increases in production will have a negative impact on load shift.

As a means of expanding the procedures and simulation model, load shift was also simulated on a cement plant and a chrome pelletizing plant using a slightly modified simulation model. Load shift was predicted successfully on both these plants. From this it can be concluded that the procedures and tools developed have a much larger impact on the DSM program than previously expected. In the end, it is concluded that the research was a success.

7.2 LIMITATIONS OF PROCEDURES AND SIMULATIONS DEVELOPED

Because DSM is such a large field of research, it is very difficult to include all the related topics into one research project. Even though there was some reference to energy efficiency in the research, the overwhelming focus of the research was on load shift and its procedures. Some of the limitations of the research are provided below:

- Even though reference was made to various savings opportunities in the different plants, the main focus was still on load shift. The research does not provide substantial energy efficiency procedures and results, except on the boilers used to heat the slurry in the elution columns.

- No practical solutions were offered to the specific problems that plague platinum concentrators with regards to DSM. Alas, this was not the purpose of the research.

- The simulation model developed only focuses on load shift of a milling circuit. Other equipment like crushers and pumps are excluded, even though their capacities are included in the savings when they are stopped by means of interlocks coupled to the mills.

- The simulation model can be more complete in terms of describing the effect of load shift on the whole plant, and not just the milling circuit. Currently it is assumed that no ill effects are suffered in the rest of the plant due to load shift.

- Currently the simulation model uses the mass balance in the milling circuit to simulate the milling circuit. However, it does not calculate the relative densities automatically. This is an important parameter in the successful extraction of gold that must currently be calculated by means of manual methods. This can be automated in further versions of the simulation model.

- Even though one of the contributions of the simulation model is to decrease the complexity of audit procedures on gold plants, some unique problems necessitates a more thorough approach to understanding a specific system.

7.3 RECOMMENDATIONS FOR FURTHER WORK

As this research progressed, it was found that there are quite a few areas that have bearing on DSM in gold plants, but were not originally part of the research. As such, the following list contains some recommendations for further work in the field:

- DSM procedures on mineral processing facilities can be expanded to include energy efficiency and carbon credits.

- Other sections on these plants, like compressed air for example, have some potential for DSM savings. These savings can possibly be realised both in terms of load shift and energy efficiency. DSM on compressed air systems can be a whole new field of research.

- It might be possible to change the carbon regeneration section of a gold plant to a more controlled process, in order to perform DSM on the regeneration kilns.

- The simulation model developed can be expanded to include all the other sections of a gold plant, as well as the effect of DSM on these sections.

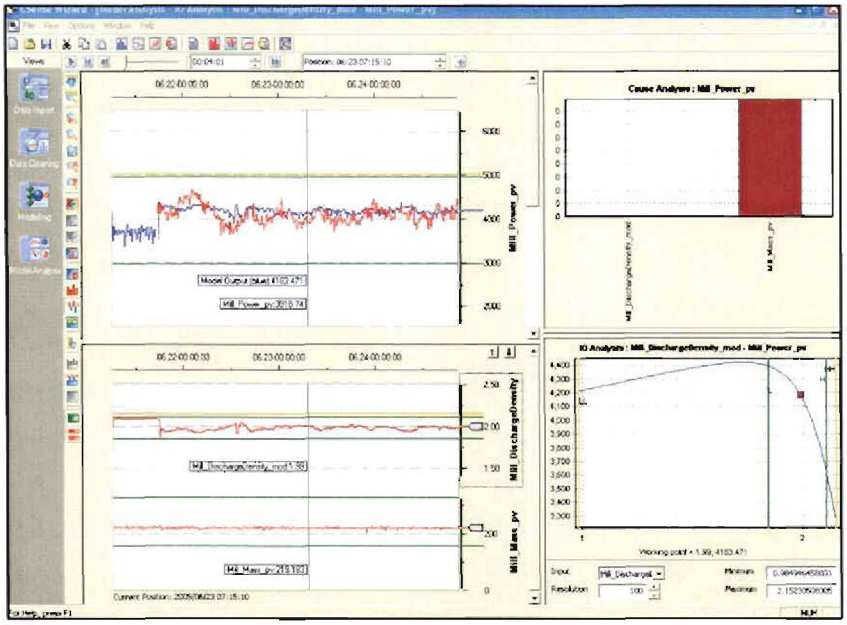
- DSM procedures developed can be expanded to include the whole cement industry, as well as the chrome industry. If research is being done in this area, it is probable that many more types of plants and industries will benefit from the procedures and tools developed in this research. As such, many more opportunities exist for research in this field.

- Solutions can be sought for the design and chemical problems that stand in the way of successful load shift on platinum concentrators.

APPENDIX A

RESULTS OF THE CSENSE MODEL ON THE MILL POWER BY ANGLOGOLD ASHANTI: JUNE 2005

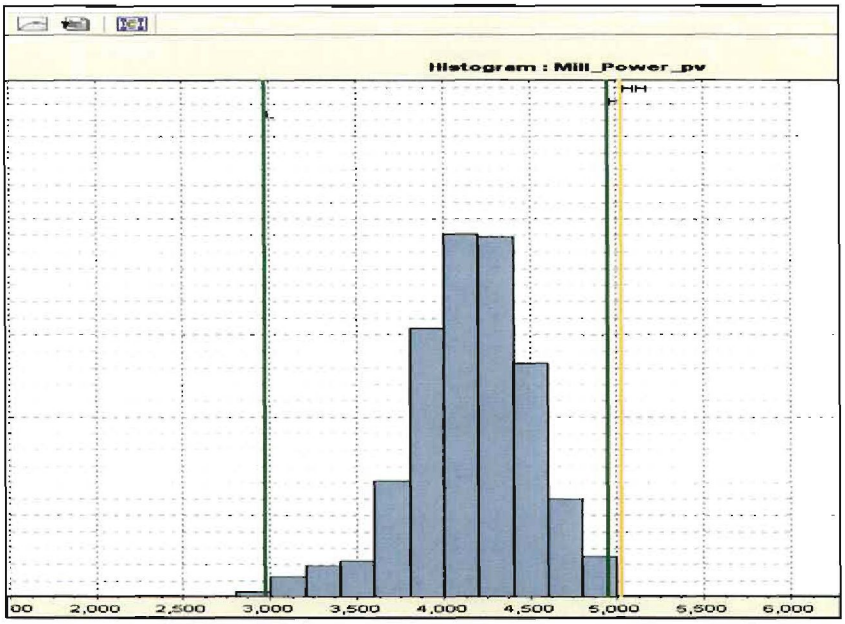
Mill Power as a Function of Mill Mass and Mill Load Density



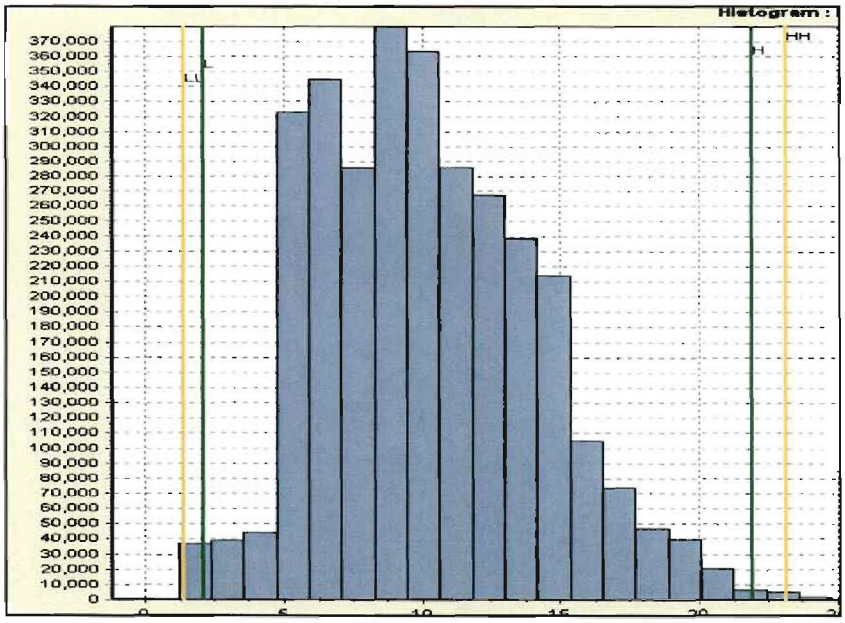
Observations:

- The Csense model produced a very good fit to the power data.
- The cause analysis showed (correctly) that the mill mass has the main influence on power draw, although the mill discharge density proved to have its own strong influence on the power draw. The bottom-right section of the figure above shows that the power reacts sensitively to large increases in the modelled prediction of the mill discharge density. The discharge density value is from the OCS mass balance, and could therefore be producing these high values under mill pulping conditions. The conclusion is simply that the mill does lose power under pulping conditions. A data range for these conditions is therefore available from this model.

- The following figure shows that during the month of June 2005, the power was controlled closely at approximately 4.3 MW



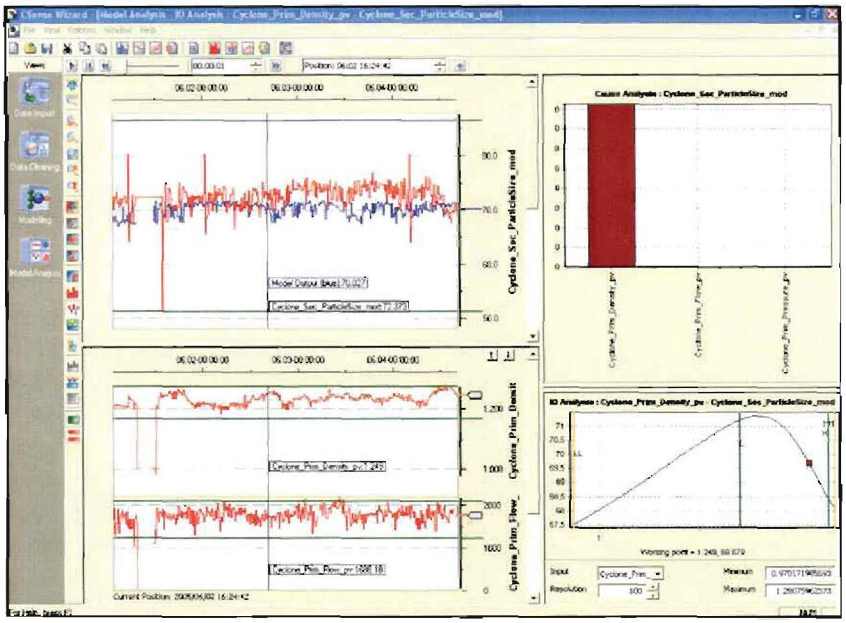
Belt Profile Analysis



Observations:

- If the belt profile histogram showed 2 distinct nodes, it could then be assumed that there are two very distinguishable profiles related to the different ore types. The histogram above shows the variation is indeed wide, but not clearly distinguishable, and so it is not possible to predict power draw on the basis of ore type (and mill mass) from the profile data presented here.

