

LB/DOM/22/04

No 7

# ECONOMIC POTENTIAL OF ENERGY CONSERVATION IN A FIVE STAR HOTEL

By -

**ABDUL MAJEED MUZATHIK**

BSc.Eng. (Hons.) THE UNIVERSITY OF MORATUWA, SRI LANKA.



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
www.lib.mrt.ac.lk

Thesis submitted to the Department of Mechanical Engineering of the University of Moratuwa in partial fulfillment of the requirements for the Degree of Master of Engineering in Energy Technology.

621.03  
620.9

University of Moratuwa



79623

**DEPARTMENT OF MECHANICAL ENGINEERING  
FACULTY OF ENGINEERING  
UNIVERSITY OF MORATUWA**

**SRI LANKA**

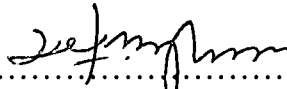
October 2003

79623

79623

## DECLARATION

I hereby declare that to the best of my knowledge, this submission is my own work and it contains neither direct material previously published nor written by another person or material, which to substantial extent, has been accepted for the award of any other academic qualification of a university or other institute of higher learning except where acknowledgment is made in the text.



.....  
A M Muzathik

October 2003



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## ABSTRACT

Economic potential of energy conservation in a five star hotel was established. The selected site was the Hotel Lanka Oberoi, Colombo. The electrical energy demand and the thermal energy demand of the hotel were assessed using the results of an energy audit carried out in the Hotel by the Energy Conservation Fund (ECF). It was found that there are several energy conservation opportunities (ECOs) for the Hotel.

Economic analysis was carried out for the six ECOs of VAV Systems, Low-e Glass Systems, Daylighting Control Systems, Energy Efficient Lighting Systems, Indoor Temperature Set Up and Thermal Energy Storage Systems.

It showed that all the six ECOs are feasible with favorable economic parameters. Nevertheless there are merits and demerits among each of these ECOs and these were discussed with reference to each ECOs. Among the ECOs, VAV Systems and Energy Efficient Lighting Systems have the most favorable economic parameters with a payback period of 0.6 years and 0.2 years respectively.

## TABLE OF CONTENTS

ITEM	PAGE
DECLARATION	I
ABSTRACT	II
TABLE OF CONTENTS	III
LIST OF TABLES	VIII
LIST OF FIGURES	XI
ABBREVIATIONS	XIII
ACKNOWLEDGEMENT	XIV
1.0 RESEARCH PROBLEM BEING ANALYZED	
1.1 Background	1
1.2 Energy Use in Sri-Lanka	3
1.3 Energy used in buildings and Industries	6
1.4 Introduction to Energy Conservation	7
1.5 Research Problem at the Scene	11
1.6 Objective of the Study	12
1.7 Rational and Justification	13
2.0 LITERATURE SURVEY ON BUILDING ENERGY EFFICIENCY AND CONSERVATION	
2.1 Energy Audits	14
2.1.1 Walk – Through Audits	14
2.1.2 Utility Cost Analysis	14
2.1.3 Standard Energy Audits	16
2.1.4 Detailed Energy Audits	16

2.1.5	General Procedure for a Detailed Energy Audit	17
2.1.5.1	Building and Utility Data Analysis	18
2.1.5.2	Walk-through Survey	19
2.1.5.3	Baseline for Building Energy Use	19
2.1.5.4	Evaluation of Energy Savings Measures	20
2.1.6	Common Energy Conservation Measures	23
2.1.6.1	Building Envelope	23
2.1.6.2	Electrical Systems	26
2.1.6.3	HVAC Systems	31
2.1.6.4	Energy Management Controls	35
2.1.6.5	Indoor Water Management	36
2.1.6.6	New Technologies	37
2.2	Energy Analysis Tools	43
2.2.1	Introduction	43
2.2.2	Ratio-Based Methods	45
2.2.2.1	Types of Ratios	47
2.2.3	Inverse Modeling Methods	49
2.2.3.1	Steady-State Inverse Models	50
2.2.3.2	Dynamic model	52
2.2.4	Forward modeling methods	53
2.2.4.1	Steady-state methods	53
2.2.4.2	Degree Day Methods	53
2.2.4.3	Bin Methods	54
2.2.5	Dynamic methods (Computer Simulation)	55
2.3	Method for Estimating Energy Savings	59
2.3.1	General Procedure	60
2.3.2	Energy Savings Estimation Models	62
2.3.2.1	Simplified Engineering Methods	62
2.3.2.2	Regression Analysis Models	62

2.3.2.3	Dynamic Models	65
2.3.2.4	Computer Simulation Models	66
2.4	Economic Evaluation Methods to Select Alternatives	69
2.4.1	Net Present Worth	69
2.4.2	Rate of return	70
2.4.3	Benefit -Cost Ratio	71
2.4.4	Payback Period	71
2.4.5	Internal Rate of Return	72
2.4.6	Life-Cycle Cost Analysis Method	73
2.4.7	General Procedure for Economic Evaluation	74

