

# **THE MANAGEMENT OF ELECTRICITY COST WITHIN AN ACADEMIC INSTITUTION**

by

**James Edward Calmeyer**

Submitted in partial fulfillment of the requirements for the degree

**Master of Engineering (Electrical Engineering)**

in the

**Faculty of Engineering**

**UNIVERSITY OF PRETORIA**

October 1999

<b>Title:</b>	The Management of Electricity Cost within an Academic Institution
<b>Author:</b>	James Edward Calmeyer
<b>Supervisor:</b>	Prof GJ Delpont
<b>Department:</b>	Electrical, Electronic and Computer Engineering
<b>Degree:</b>	Master of Engineering (Electrical)

### SUMMARY

With the rationalisation of government and sponsor funding, concern for the environment, increasing energy prices and possible government legislation, institutions have begun to pursue the management of resource cost and in particular the cost of electrical energy. Unfortunately an abundance of financial and human resources are not available within these institutions and as such these programmes are very seldom initiated or supported. The solution lies in the adoption of a systematic approach that ensures the sustainability and viability of an energy management programme.

The systematic approach to an energy management programme involves a clear definition of the link between an energy policy and energy strategy and the subsequent breakdown of the energy strategy into four areas-of-activity, namely Energy Diagnosis, Energy Load Management, Energy Maintenance Management and Energy Awareness and Education. This novel methodology ensures that the often forgotten areas of maintenance and awareness are brought into the energy management fray ensuring the completeness of the energy management programme. Each area-of-activity is covered in detail in a separate chapter. The conclusion of this dissertation focuses on evaluation methods with which to provide feedback and ensure that the energy strategy and policy remain focussed on the task of managing the electricity cost.

This dissertation includes all of the energy management and financial analysis tools that are required in order to plan and evaluate individual projects and where necessary, the models and methodologies in this dissertation have been explained through elements of the energy management programme at the University of Pretoria.

### KEYWORDS

Academic Institution, Energy Management Programme, Energy Policy, Energy Strategy

## Opsomming

---

<b>Titel:</b>	Die Bestuur van Elektriesiteitskoste binne 'n Akademiese Inrigting
<b>Outeur:</b>	James Edward Calmeyer
<b>Toesighouer:</b>	Prof GJ Delport
<b>Departement:</b>	Elektries, Elektroniese en Rekenaar Ingenieurswese
<b>Graad:</b>	Meester in Ingenieurswese (Elektries)

### OPSOMMING

Met die rationalisering van die staats- en borgbefondsing, omgewingsbesorgdheid, toenemende energiepryse en moontlike regeringswetgewing, het inrigtings begin om hulpbronskostebestuur na te streef – in besonder die koste van elektriese energie. Ongelukkig is 'n oorvloed van finansiële en menslike hulbronne nie beskikbaar binne hierdie inrigtings nie, en daarom word sulke programme baie selde op die been gebring of ondersteun. Die oplossing lê in die aanname van 'n stelselmatige benadering, wat die instandhouding en uitvoerbaarheid van die energie program sal verseker.

Die sistematiese benedaring tot 'n energiebestuur program, behels 'n duidelike definisie van die skakel tussen 'n energiebeleid en –strategie en die gevolglike ontleding van die energiestrategie in vier aktiwiteitsareas, naamlik Energiediagnose, Energielasbeheer, Energieonderhoudbestuur en Energiebewustheid en -opvoeding. Hierdie unike metodiek veresker dat die gebiede van onderhoud en bewustheid wat dikwels vergeet word ook na die energiebesturomgewing toegevoeg word. Dit verseker die volledigheid van die energiebestuursprogram. Die vier aktiwiteitsareas word elkeen in diepte in aparte hoofstukke behandel. Die gevolgtrekking van hierdie verhandeling fokus op evaluaeringsmetodes waardeur terugvoer voorsien kan word om te verseker dat die energiestrategie en –beleid op die taak van bestuur van elektrisiteitskoste toegespits word.

Hierdie verhandeling sluit all energiebestuur- en finansiële ontledingsgereedskap wat benodig word om individuele projekte te evalueer en waar nodig, die modelle en metodiek in hierdie verhandeling word deur die elemente van die energiebestuursprogram van die Universiteit van Pretoria verduidelik.

### SLEUTELWOORDE

Akademiese Inrigting, Energiebestuursprogram, Energiebeleid, Energiestrategie

---

## ACKNOWLEDGMENTS

There are many people I need to acknowledge and thank for helping me to finish this dissertation. Without their constant encouragement and caring support the past two years would have been very difficult.