Secondary Cyclone: Particle Size as a function of Cyclone Feed Flow, Pressure and Density



Observations:

- The Csense model produced a reasonable fit to the data.
- The causation analysis showed that density affected the cyclone P80 much more strongly than pressure.
- The particle size showed a parabolic relationship to density, suggesting a narrow optimum value close to 1.22.
- Process data indicated a mean operating value near 1.24.

APPENDIX B

COST AND SUPPLY OF COAL FIRED BOILERS

BUDGET PRICE SCHEDULE (indicative only)

OPTION 1

Description	Price R
Two Thompson Afripac MK4 model TA 500 Packaged Boilers complete with two Swing Chutes, two Grit Collectors, two ID fans & two sets of Gas ducting	included
Two inclined Coal Screws complete with one Control Panel	included
Two Coal Surge Hoppers complete with support steelwork	included
Two Guyed Chimney Stacks	included
One Delivery to site at Orkney of all equipment in our Scope of Supply	included
One Installation and Commissioning of all equipment in our Scope of Supply	included
Total for above (excluding VAT)	**5 200 000-00**

OPTION 2

Description	Price R
Two Thompson Compac Mk II model TC500 package boilers	included
Two Weishaupt natural gas burners	included
Two Guyed Chimney Stacks	included
One Delivery to site at Orkney of all equipment in our Scope of Supply	included
One Installation and Commissioning of all equipment in our Scope of Supply	included
Total for above (excluding VAT)	**2 600 000-00**

SCOPE OF SUPPLY

For the supply of equipment and services as follows:

STEAM GENERATING PLANT

OPTION ONE

Two Thompson Afripac Package Steam Boilers

Boiler Model	:	TA 500
Nominal Rating	:	5000 kg/h (from and at 100°C)
Actual Evaporation	:	4185 kg/h (with feedwater at 20°C)
Working Pressure	:	960 kPa
Design Pressure	:	1 034 kPa
Design Code	:	BS2790 (Current Edition and Revision)
Fuel Specification	:	Grade A Pea Coal
Gross Calorific Value	:	27.5 - 28.5 MJ/kg
Boiler Thermal Efficiency on NCV	:	85% to provide 10kg steam per kg coal

Each boiler is supplied complete with the following:

- Front smokebox
- Rear smokebox incorporating contra-rotating dampers with a horizontal gas outlet
- Spiral Tubes in the first tube pass
- Access ladder and platforms
- Insulation and Stainless Steel cladding
- Furnace refractories
- Triumph chaingrate stoker/s and Forced Draught fan/s, both with AC variable speed drives
- Boiler valves and mountings including manually operated rear sootblowers
- On-off feedwater level controls
- Two boiler mounted feedwater pumps
- Boiler mounted control panel
- Grit collector for an emission of 250 mg/Nm^3 complete with flap valve and trolley
- Floor mounted induced draft fan
- Standard Boiler tools and spares
- One Boiler Operating and Maintenance manual

One Thompson Triumph Chaingrate Stoker per boiler

Stoker Model	:	46
Nominal Grate Area	:	3.1 m^2
Fuel Specification	:	Grade A Pea Coal
Gross Calorific Value	:	27.5 - 28.5 MJ/kg

Each stoker is supplied complete with the following:

- Mainframe
- Air control dampers
- Chain grate
- Ignition arch
- Guillotine door to control bed depth
- Side seals
- Set of stoker removal trolleys
- Swinging coal chute and drive table
- Coal and riddlings hoppers
- Moisturising pipework
- Forced draft fans
- AC variable speed drive for both stoker and FD fan motors
- Combustion control unit
- Stoker Tools, spares and accessories
- One Stoker Operating and Maintenance manual

One Multi-Cyclone Grit Collector per boiler

Emission : 250 mg/Nm^3

Note: For all new and relocated coal fired boilers operating under a balanced draught condition, burning more than 100 kg/h of coal the installation of a grit collector with a minimum capability of a 250 mg/Nm^3 particulate emission level is a legal requirement. This requirement was introduced in 1994 and documented in the Department of National Health and Population Development circular number 7 under the heading Atmospheric Pollution Prevention Act.

One Induced Draught Fan per boiler

Mounting	:	Floor

Set Flue Gas Ducting per boiler

Construction material	:	Mild steel

Flue gas ducting complete with necessary expansion joints and supports, for interconnection of the following, 5 m from the boiler.

- Boiler rear smokebox and grit collector gas inlet
- Grit collector gas outlet and ID fan suction
- ID fan discharge and stack inlet

One Stack per boiler

Stack Type	:	Guyed
Nominal Diameter	:	600 mm
Height above firing floor level	:	20 m
Mounting	:	Floor
Construction material	:	Mild steel

The guyed stack is supplied complete with the following:

- Assembly fittings
- 3 Sets galvanised guy wires and fittings

Note: All users of fuel burning appliances must comply with the relevant Government Regulations concernin Atmospheric Pollution Act before installing and operating the boilerplant. The height of the chimney must be accepted by the Local Atmospheric Pollution Officer and in view of this, the nominal height quoted may be subjected to price alteration depending on the final acceptable height and design.

STEAM GENERATING PLANT

OPTION 2

Two Thompson Compac Mkll Package Steam Boilers

Boiler Model	:	TC500
Nominal Rating	:	5000 kg/h (from and at 100°C)
Actual Evaporation	:	4185 kg/h (with feedwater at 20°C)
Working Pressure	:	1000 kPa
Design Pressure	:	1100 kPa
Design Code:		BS2790 (Current Edition and Revision)
Fuel Specification	:	Sasol natural gas

Each boiler is supplied complete with the following:

- Front and rear smokebox with horizontal gas outlet
- Access ladder and platform
- Insulation and Stucco aluminium cladding
- Smokebox refractories
- Burner unit and gas filter
- Valves and mountings
- On-off feedwater level controls
- One boiler mounted feedwater pump
- Boiler mounted control panel
- Standard Boiler tools and spares
- Operating and maintenance manual

One Stack per boiler

Stack Type	:	Guyed	
Nominal Diameter	:	550	mm
Height above firing floor level	:	18	m
Mounting	:	Boiler	
Construction material	:	Mild steel	

The stack is supplied complete with the following:

- Stack sections
- Assembly fittings
- 3 Sets galvanised guy wires and fittings

Note: All users of fuel burning appliances must comply with the Government Regulations concerning the Atmospheric Pollution Act before installing and operating the boilerplant. The height of the chimney must be accepted by the Local Atmospheric Pollution Officer and in view of this, the nominal height quoted may be subjected to price alteration depending on the final acceptable height and design.

COAL HANDLING PLANT (OPTION 1 only)

One Inclined Elevator per boiler

Type	:	Rotating Screw	
Diameter	:	150	mm
Length	:	9	m

Inclined coal elevator for transferring coal from coal bunker to surge hopper, complete with geared motor drive and support steelwork.

One Coal Surge Hopper per boiler

Nominal Storage Capacity	:	500	kg

Coal surge hopper for storage of coal for feeding into boiler swinging coal chute, complete with low level switch.

One Coal Plant Control Panel per installation of two boilers

Remote mounting control panel housing controls and switchgear for coal plant as follows:
- Mains isolator
- Inclined elevator controls and switchgear as follows:
  - Drive motor starter
  - Control switch (manual/off/auto)
  - Automatic control timer (on/off)
- Swinging chute controls and switchgear as follows:
  - Drive motor starter
  - Control switch (on/off)

SERVICES

Delivery to Site

Packaging of equipment in our supply, and delivery to site at Orkney, including road insurance.

Installation

Installation of equipment in our supply comprising work as follows:
- Off-loading from transport vehicles.
- Assembly, positioning and erection of equipment onto foundations.
- Supply and installation of boilerhouse and mainsteam pipework comprising:
  - Mainsteam pipework connected to existing pipework within confines of the boilerhouse
  - Feedpump suction pipework complete with supply isolating valve, strainer and feedpump isolating valves
  - Feedpump delivery pipework complete with pump discharge SDNR valves
  - Boiler blowdown pipework
  - Boiler drains pipework
- Site electrical wiring
- Preparation and performance of regulation site hydraulic test including independent inspection authority

Commissioning

Commissioning of equipment in our supply on completion of installation.

TERMINAL POINTS

OPTION 1

The terminal points for the scope of supply are as follows:

Coal	-	Inlet of inclined coal screw.
Feedwater	-	Treated water outlet connection on feedwater tank.
Mainsteam	-	Connect to mainsteam header in boilerhouse.
Blowdown	-	Outlet of blowdown pipework in blowdown sump.
Safety Escape	-	Outlet of safety valve escape pipework above boilerhouse roof.
Boiler Drains	-	Outlets of individual drain pipes on boiler in blowdown trench.
Flue Gas	-	Discharge to atmosphere at top of stack.
Ash	-	Outlet of ash valve on boiler, discharging into ash trolley.
Grits	-	Outlet of grit valve on grit collector, discharging into grit trolley.
Electrics	-	Mains incoming connections inside boiler control panel.

OPTION 2

The terminal points for the scope of supply are as follows:

Mains Gas	-	Inlet to isolating valve on burner gas train (incoming pressure of 1bar assumed).
Feedwater	-	Suction flange of boiler feedpump.
Mainsteam	-	Discharge flange of mainsteam valve on boiler.
Blowdown	-	Outlet of bottom blowdown valve.
Safety Escape	-	Outlet of safety valve.
Boiler Drains	-	Outlet of individual drain pipes on boiler.
Flue Gas	-	Discharge to atmosphere at top of stack.
Electrics	-	Mains supply connections inside boiler control panel.