### 3.0 ENERGY SITUATION OF THE HOTEL LANKA OBEROI

3.1	Introduction	77
3.2	Construction Details	78
3.3	Electrical System	81
3.4	Thermal System	82
3.5	Air Conditioning System	82
3.6	Existing Energy Balance	82
3.6.1	Annual Energy Balance Year 2000	84
3.6.2	Annual Energy Balance year 2001	85
3.7	Electricity Demand profile	87
3.8	Tariff System	88
3.9	Lighting	90
3.10	Pumping Stations	91
3.11	Laundry Equipment	91
3.12	Kitchen/Bakery Equipment	91

4.0	ENERGY AND ECONOMIC ANALYSIS OF CONSERVATION OPTIONS IN THE HOTEL - USING DOE2	
4.1	Methodology	92
4.2	Simulation Model	92
4.3	The Flowchart of Visual DOE	95
4.4	Input Information for Visual DOE	96
4.5	Weather Input Data	97
4.6	Economic Parameters	98
4.7	Simplifications	99
4.8	Calibration	99
4.9	Calibration Result	101
4.10	Energy Conservation Opportunities	103
4.10.1	CAV Systems Replaced by VAV Systems	104
4.10.2	Clear Glass Replaced by Low-e Glass Systems	105
4.10.3	Daylighting Control Systems	105
4.10.4	Energy Efficient Lighting Systems	105
4.10.5	Indoor Temperature Set Up	106
4.10.6	Thermal Energy Storage (TES) Systems	106
4.11	Analysis of Selected ECOs by Visual DOE	107
4.12	Economic Analysis of ECOs	111
4.12.1	Investment Cost Estimation	111
4.12.2	Payback-Period Calculation	112
4.12.3	Calculation for Cost of Conserved Energy	113
4.12.4	IRR Calculation	114
5.0	RESULTS AND DISCUSSION	117
6.0	CONCLUSIONS	124

**APPENDIX**

APPENDIX	A:	Data related to Hotel Lanka Oberoi	130
APPENDIX	B	Input Information for Visual DOE	135
APPENDIX	C	Detail Calculations	140
APPENDIX	D	Visual DOE Outputs	150
APPENDIX	E	Sample Visual DOE Printed Results	163



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)



## LIST OF TABLE

### CHAPTER 1

Table 1.1: Energy consumption by region

Table 1.2: Energy consumption by energy sources for commercial source attributed to commercial and residential buildings in Sri Lanka.

Table 1.3: Energy Intensity by Principal Buildings Activity in kWh/m<sup>2</sup>.

### CHAPTER 2

Table 2.1: Energy Audit Summaries for Residential & Commercial Buildings

Table 2.2: Typical efficiencies of Motors

Table 2.3: Usage characteristics of water-using fixtures

Table 2.4: Energy Ratio (Energy Intensity) by Principal building activity in kWh/m<sup>2</sup>



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

### CHAPTER 3

Table 3.1: Building Construction Materials

Table 3.2: Energy Sources for year 2000 and 2001.

Table 3.3: Unit cost comparison of the energy source.

Table 3.4: The Electrical Tariff System.

Table 3.5: Maximum and Minimum kWh of Transformers.

Table 3.6: Lamp Population of the Hotel.



## CHAPTER 4

Table 4.1: Monthly Electricity Usage (kWh) by Visual DOE

Table 4.2: Electrical Use Summary for Base-Case and Six ECOs

Table 4.3: Cumulative Electrical Saving (kWh) of ECOs, Compared with Base-Case, negative savings represent increases

Table 4.4: Annual Electrical Energy Savings Compared with Base-Case

Table 4.5: Investment cost summary of ECOs.

Table 4.6: Economic Analysis Summary of six ECOs

## APPENDIX A

Table A1: Chiller Details.

Table A2: Cooling Tower Details.

Table A3: Water Consumption for year 2000 and 2001.

Table A4: Conversion Factor



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Table A5: Occupancy Percentage for year 2000 and 2001.

Table A6: Condenser Water Pumps.

Table A7: Chilled Water Pumps.

Table A8: Chilled Water Booster Pumps.

## APPENDIX D

Electrical End-use Totals (kWh)

Incremental Electrical Savings (kWh)

Cumulative Electrical Savings (kWh)

Energy Cost Summary (\$/y)

Total Energy Costs (\$/y)

Incremental Energy Savings (\$/y)

Cumulative Energy Savings (\$/y)  
Monthly Electrical Usage (kWh)  
Monthly Electrical Power (kW)



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## LIST OF FIGURES

### CHAPTER 1

Figure 1.1: Energy Supply by Source (2000)

Figure 1.2: Electricity Consumption by Sectors.