- To the Lord, my God, this piece of work and all those that follow I dedicate to Your glory.
- My colleagues at the University of Bordeaux in France, Prof Jacques Roturier, Dr Jean-Francois Bonnet and Dr Patrick Faucher, who have opened my eyes to a wider scope of energies and etched the environment on my list of concerns.
- To my mentor and close friend, Johan Delpont. All that I know and understand about energy management I owe to you. Thank you for teaching me how to think and for the experience of an overseas trip to France and the Netherlands. Our sessions in front of the whiteboard have proved that you still are the master. The University of Pretoria is truly fortunate.
- To my parents who sacrificed a great deal in order to give me my opportunities in life. I am truly blessed to have such parents and this dissertation would not have been possible without your tireless patience and unselfish sacrifices during my studies.
- To my family and friends, especially Graham, who always had time to enquire about my progress and kept me sustained and refuelled in front of my computer.
- To my Grandparents. I wish you were all alive to share in this work. I miss you all.
- To my dearest Lindy, I love you. We have sacrificed a great deal in order for me to complete this dissertation. I dedicate it to you. You are my soulmate and confidant and your support through all the years is priceless. I look forward to spending the rest of my life with you.

*To Lindy*

---

**TABLE OF CONTENTS**

<b>1</b>	<b>PROBLEM IDENTIFICATION AND BACKGROUND</b>	<b>1</b>
1.1	ENERGY MANAGEMENT BACKGROUND	1
1.2	ENERGY MANAGEMENT IN SOUTH AFRICA	3
1.3	DEMAND-SIDE MANAGEMENT AND THE ROLE OF GOVERNMENT	4
1.4	PROGRAMME ACCEPTANCE AT ACADEMIC INSTITUTIONS	6
1.5	ENERGY MANAGEMENT PROGRAMMES AT INTERNATIONAL ACADEMIC INSTITUTIONS	10
1.6	ENERGY MANAGEMENT PROGRAMMES AT SOUTH AFRICAN ACADEMIC INSTITUTIONS	12
1.7	DISSERTATION OBJECTIVES	14
1.8	HOW THIS DISSERTATION IS STRUCTURED	15
<b>2</b>	<b>PRINCIPLES OF AN ENERGY MANAGEMENT PROGRAMME</b>	<b>16</b>
2.1	INTRODUCTION	16
2.2	SCHEMATIC REPRESENTATION OF THE ENERGY MANAGEMENT PROGRAMME	17
2.3	AN ENERGY POLICY	18
2.4	AN ENERGY STRATEGY AND AREAS-OF-ACTIVITY	21
2.5	ENERGY POLICY AND STRATEGY INTERACTION	22
2.6	AREA-OF-ACTIVITY INTERACTION IN THE ENERGY STRATEGY	23
2.6.1	<i>Example of a Lighting Retrofit Project</i>	24
2.6.2	<i>Example of a Lighting Maintenance Project</i>	25
2.6.3	<i>Summary</i>	26
2.7	STAFFING REQUIREMENTS OF THE ENERGY MANAGEMENT PROGRAMME	27
2.8	CONCLUSION	28
<b>3</b>	<b>THE ENERGY MANAGER'S TOOLBOX</b>	<b>30</b>
3.1	INTRODUCTION	30
3.2	ELECTRICITY LOAD ANALYSIS	30
3.2.1	<i>Load Profiles</i>	30
3.2.2	<i>Load Duration Plots</i>	31
3.2.3	<i>Scatter Plots</i>	32
3.2.4	<i>Power Factor (PF)</i>	33
3.2.5	<i>Load Factor (LF)</i>	34
3.2.6	<i>Coincident Maximum Demand and Diversity Factor</i>	35
3.3	ELECTRICITY TARIFFS	36
3.3.1	<i>Tariff Design</i>	36
3.3.2	<i>The Demand Tariff (or the Two-part Tariff)</i>	38
3.3.3	<i>The Time-Of-Use Tariff</i>	38
3.3.4	<i>Notified Demand Tariff</i>	39
3.3.5	<i>Equivalent Cost Per Unit (c/kWh)</i>	39
3.4	FINANCIAL ANALYSIS	40
3.4.1	<i>Cash Flow Diagrams</i>	40