EXCLUSIONS

Our offer does not include for any equipment or service not specifically mentioned. We highlight the following exclusions in particular:

- Foundations, civil works, boilerhouse modifications, boilerhouse fittings, stack anchor points and civil design.
- Mains electrical reticulation system.
- Coal storage system.
- Ash conveying equipment.
- Mains electrical reticulation system.
- Gas pressure boosting or reducing equipment (supply to burner gas train of 1bar assumed), gas meter, gas line pipework and fittings, gas pressure gauges.
- Water softening and chemical dosing equipment.
- Make-up water pressure boosting or reducing equipment.
- TDS controller and water sample cooler.
- De-aerator and feedwater tank.
- Boilerhouse valves and pipework other than offered in this tender.
- Steam and condensate reticulation, including headers, valves, steam traps and supports
- Mainsteam screwdown non-return valve/s.
- Lagging and cladding of feedwater storage tank, interconnecting ducting, pipework and stack.
- Fuel, water, power, chemicals and operating labour required for commissioning.
- Operator training.
- Equipment testing.
- Statutory formalities.
- Any item of equipment or services not specifically mentioned.

SITE CONDITIONS

The equipment offered is designed to operate under the site conditions as follows:

Site Location	:	Orkney
Site Altitude	:	1300 masl
Power Supply	:	380 Volt/3 ph/50 Hz/4 Wire
Control Voltage	:	220 Volt

FEEDWATER SPECIFICATIONS

The required water specifications to the water treatment plant should be as follows:

- Make up supply water pressure between 2.5 and 5.5 Bar (maximum).
- pH between 8,5 and 9,5.

We highly recommend the use of softened water to ensure optimum performance and extended life of the boiler

COMMERCIAL

TERMS OF PAYMENT

Our offer is based on the following terms of payment:

- 50% of total contract value payable on invoice on order.
- 42½% of the total contract value payable on invoice on availability of the equipment for despatch and before the equipment is despatched ex our Works.
- 7½ % of the total contract value payable on invoice on completion of commissioning.

Payment is to be net and free of any deductions and made directly into our bank account, details of which will be given on our invoices.

Please be advised that should you require a change to the above terms of payment, the price/s quoted could be affected due to the effect such a change may have on the project's cash flow.

PRICE BASIS

Our price is indicative budget only and is variable. It is based on the cost of materials, labour, transport and overhead costs ruling at time of tender.

VALIDITY

This tender is for budget purposes only. Please contact us should you require our firm offer.

CONDITIONS OF TENDER

Any contract resulting from this tender will be subject to the terms and conditions stated herein and in the Alstom Standard Conditions of Sale and Tender. If applicable the Alstom Supplementary Conditions For Use Where Goods Are To Be Delivered To And Erected On Site, will also apply.

These conditions are available on request.

PROGRAMME

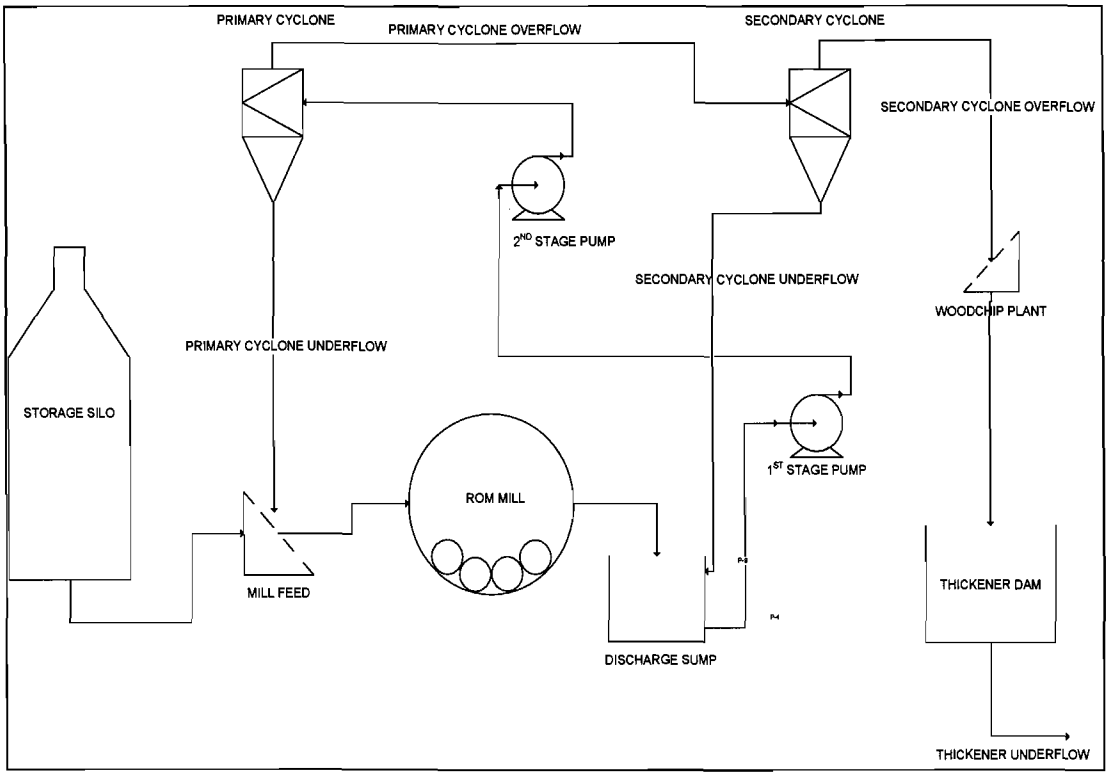
The equipment offered will normally be programmed for a despatch of 16 working weeks (Option 1) and 13 working weeks (Option 2) from receipt of firm order and accompanying down payment, subject to materials availability and works loading at time of order placement.

Please be advised that there is currently a 3 month lead time required for the delivery of material from the steel mills. We do, however, carry stock of plate, but this is subject to prior sale and may only be allocated upon receipt of order.