Figure 1.3: Per Capita Energy Consumption / Population Growth Ratio in Sri Lanka

### CHAPTER 2

Figure 2.1: Basic approach of a typical forward energy analysis model

Figure 2.2: Basic approach of a typical inverse energy analysis model

Figure 2.3: Flow chart of complete building model

Figure 2.4: Daily variation of building energy consumption

Figure 2.5: Typical calibration procedure for building energy simulation models



### CHAPTER 3

Figure 3.1: A typical floor of stage I

Figure 3.2: A typical floor of stage II & III

Figure 3.3: A typical floor of front office

Figure 3.4: A typical floor of the hotel

Figure 3.5: Energy share by source 2000

Figure 3.6: Energy cost share by source 2000

Figure 3.7: Energy share by source 2001

Figure 3.8: Energy cost share by source 2001

Figure 3.9: Comparison of unit cost by source.

Figure 3.10: Electricity Demand Profile.

## CHAPTER 4

Figure 4.1: Building zoning configuration for Visual DOE computer simulation

Figure 4.2 (a): Average monthly dry & wet bulb temperature data for Colombo

Figure 4.2 (b): Average monthly solar radiation for Colombo

Figure 4.3: Perspective view of Visual DOE model for the Hotel Lanka Oberoi

Figure 4.4: Plan view of Visual DOE model for the Hotel Lanka Oberoi

Figure 4.5: Calibration results of the monthly electricity predictions of Visual DOE model with actual billing electrical energy consumption in year 2000 for Hotel Lanka Oberoi

Figure 4.6: Percentage of electricity end-uses based on the calibrated Visual DOE model of Hotel Lanka Oberoi

## APPENDIX D

Visual DOE Outputs



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Electrical energy comparison between billing history and ECOs

Perspective views of Visual DOE model for the Hotel Lanka Oberoi



## ABBREVIATIONS

(Used in the thesis)

AC	Air Conditioning
AHU	Air Handling Unit
ASD	Adjustable Speed Drives
ASHRAE	American Society of Heating, Refrigerating & Air Conditioning Engineers
BCR	Benefit Cost Ratio
CAV	Constant Air Volume
CCE	Cost of Conserved Energy
CEB	Ceylon Electricity Board
CFL	Compact Fluorescent Light
COV	Coefficient of Variance
CRF	Capital Recovery Factor
CV	Constant Volume
DPB	Discounted Payback Period
ECO	Energy Conservation Opportunity
EMCS	Energy Management and Control System
FCU	Fan Coil Unit
FL	Fluorescent Light
GJ	Giga Joules
HP	Horse Power
HVAC	Heating, Ventilating and Air Conditioning
IAQ	Indoor Air Quality
IL	Incandescent Light
IRR	Internal Rate of Return
LCC	Life Cycle Cost
MBE	Mean Bias Error
M&V	Measurement and Verification
NA	Not Applicable
NNs	Neutral Networks
NPV	Net Present Value
NPW	Net Present Worth
O&M	Operation and Maintenance
ROR	Rate of Return
RT	Refrigerant Ton
SIR	Saving to Investment Ratio
SPB	Simple Payback Period
SPPW	Single Payment Present Worth
TES	Thermal Energy Storage
USPW	Uniform Series Present Worth
VAV	Variable Air Volume
VBDD	Variable Base Degree Days
VSD	Variable Speed Drives

## ACKNOWLEDGEMENT

I would be very much grateful to Mr. A. Gunasekara, Chief Engineer, Hotel Lanka Oberoi; Colombo for permitting the selection of the hotel for this study. I wish to express my deepest gratitude to Chief Engineer and all the supporting staff of the Hotel Lanka Oberoi, for their fullest support in collecting all the data in the hotel, related to my project.

I wish to thank Mr. H. Wickaramasighe, Director and Mr. Wimal Nadeera, Project Engineer, Energy Conservation Fund, for supporting to collect information on energy audit of hotel and power generation of Sri Lanka.

I would like to thank Prof. P D C Wijayatunga, Dean and the staff of the faculty of Information Technology, University of Moratuwa, Sri Lanka for permitting to use their computer facility to analyze the energy audit result of the hotel.



This research project was carried out under the supervision of Dr. R A Attalage, Head, Department of Mechanical Engineering and Prof. P D C Wijayatunga, Dean, Faculty of Information Technology, University of Moratuwa, Sri Lanka. I am indebted to them, for the valuable guidance, kind-hearted co-operation and encouragement extended throughout the study.

I am very thankful to Dr. A G T Sugathapala, M.Eng/PGD Course Coordinator, Energy Technology and Dr. K K C K Perera, Senior Lecturer, Department of Mechanical Engineering, University of Moratuwa, Sri Lanka for giving me the opportunity to do this research. In addition to the above I wish to thank my lecturers who helped me in providing valuable suggestions, recommendations and technical information to make this effort a success.

My M Eng would not have been materialized if the financial assistance by the Asian Development Bank through the Ministry of Science and Technology. I gratefully acknowledge the grant offered to me for my post-graduate program.

Finally, I would appreciate everybody, who helped me in numerous ways in different stages of the project, which was of utmost importance in bringing out this effort a success.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)