## Table of Contents

3.4.2	<i>Time Value of Money</i>	40
3.4.3	<i>Net Present Value (NPV)</i>	41
3.4.4	<i>Internal Rate of Return (IRR)</i>	42
3.4.5	<i>Payback Period</i>	43
3.4.6	<i>Minimum Attractive Rate of Return (MARR)</i>	43
3.5	SUMMARY	43
<b>4</b>	<b>ENERGY DIAGNOSIS</b>	<b>45</b>
4.1	INTRODUCTION	45
4.2	INSIDE THE ENERGY DIAGNOSIS AREA-OF-ACTIVITY	46
4.3	PURPOSE	47
4.3.1	<i>Benchmarks</i>	47
4.3.2	<i>Benchmark Fluctuations</i>	48
4.4	DATA ACQUISITION	50
4.4.1	<i>Documentation Audit</i>	50
4.4.2	<i>Personnel Audit</i>	50
4.4.3	<i>Walk Audit</i>	51
4.4.4	<i>Measurement Audit</i>	52
4.4.5	<i>Benchmark Calculation Case Study</i>	52
4.5	INFORMATION PROCESSING	56
4.6	DISSEMINATION OF KNOWLEDGE	57
4.7	CONCLUSION	59
<b>5</b>	<b>ENERGY LOAD MANAGEMENT</b>	<b>60</b>
5.1	INTRODUCTION	60
5.2	INSIDE THE ENERGY LOAD MANAGEMENT AREA-OF-ACTIVITY	60
5.3	ECONOMIC ANALYSIS	61
5.4	EQUIPMENT UPGRADES: A LIGHTING CASE STUDY	65
5.5	DIRECT EQUIPMENT CONTROL: A HOT WATER CASE STUDY	69
5.6	INSTALLATION OF NEW EQUIPMENT: A POWER FACTOR CORRECTION CASE STUDY	74
5.7	PROJECT PRIORITISATION	78
5.8	IMPLEMENTATION	81
5.9	CONCLUSION	82
<b>6</b>	<b>ENERGY MAINTENANCE MANAGEMENT</b>	<b>84</b>
6.1	INTRODUCTION	84
6.2	INSTITUTION MAINTENANCE	85
6.3	INSIDE THE ENERGY MAINTENANCE MANAGEMENT AREA-OF-ACTIVITY	87
6.4	PLANNING	88
6.5	SCHEDULING	89
6.6	IMPLEMENTATION	89
6.7	MAINTENANCE EXAMPLES	90
6.7.1	<i>Building Preventive Maintenance</i>	90

## Table of Contents

6.7.2	<i>Lighting Maintenance</i>	91
6.7.3	<i>Sub-Station Reliability</i>	92
6.8	CONCLUSION	93
<b>7</b>	<b>ENERGY AWARENESS AND EDUCATION</b>	<b>95</b>
7.1	INTRODUCTION	95
7.2	A MARKETING STRATEGY	95
7.3	INSIDE THE ENERGY AWARENESS AND EDUCATION AREA-OF-ACTIVITY	97
7.4	IDENTIFYING THE TARGET MARKET	98
7.5	SELECTING A MEDIUM	98
7.6	DESIGNING THE MESSAGE	99
7.7	CASE STUDIES	100
7.7.1	<i>Separate Metering and Billing of Vendors</i>	100
7.7.2	<i>Light Audit Night</i>	102
7.8	CONCLUSION	103
<b>8</b>	<b>EVALUATING THE ENERGY MANAGEMENT ACTIVITIES</b>	<b>105</b>
8.1	INTRODUCTION	105
8.2	EVALUATING THE ENERGY STRATEGY	105
8.2.1	<i>Internal Evaluation: Intra-Institution Comparison</i>	106
8.2.2	<i>External Evaluation: Inter-Institution Comparison</i>	109
8.3	EVALUATING THE ENERGY POLICY	111
8.4	EVALUATING THE ENERGY MANAGEMENT PROGRAMME	111
8.5	ACQUIRING FUNDING	114
8.6	THE EMPLOYMENT OF SAVINGS	115
8.7	CONCLUSION	118
<b>9</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	<b>120</b>
9.1	INTRODUCTION	120
9.2	CONCLUSIONS ON THE OBJECTIVES	120
9.3	RECOMMENDATIONS AND FUTURE WORK	123
9.3.1	<i>Recommendations Regarding Energy Management on Campus</i>	124
9.3.2	<i>Future Work</i>	126
<b>10</b>	<b>REFERENCES</b>	<b>128</b>
<b>11</b>	<b>APPENDIX A: MONTHLY ENERGYWISE REPORT</b>	<b>133</b>
<b>12</b>	<b>APPENDIX B: MONTHLY HOSTELWISE REPORT</b>	<b>134</b>
<b>13</b>	<b>APPENDIX C: COMPACT FLUORESCENT LAMP POSTER</b>	<b>135</b>
<b>14</b>	<b>APPENDIX D: HOSTEL INFORMATION POSTER</b>	<b>136</b>
<b>15</b>	<b>APPENDIX E: COMPUTER EFFICIENCY POSTER</b>	<b>137</b>