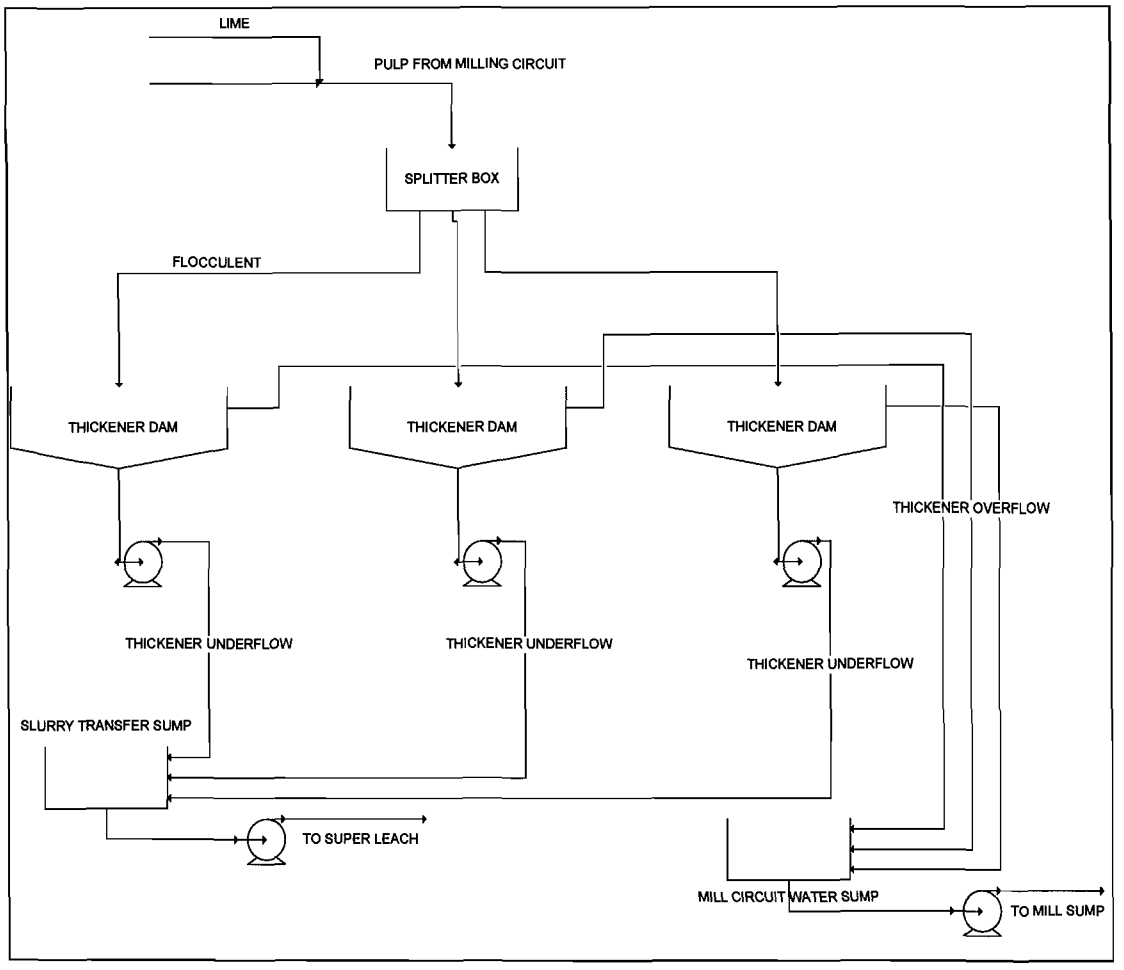
APPENDIX C

SIMPLIFIED LAYOUTS OF THE DIFFERENT SECTIONS ON A CIP GOLD PLANT

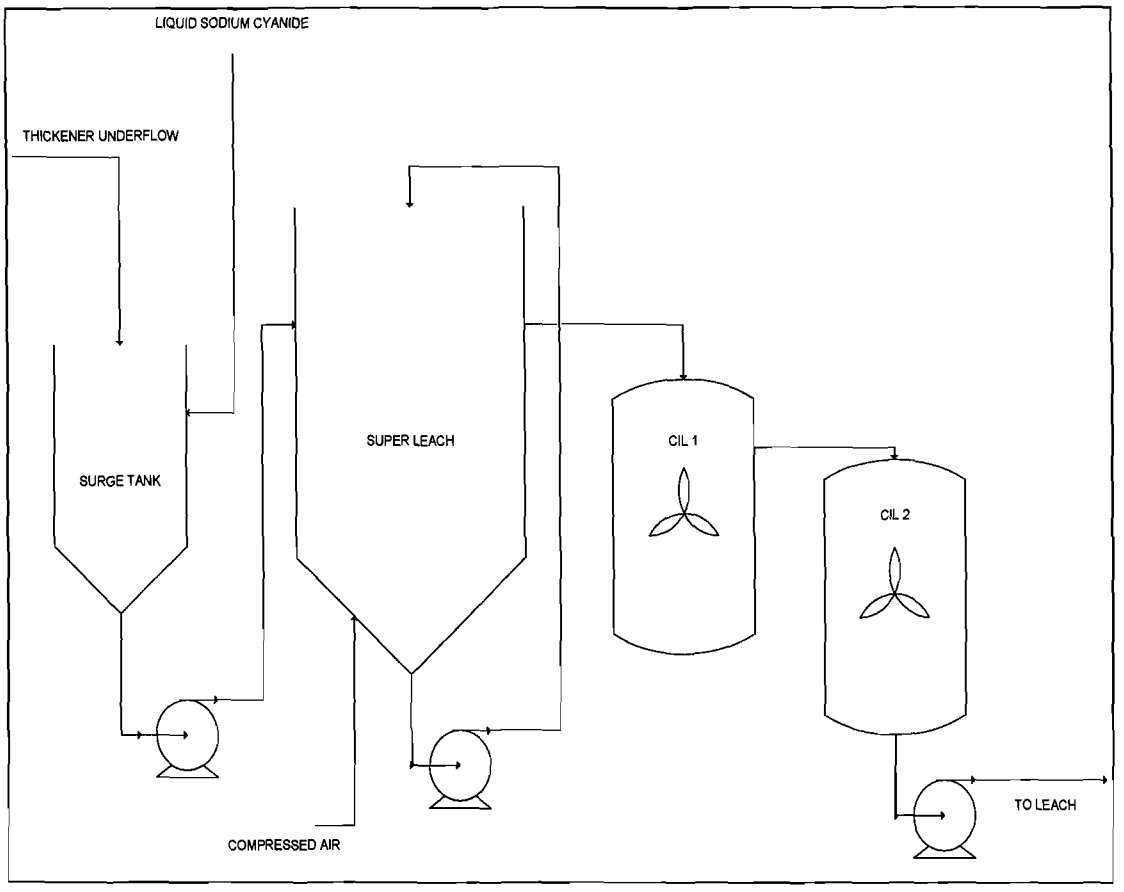
Milling and Classification Section



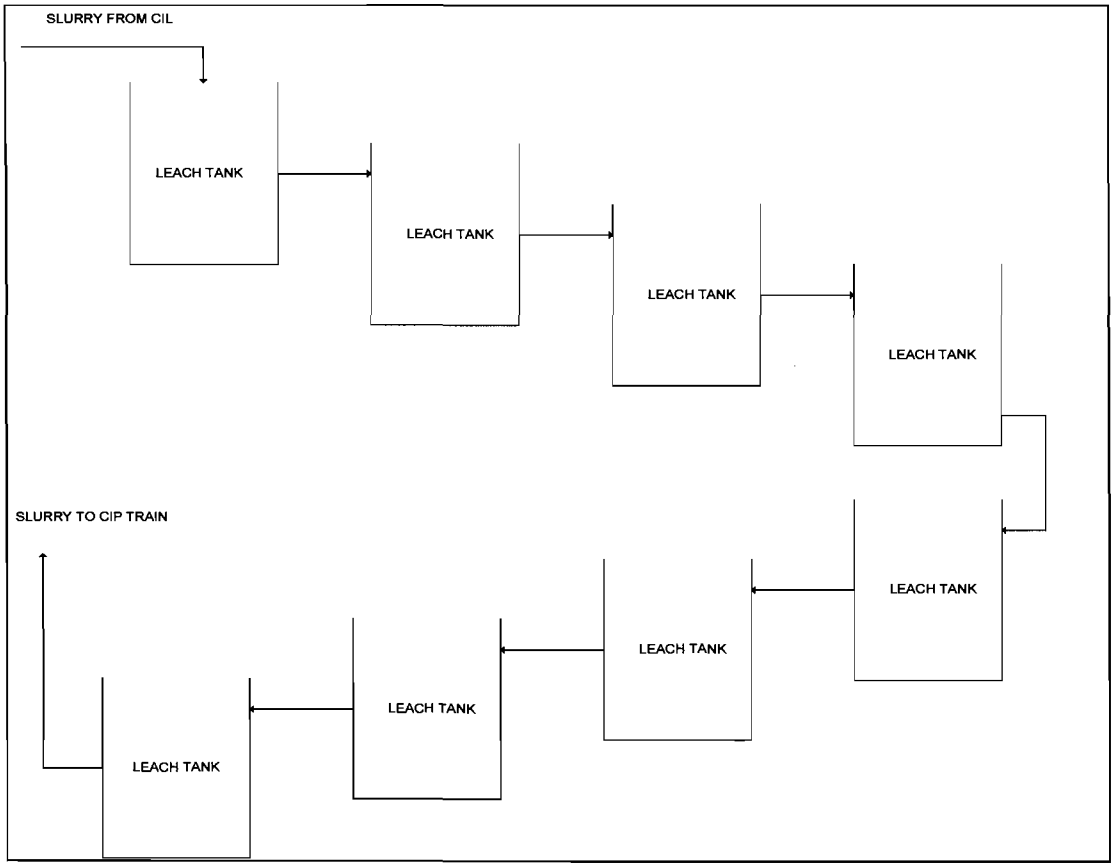
Thickening Section



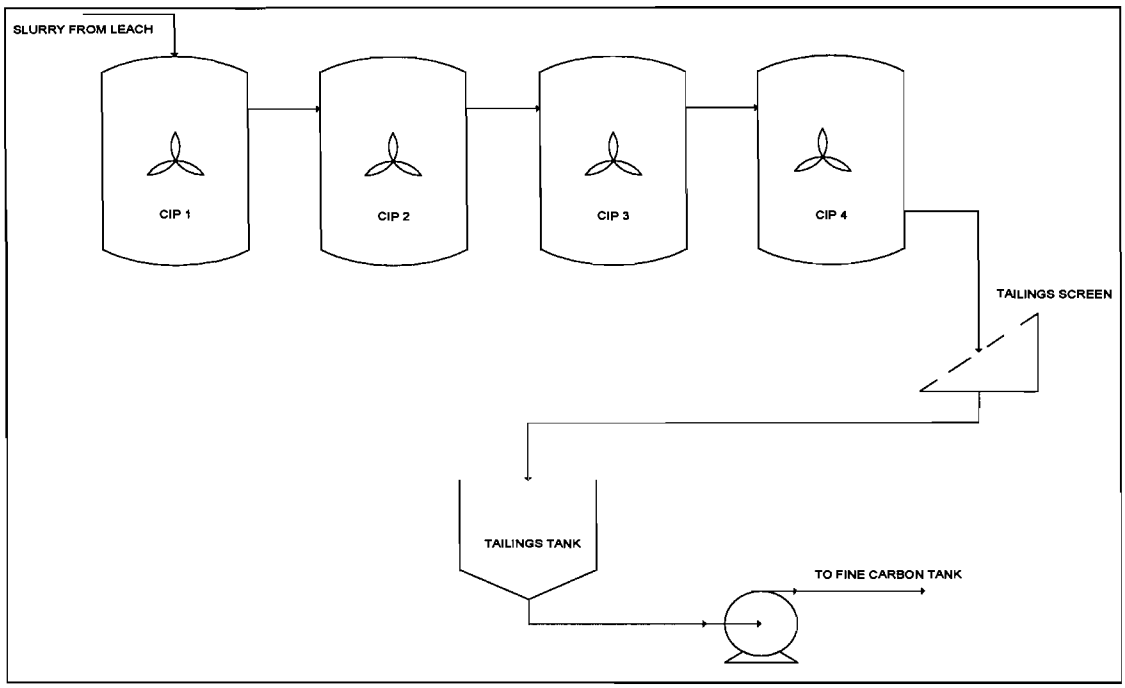
Super Leach and Carbon in Leach (CIL)



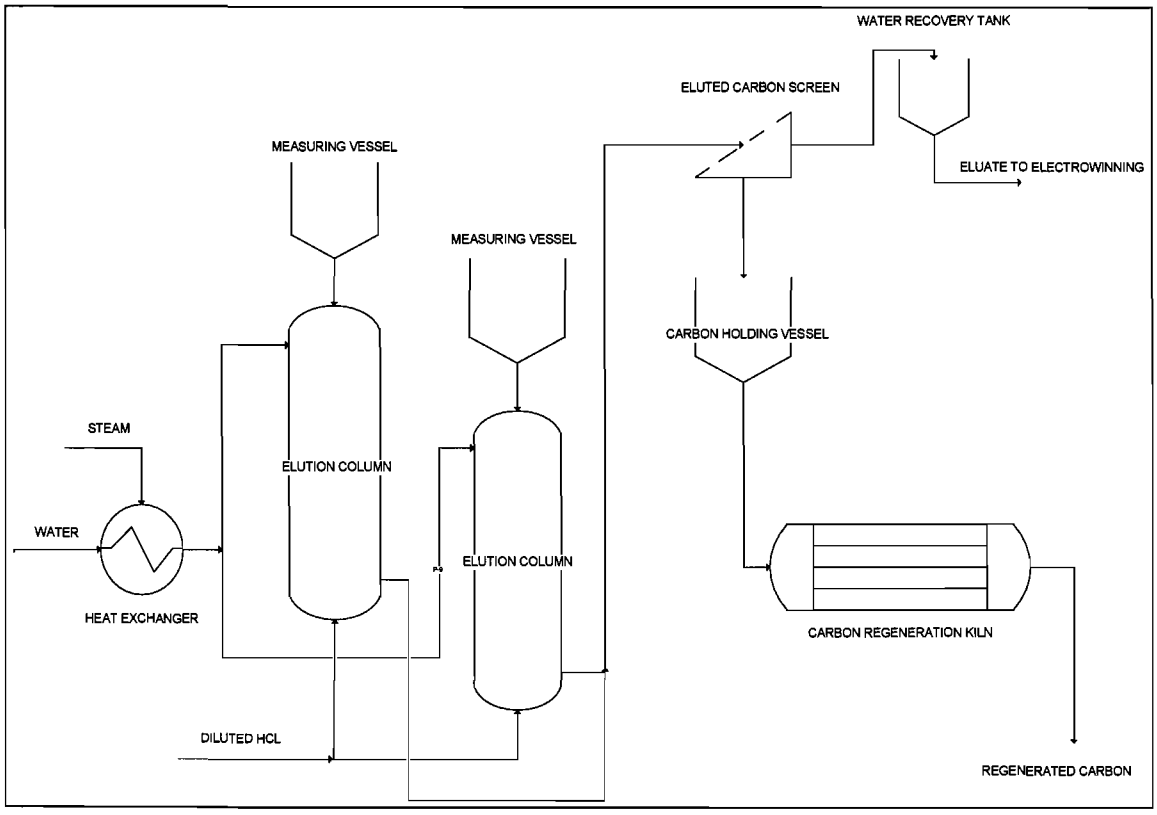
Cyanide Leaching



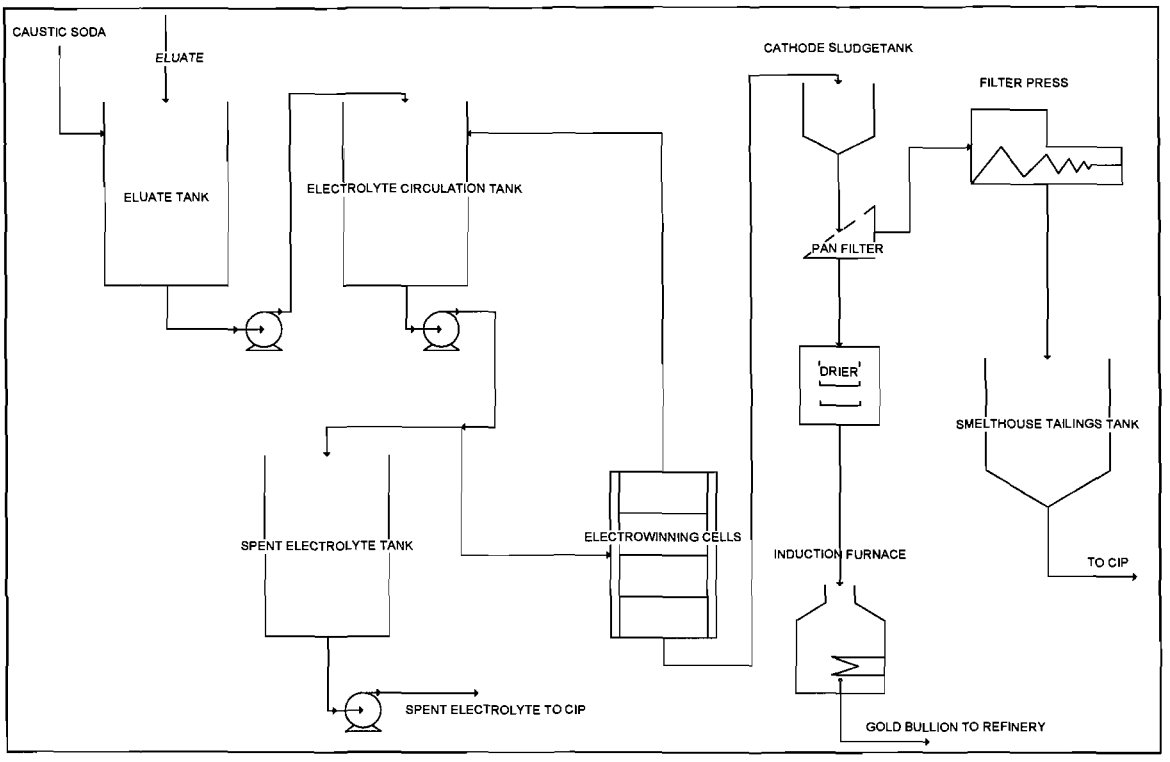
Carbon in Pulp (CIP) Absorption



Elution Section



Electro Winning



APPENDIX D

ESKOM'S URBAN TARIFFS AND CHARGES FOR 2007/8

Urban$_p$ tariffs (non-local-authority supplies)



NIGHTSAVE Urban

Electricity tariff for urban$_p$ customers with an NMD from 25 kVA

This tariff is characterised by:

- Seasonally differentiated energy demand and active energy charges.
- Two time periods namely: peak and off-peak (refer to Appendix C).
- A network access charge applicable during all time periods.
- A network demand charge and energy demand charge applicable during peak period.
- A c/kWh contribution to cross subsidies to the rural and Homelight tariffs.

Capital costs:

A connection charge will be payable in addition to the tariff for new connections or additional capacity.

Connection fee:

Refer to Appendix E (Table 1).

The rates listed below are for non-local-authority supplies. The rates for local-authority supplies are listed at the end of this book.

Service charge:

Charged per account and is based on the sum of the monthly utilised capacity of all premises linked to an account.

≤ 100 kVA	R 1,01 +VAT = **R 1,15/day**
> 100 kVA and ≤ 500 kVA	R 12,68 + VAT = **R 14,46/day**
> 500 kVA and ≤ 1 MVA	R 62,22 + VAT = **R 70,93/day**
> 1 MVA	R 62,22 + VAT = **R 70,93/day**
Key customers	R 487,02 +VAT = **R 555,20/day**

Administration charge:

Based on, and payable for, the monthly utilised capacity of each premise linked to an account.

≤ 100 kVA	R 2,49 +VAT = **R 2,84/day**
> 100 kVA and ≤ 500 kVA	R 4,01 +VAT = **R 4,57/day**
> 500 kVA and ≤ 1 MVA	R 33,29 + VAT = **R 37,95/day**
> 1 MVA	R 33,39 + VAT = **R 38,06/day**
Key customers	R 35,19 + VAT = **R 40,12/day**

Network demand charge:

R7,08 + VAT = **R8,07/kVA** payable for each kVA of the chargeable demand supplied during peak periods per premise per month.

Urban$_p$ tariffs *continued...*



Network access charge:
R 6,26 + VAT = **R 7,14/kVA** payable each month and is based on the annual utilised capacity of each premise. This charge is applicable during all time periods.

Energy demand charge:
Payable for each kVA of the chargeable demand supplied during peak periods per premise per month.

High-demand season (June - August)	Low-demand season (September - May)
R 32,37 + VAT = **R 36,90/kVA**	R 4,59 + VAT = **R 5,23/kVA**

Active energy charge:

High-demand season (June - August)	Low-demand season (September - May)
11,28c + VAT = **12,86c/kWh**	8,02c + VAT = 9,14**c/kWh**

Voltage surcharge:
Calculated as a percentage of network demand, network access, energy demand and active energy charges.

Supply voltage	Surcharge
> 132 kV	0,00%
≥ 66 kV and ≤ 132 kV	7,63%
≥ 500V and < 66 kV	10,07%
< 500V	17,30%

Transmission surcharge:
Calculated as a percentage of network demand, network access, energy demand and active energy charges after the voltage surcharge have been levied. The surcharge rate depends on the distance from a central point in Johannesburg.

≤ 300 km	0%
> 300 km and ≤ 600 km	1%
> 600 km and ≤ 900 km	2%
> 900 km	3%

Rate-rebalancing levy:
2,97c + VAT = **3,39c/kWh** applied to the total active energy consumption (not subject to the

Urban$_p$ tariffs *continued...*



MEGAFLEX

TOU electricity tariff for urban$_p$ customers with an NMD > 1 MVA that are able to shift load

This tariff is characterised by:

- Seasonally and time differentiated c/kWh active energy charges.
- Three time-of-use periods namely: peak, standard and off-peak.
- A R/kVA network access charge applicable during all time periods, differentiated by voltage and transmission zone.
- A R/kVA network demand charge applicable during peak and standard periods.
- A R/day service and administration charge based on the size of supply.
- A c/kWh contribution to cross-subsidies to the rural and Homelight tariffs.

Capital costs:
A connection charge will be payable in addition to the tariff for new connections or additional capacity.

Connection fee:
Refer to Appendix E (Table 1).

The rates listed below are for non-local-authority supplies. The rates for local-authority supplies are listed at the end of this book.

Service charge:
Charged per account and is based on the sum of the monthly utilised capacity of all premises linked to an account.

≥ 1 MVA	R 62,22 +VAT = **R70,93/day**
Key customers	R 487,02 +VAT = **R555,20/day**

Administration charge:
Based on, and payable for, the monthly utilised capacity of each premise linked to an account.

≥ 1 MVA	R 35,89 +VAT = **R40,91/day**
Key customers	R 37,19 +VAT = **R42,40/day**

Network demand charge:
R 7,08 + VAT = **R8,07/kVA** payable for each kVA of the chargeable demand supplied during peak and standard periods per premise per month.

Network access charge:
R 6,26 + VAT = **R7,14/kVA** payable each month and is based on the annual utilised capacity of each premise. This charge is applicable during all time periods.

Urban$_p$ tariffs *continued...*



Active energy charge:

High-demand season (June - August)		Low-demand season (September - May)
55,30c + VAT = **63,04c/kWh**	Peak	15,69c + VAT = **17,89c/kWh**
14,62c + VAT = **16,67c/kWh**	Standard	9,74c + VAT = **11,10c/kWh**
7,95c + VAT = **9,06c/kWh**	Off-peak	6,90c + VAT = **7,87c/kWh**

Reactive energy charge:

2,79c + VAT = **3,18c/kvarh** supplied in excess of 30% (0,96 PF) of kWh recorded during peak and standard periods. The excess reactive energy is determined per 30-minute integrating period and accumulated for the month and will only be applicable during the high demand season.

Voltage surcharge:

Calculated as a percentage of network demand, network access and active energy charges.

Supply voltage	Surcharge
> 132 kV	0,00%
≥ 66 kV and ≤ 132 kV	7,63%
≥ 500V and < 66 kV	10,07%
< 500V	17,30%

Transmission surcharge:

Calculated as a percentage of the network demand, network access, active energy and reactive energy charges after the voltage surcharge has been levied. The surcharge rate depends on the distance from a central point in Johannesburg.

≤ 300 km	0%
> 300 km and ≤ 600 km	1%
> 600 km and ≤ 900 km	2%
> 900 km	3%

Rate-rebalancing levy:

1,61c + VAT = **1,84c/kWh** applied to the total active energy consumption (not subject to the voltage and/or transmission surcharge).

Urban$_p$ tariffs *continued...*



MINIFLEX

TOU electricity tariff for urban$_p$ customers with an NMD from 25 kVA up to 5 MVA

This tariff is characterised by:

- Seasonally and time differentiated c/kWh active energy charges.
- Three time of use periods namely: peak, standard and off-peak.
- A R/kVA network access charge applicable during all time periods, differentiated by voltage and transmission zone.
- A R/kVA network demand charge included in the energy charge.
- A R/day service and administration charge based on the size of supply.
- A c/kWh contribution to cross-subsidies to the rural and Homelight tariffs.

Capital costs:
A connection charge will be payable in addition to the tariff for new connections or additional capacity.

Connection fee:
Refer to Appendix E (Table 1)

The rates listed below are for non-local-authority supplies. The rates for local-authority supplies are listed at the end of this book.

Service charge:
Charged per account and is based on the sum of the monthly utilised capacity of all premises linked to an account.

≤ 100 kVA	R2.32 + VAT = **R2.64/day**
> 100 kVA and ≤ 500 kVA	R12.68 + VAT = **R14.46/day**
> 500 kVA and ≤ 1 MVA	R62.22 + VAT = **R70.93/day**
> 1 MVA	R62.22 + VAT = **R70.93/day**
Key customers	R487.02 + VAT = **R555.20/day**

Administration charge:
Based on, and payable for, the monthly utilised capacity of each premise linked to an account.

≤ 100 kVA	R2.61 + VAT = **R2.98/day**
> 100 kVA and ≤ 500 kVA	R4.25 + VAT = **R4.85/day**
> 500 kVA and ≤ 1 MVA	R34.71 + VAT = **R39.57/day**
> 1 MVA	R34.71 + VAT = **R39.57/day**
Key customers	R34.71 + VAT = **R39.57/day**

Urban$_p$ tariffs *continued...*



Network access charge:
R6,26+ VAT = **R7,14/kVA** payable each month and is based on the annual utilised capacity of each premise. This charge is applicable during all time periods.

Active energy charge:

High-demand season (June - August)		Low-demand season (September - May)
56,55c +VAT = **64,47c/kWh**	Peak	17,44c +VAT = **19,88c/kWh**
16,37c +VAT = **18,66c/kWh**	Standard	11,55c +VAT = **13,17c/kWh**
7,87c + VAT = **8,97c/kWh**	Off-peak	6,82c + VAT = **7,77c/kWh**

Reactive energy charge:
1,22c +VAT = **1,39c/kvarh** supplied in excess of 30% (0,96 PF) of the kWh recorded during the entire billing period. The excess reactive energy is determined using the billing period totals and will only be applicable during the high-demand season.

Voltage surcharge:
Calculated as a percentage of network access and active energy charges.

Supply voltage	Surcharge
> 132 kV	0,00%
≥ 66 kV and ≤ 132 kV	7,63%
≥ 500 V and < 66 kV	10,07%
< 500 V	17,30%

Transmission surcharge:
Calculated as a percentage of the network access, active energy and reactive energy charges after the voltage surcharge has been levied. The surcharge rate depends on the distance from a central point in Johannesburg.

≤ 300 km	0%
> 300 km and ≤ 600 km	1%
> 600 km and ≤ 900 km	2%
> 900 km	3%

Rate-rebalancing levy:
1,47c + VAT = **1,68c/kWh** applied to the total active energy consumption (not subject to the voltage and/or transmission surcharge).

Urban$_p$ tariffs *continued...*



BUSINESSRATE

Electricity tariff for small businesses governmental institutions or similar supplies in urban$_p$ areas with an NMD up to 100 kVA

The Businessrate tariff is made up of a range of tariffs as follows:

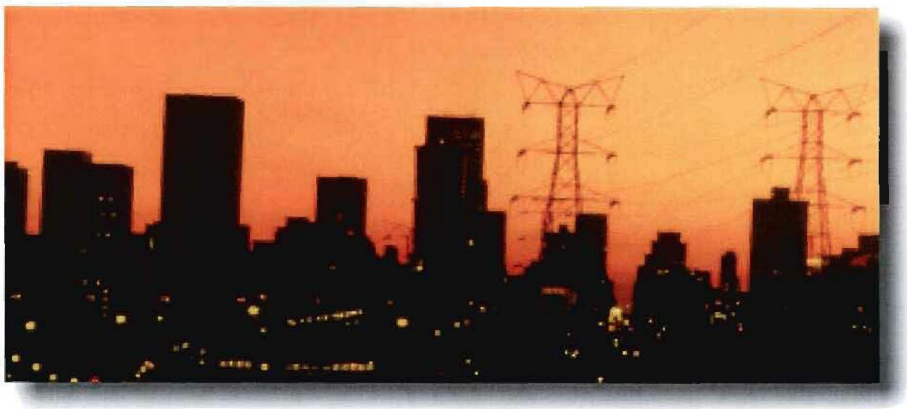
Businessrate 1: for supplies ≤ **25 kVA** using more than 622 kWh per month
Businessrate 2: for supplies > **25 kVA** and ≤ **50 kVA**
Businessrate 3: for supplies > **50 kVA** and ≤ **100 kVA**
Businessrate 4: for supplies ≤ **25 kVA** using less than 622kWh per month

This tariff is characterised by:

- a single c/kWh active energy charge;
- a R/day network charge based on the NMD of the supply; and
- a R/day service charge based on the size of supply

Conventional metered supplies:
Meters are read at least once every three months. Estimated charges are raised in months during which no meter readings are taken and these are subsequently adjusted when actual consumption is charged for. A security deposit covering three months' consumption is required.

Capital costs:
A connection charge will be payable in addition to the tariff for new connections or additional capacity.



Urban$_p$ tariffs *continued...*



Connection fees:

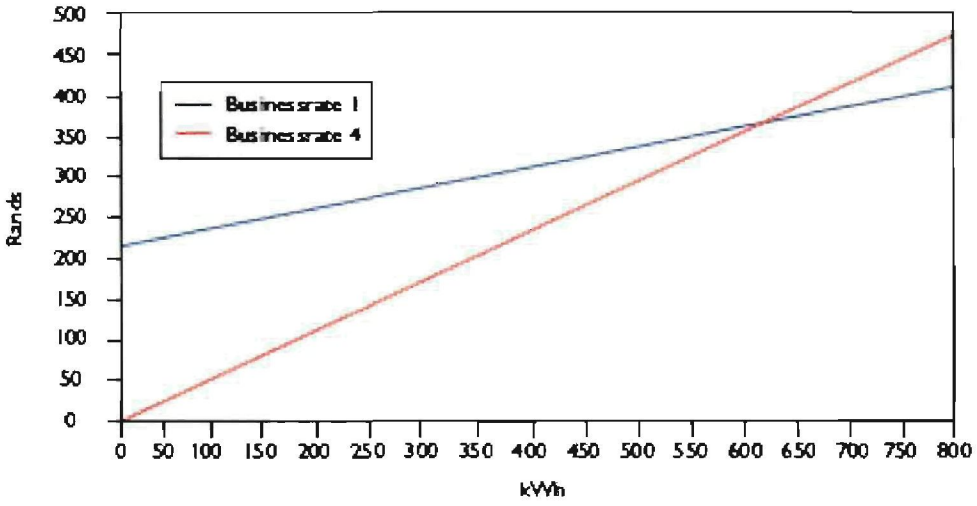
Refer to Appendix E (Table 1).

The rates listed below are for non-local-authority supplies. The rates for local-authority supplies are listed at the end of this book.

Charges:	Network charge (per day)	Service charge (per day)	Energy charge (per unit)
Businessrate 1	R3,45 + VAT = R3,93	R3,59 + VAT = R4,09	25,06c + VAT 28,57c/kWh
Businessrate 2	R4,97 + VAT = R5,67		
Businessrate 3	R9,73 + VAT = R11,09		
Businessrate 4	N/A	N/A	59,48c + VAT = 67,81c/kWh

Note: The service and network charge is payable for each premise per billing month whether electricity is consumed or not. The service and network charge on Businessrate 4 is not charged as a fixed charge per month and is included in the energy charge.

Comparing Businessrate 1 and Businessrate 4



The break-even between Businessrate 1 and Businessrate 4 is 622 kWh/month.

- If less than 622 kWh/month is used, Businessrate 4 is cheaper.
- If more than 622 kWh/month is used, Businessrate 1 is cheaper.

APPENDIX E

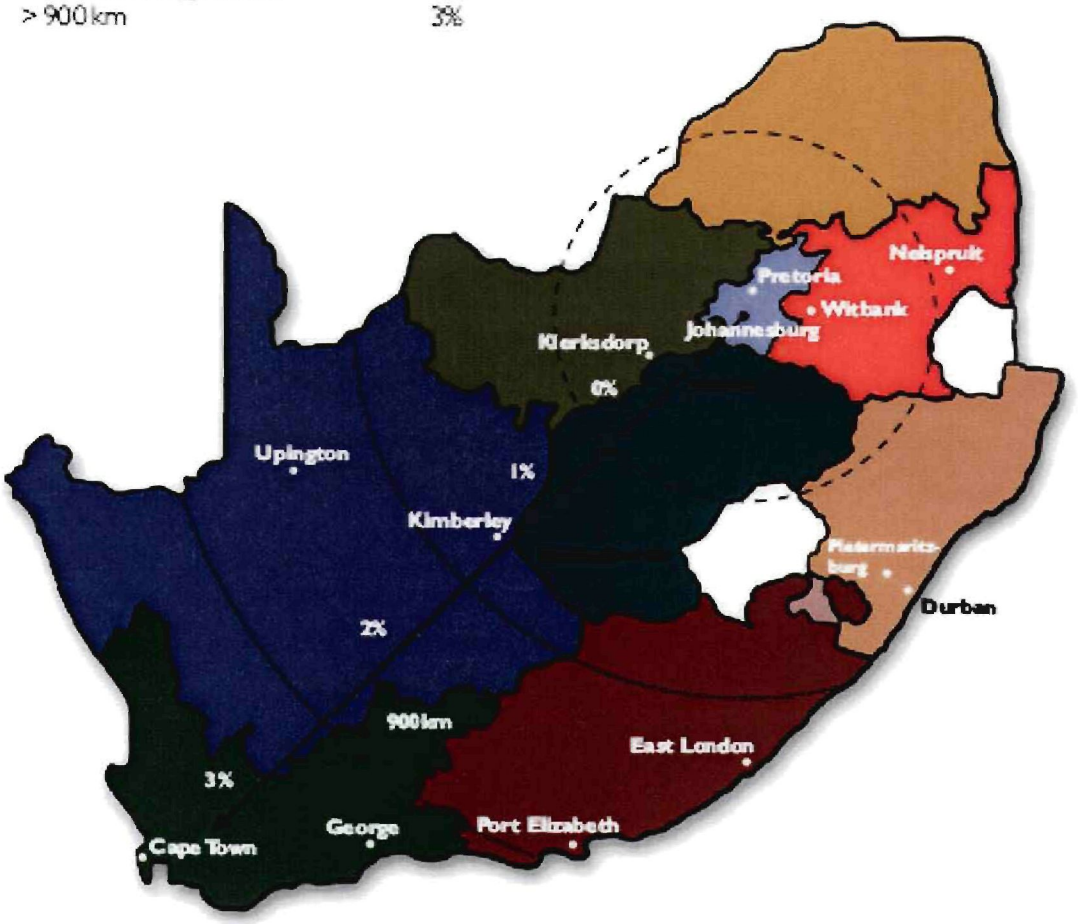
ESKOM'S TARIFFS AND CHARGES FOR 2007/8 - APPENDICES

Appendices

Appendix A: Transmission percentage surcharge

The energy demand charge (where applicable), active energy charge, reactive energy charge (where applicable) and network charge are subject to a transmission surcharge after the voltage surcharge has been levied. The surcharge rate depends on the distance from a central point in Johannesburg.

≤ 300 km	0%
> 300 km and ≤ 600 km	1%
> 600 km and ≤ 900 km	2%
> 900 km	3%



Appendices *continued...*



Appendix B: Treatment of public holidays for 2007/8

The table below indicates the treatment of public holidays for the TOU tariffs, namely: **Nightsave (Urban)**, **Megaflex** and **Miniflex** tariffs for the period 1 April 2007 to 31 March 2008 for non-local authority supplies. The holidays from 24 March 2008 until 16 June 2008 are shown for local authority supplies. The appropriate seasonally differentiated energy charges will be applicable on these days. Any unexpectedly announced public holiday will be treated as the day of the week on which it falls.

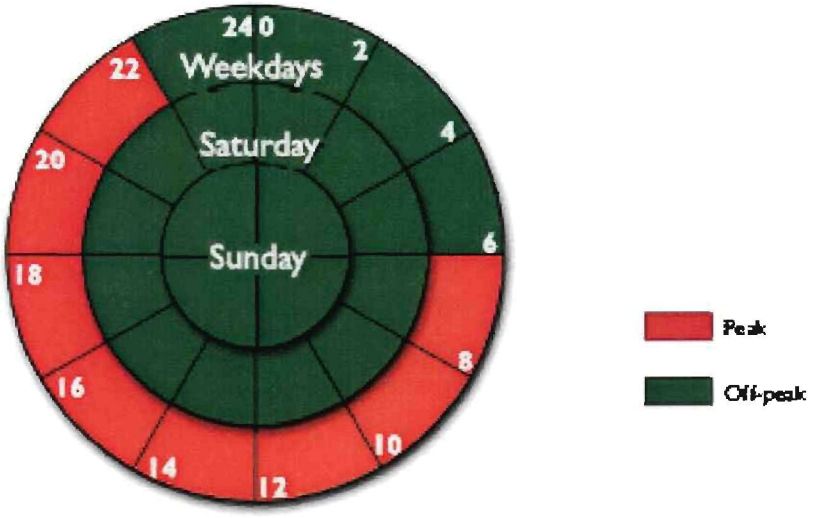
*NOTE: All public holidays for the **Nightsave (Rural)** and **Ruraflex** tariffs will be treated as the day of the week on which it falls.*

Date	Day	Actual day of the week	TOU day treated as NIGHTSAVE Urban	MEGAFLEX / MINIFLEX
1 January 2007	New Year's Day	Monday	Sunday	Sunday
21 March 2007	Human Rights Day	Wednesday	Sunday	Saturday
6 April 2007	Good Friday	Friday	Sunday	Sunday
9 April 2007	Family Day	Monday	Sunday	Sunday
27 April 2007	Freedom Day	Friday	Sunday	Saturday
1 May 2007	Workers' Day	Tuesday	Sunday	Saturday
16 June 2007	Youth Day	Saturday	Sunday	Saturday
9 August 2007	National Women's Day	Thursday	Sunday	Saturday
24 September 2007	Heritage Day	Monday	Sunday	Saturday
16 December 2007	Day of Reconciliation	Sunday	Sunday	Sunday
17 December 2007	Public Holiday	Monday	Sunday	Saturday
25 December 2007	Christmas Day	Tuesday	Sunday	Sunday
26 December 2007	Day of Goodwill	Wednesday	Sunday	Sunday
1 January 2008	New Year's Day	Tuesday	Sunday	Sunday
21 March 2008	Human Rights Day	Friday	Sunday	Sunday
21 March 2008	Good Friday	Friday	Sunday	Sunday
24 March 2008	Family Day	Monday	Sunday	Sunday
27 April 2008	Freedom Day	Sunday	Sunday	Sunday
28 April 2008	Public Holiday	Monday	Sunday	Saturday
1 May 2008	Workers' Day	Thursday	Sunday	Saturday
16 June 2008	Youth Day	Monday	Sunday	Saturday

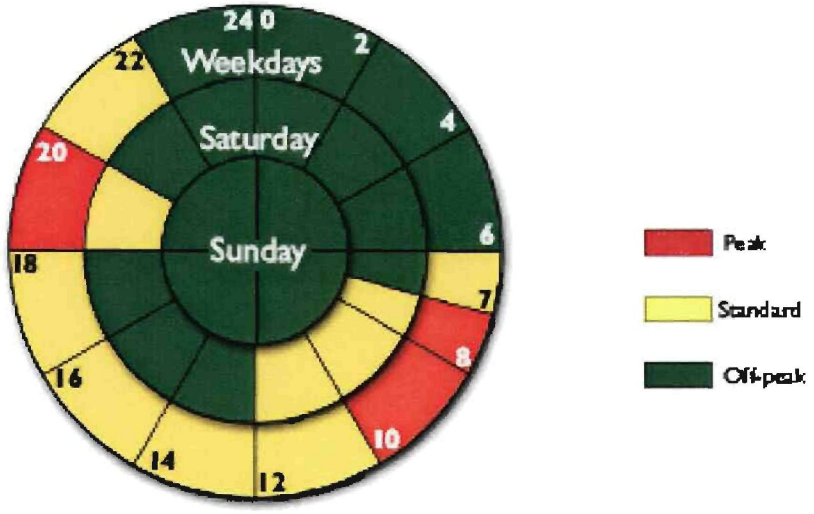
Appendices *continued...*

Appendix C: Eskom's defined time periods

Nightsave (Urban) & Nightsave (Rural)



Megaflex, Miniflex & Ruraflex



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Appendix D: TOU conversion surcharge

TOU tariffs (Megaflex, Miniflex and Ruraflex) are suitable for customers that are able to manage their energy consumption according to Eskom's specified time schedule. These tariffs are available upon conclusion of an electricity supply agreement with Eskom.

Existing > 150 kVA customers converting to TOU, where an impact study indicates a financial saving due to the conversion, **will be subject to a conversion surcharge.** The conversion surcharge is calculated as a percentage of the saving arising from the conversion without load shifting taking place. A 90% conversion surcharge will be applicable to all conversions for a period of 12 months after conversion, **regardless of the year of conversion.** The conversion surcharge will reduce by 18 percentage points after every completed 12 months; after conversion to TOU. The conversion surcharge will therefore reduce to 0% once the customer has been on a TOU tariff for five years.

The reduction of the conversion surcharge is indicated below:

	Months after conversion				
	1 - 12	13 - 24	25 - 36	37 - 48	49 - 60
Conversion surcharge	90%	72%	54%	36%	18%



Appendices *continued...*



Appendix E: Connection fees

The fees listed below are the minimum cash amounts payable. Additional charges based on allocated costs may be raised as per Eskom's Recovery of Capital policy.

Table 1 - Urban connection fees (including Homepower)

Capacity	Conventional
≤ 80 A (single-phase)	R964,91 + VAT = **R1 100,00**
16 kVA (single-phase)	R964,91 + VAT = **R1 100,00**
25 kVA (40 A per phase)	R3 815,79 + VAT = **R4 350,00**
50 kVA (80 A per phase)	R4 254,39 + VAT = **R4 850**[R]
70 kVA (100 A per phase)	R5 043,86 + VAT = **R5 750,00**
100 kVA (150 A per phase)	R5 043,86 + VAT = **R5 750,00**
200 kVA	R7 105,26 + VAT = **R8 100,00**
315 kVA	R7 587,72 + VAT = **R8 650,00**
500 kVA	R12 631,58 + VAT = **R14 400,00**
1 000 kVA	R25 263,16 + VAT = **R28 800,00**
> 1 000 kVA	The greater of R25 263,16 + VAT or 5% of allocated costs

Table 2 Rural connection fees

Capacity	Conventional
5 kVA (single-phase)	R1 842,11 + VAT = **R2 100**[R]
16 kVA (single-phase)	R3 026,32 + VAT = **R3 450**[R]
25 kVA (three-phase)	R4 561,40 + VAT = **R5 200,00**
32 kVA (dual-phase)	R4 561,40 + VAT = **R5 200,00**
50 kVA (three-phase)	R6 228,07+ VAT = **R7 100**[R]
64 kVA (dual-phase)	R6 228,07 + VAT = **R7 100,00**
100 kVA (three-phase)	R7 105,26 + VAT = **R8 100,00**
100 kVA (dual-phase)	R7 105,26 + VAT = **R8 100,00**
200 kVA	R10 394,74 + VAT = **R11 850,00**
315 kVA	R11 052,63 + VAT = **R12 600,00**
500 kVA	R18 464,91 + VAT = **R21 050,00**
1 000 kVA	R36 885,96 + VAT = **R42 050,00**
> 1 000 kVA	The greater of R36 885,96 + VAT or 5% of allocated costs

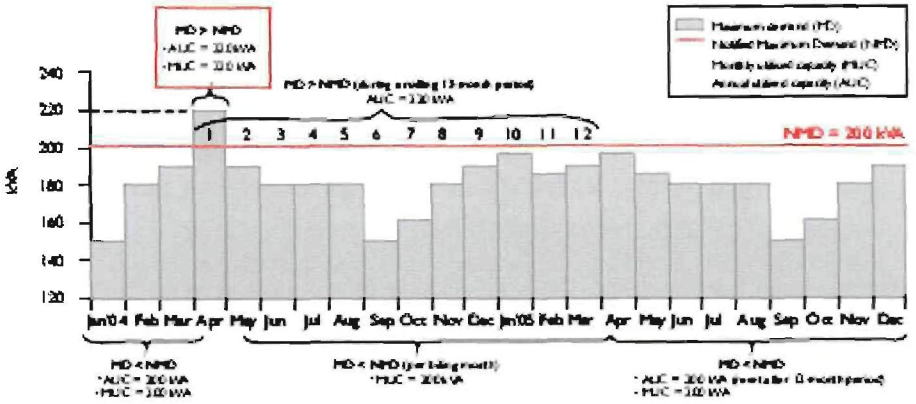
R Rounded to the nearest Rand value.

Appendices *continued...*



Appendix F: Illustration of monthly & annual utilised capacity

- **Monthly utilised capacity** (MUC) is the higher of the customer's notified maximum demand (NMD) or maximum demand (MD), measured in kVA, and registered during the billing month.
- **Annual utilised capacity** (AUC) is the higher of the customer's NMD or MD, measured in kVA, registered during a rolling 12-month period.



Month	MD (kVA)	NMD (kVA)	Comments	MUC (kVA)	AUC (kVA)
January '04	150	200	NMD is higher than MD for billing month and over a 12-month period.	200	200
February	180	200			
March	190	200			
April	**220**	**200**	**MD is higher than NMD**	**220**	**220**
May	195	200	NMD is higher than MD for the billing month. (MUC is reset.) MD registered in April '04 is higher than NMD over a 12-month period. (AUC remains at higher level.)	200	220
June	180	200			
July	180	200			
August	180	200			
September	150	200			
October	160	200			
November	180	200			
December	190	200			
January '05	195	200			
February	185	200			
March	190	200			
April	195	200	NMD is higher than MD for billing month and over a 12-month period. (MD registered in April '04 is no longer applicable. AUC is reset.)	200	200
May	185	200			
June	180	200			
July	180	200			
August	180	200			
September	150	200			
October	160	200			
November	180	200			
December	190	200			

Appendices *continued...*

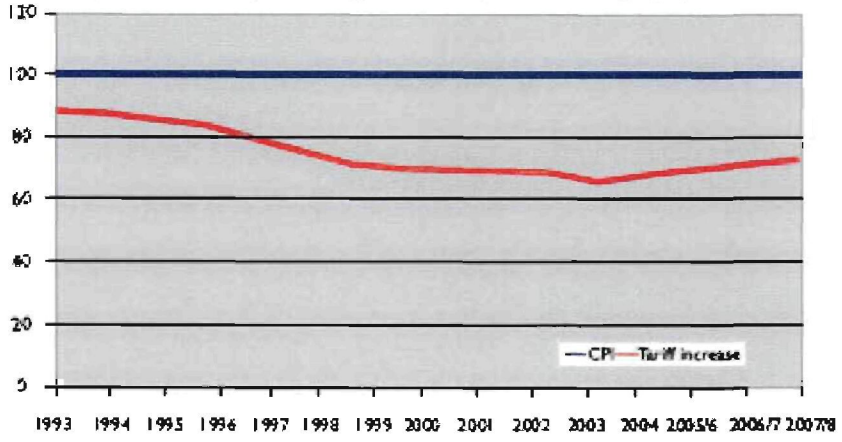
Appendix G: Eskom's average price adjustment

Eskom's tariffs are adjusted on an annual basis previously on 1 January, but due to the change in Eskom's financial year price adjustments now take place on 1 April every year. The average tariff adjustments for the last 15 years are indicated in the table below. Some tariffs, due to structural changes, have experienced a higher or lower impact than the average tariff adjustment.

Eskom's average tariff adjustment for the last 15 years

Year	Average tariff adjustment	CPI
1 January 1993	8,00%	9,87%
1 January 1994	7,00%	8,82%
1 January 1995	4,00%	8,71%
1 January 1996	4,00%	7,32%
1 January 1997	5,00%	8,62%
1 January 1998	5,00%	6,87%
1 January 1999	4,50%	5,21%
1 January 2000	5,50%	5,37%
1 January 2001	5,20%	5,70%
1 January 2002	6,20%	9,20%
1 January 2003	8,43%	5,80%
1 January 2004	2,50%	1,40%
1 January 2005	4,10%	3,42%
1 April 2006/7	5,10%	(projected) 4,60%
1 April 2007/8	5,90%	(projected) 5,20%

Eskom's tariff adjustment as a percentage of CPI (cumulative graph) – Base = 1990





Appendix H: Pricing of electricity

Eskom's average price for electricity is based on the overall cost of supply but, in order to determine tariffs, it is first necessary to break down the overall costs into relevant cost categories. Costs are expressed in a manner that will ultimately be applied to derive the tariffs according to an appropriate cost driver. By using the correct cost driver for each cost component, inappropriate pooling of costs is reduced.

Common cost drivers are:

- R/customer/month or R/customer/day - typically for customer service and administration costs
- R/kVA - typically for network costs
- c/kWh - typically for energy costs
- c/kvarh - reactive energy costs
- Energy loss factors for energy loss costs

The cost of providing electricity to customers varies according to:

- The quantity of electricity used and the period (time or season) when the electricity is used
- The size/capacity of the supply required
- The geographic location of the customer
- The voltage at which supply is provided
- The cost of connecting a supply

A totally cost-reflective tariff will reflect the cost drivers and the factors that could influence cost by taking into account the following:

- The time of use and seasonal variance of energy costs
- Unbundled costs for distribution and transmission networks. These costs are differentiated according to:
  - The supply voltage
  - The density of the points of delivery
- Retail charges that reflect the size of the customer and the service provided
- A connection charge that reflects the location of the supply and the impact on upstream costs

However, the tariff applied depends on meter capability, billing functionality and logistics, as well as limitations on tariff complexity and the impact of changes to existing tariffs. For more energy-intensive users of electricity, tariff structures tend to be more complex, whereas for users such as domestic customers tariffs are simpler.

Appendices *continued...*



A larger customer will have a much lower supply cost than a smaller customer. In Eskom, larger customers generally subsidise smaller customers. The reasons for the higher cost for small customers are as follows:

- As a ratio of overall consumption, smaller customers tend to use much more electricity in the more expensive peak periods and have a poorer load factor than that of larger customers.
- Significantly more network capacity is required at the lower voltage level (e.g. 500V) to supply a smaller customer than is required to supply a larger customer (e.g. 132kV). This means that more electrical networks have to be built, maintained and operated to supply smaller customers. Also, more electrical losses occur in the latter sector.

For Eskom the overall price of electricity is regulated and is based on approved costs plus a return on investment as determined by the National Energy Regulator of South Africa (NERSA). While Eskom's ***average*** price (total revenue/total consumption) is based on cost, ***individual*** price levels per customer or per customer class might not be cost-reflective. This is due to cost averaging, historical cross-subsidies and social factors such as the customer's ability to pay the determined price.

Pro-rating of customer bills

The rates will be pro-rated based on the number of days in each period:

- At times of price changes.
- Where a billing period spans the price change period.
- Where readings for demand or energy are not measured.



Appendices *continued...*



Appendix I: Energy saving tips for residential customers

Here are some energy saving tips that can help consumers to use electricity effectively especially during peak times.

Peak times are between 07:00 and 10:00 in the morning and 18:00 and 21:00 in the evening. These are the times during which most households consume large amounts of electricity. So, consumers can use appliances as efficiently as possible by switching off non-essentials during these peak periods, and in this way a surprising amount of electricity can be conserved.

Air conditioner: 	Avoid using the air conditioner to heat your bedroom, because as far as appliances go, it's the largest user of electricity in your house.
Cellphone: 	If your cellphone is not charging, unplug the charger from the wall - remember, while it is plugged in it still pulls current!
Computer: 	Always switch your computer off at the main power switch. If you leave it on standby or on sleep mode, it uses up to 50% of the power it uses when it is actually on.
Dishwasher: 	Remember, every time you switch on your dishwasher, it's the same as switching on 120 CFLs (compact fluorescent lamps). So, to save electricity, wait until the dishwasher is full and use it only during off-peak periods.
Electric blanket: 	Instead of heating the entire bedroom with a heater or air-conditioner, use an electric blanket to make your bed cosy. But switch off the electric blanket before you fall asleep. It's not only dangerous to keep it on while you are sleeping, it's an energy waster.
Fridge: 	When you leave your fridge door open for a long time, the fridge loses cool air. To cool it down again takes a lot of electricity. So be quick and don't let all that cool air out!
Geyser: 	To save electricity, get a geyser blanket. Insulate the hot water pipes and turn the thermostat down to 60 degrees. Better still, switch off your geyser when you get home after work and switch it back on when you go to bed. Take a shower in the mornings rather than a bath; you'll save a small fortune.

Appendices *continued...*



Heater: 	To save electricity in winter, use a temperature-controlled oil heater or a gas heater.
Kettle: 	Pouring one cup of water into the kettle for one cup of tea will save time and money. Also remember that boiling water in a kettle is much easier and cheaper than using the stove.
Light bulb: 	Replace as many of your light bulbs as possible with CFL energy-saving bulbs. They last much longer and they use far less electricity. (CFLs last eight times longer and use 80% less electricity than ordinary light bulbs.) Also, remember to switch off non-essential lighting; you'll save a lot of money in the long run.
Microwave: 	Did you know that a conventional oven uses the same amount of power as 18 microwave ovens? So, rather use a microwave oven to cook. It's much quicker and a lot cheaper.
Printer and related equipment: 	Any office equipment, such as printers, should also be switched off when they are not in use. By leaving them on, you're just wasting electricity and putting the machine under unnecessary strain.
Radio: 	Here's another tip to tune into. If you're not listening to the radio or the stereo system, switch it off. It's an instant saving.
Shower: 	Shower instead of taking a bath; you'll save a considerable amount of money. And by fitting a low-flow shower head, you will save even more money.
Stove: 	When you use your stove, match your pots to the size of your stove plate. Also, keep the lid on the pot to conserve heat and energy.
Tumble dryer: 	When the weather is good, try drying your clothes on the line outside. It's just as effective as the tumble dryer and you'll save a lot of money in the long run.
TV: 	Did you know that if you leave your TV on standby mode, the standby light alone uses up to 50% of the power that your TV uses when it is actually on? So, switch it off at the power button if nobody is watching. You'll be amazed at how much electricity you'll save.