ENERGY CONSUMPTION AND POTENTIAL RETROFITTING OF HIGHWAY REST AND SERVICE AREAS (RSAs)

FARINEE BINTI AINEE

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

20 JANUARY 2012

DEDICATION

To my beloved mother,
who paints a picture of love in my heart every day.

Thank you for all love and inspiration
throughout the entire creation of this thesis.

I love you today, tomorrow and forever!

In Loving Memory of
Allahyarham Ainee Bin Kim
(10 November 1951- 17 September 2011)

"I love you, daddy!"

ACKNOWLEDGEMENT

Special thanks and sincere appreciation goes to my project report supervisor, Dr. Rozana binti Zakaria for her invaluable guidance, encouragement, advice and helpful insights to ensure this project complete accuracy. Thank you for gift of your time and reminding me when things got tough.

I would like to thank everyone at Lembaga Lebuhraya Malaysia (LLM) and PLUS Expressway for their cooperation and support during the creation of this thesis. I am forever indebted to PLUS Expresway officer, Tuan Haji Sulaiman Bin Abu Bakar for giving me best cooperation through sharing the information and responding to all the difficulty during the data collection process.

I'd also like to thank my family for all the moral, emotion and financial support. Many thanks go to my beloved mother, Habsah binti Mansor for all the motivational saying and keep me to stay on track of my goal. Remarkable merits to all my brothers who believe that my dream to finish this thesis was more than just a dream.

Special thanks to the following individuals for the interest in helping support my project and reminding that I could do it. To my best friend, Nurul Nadia, thanks for your rock-solid friendship over the years. Credits to EE Anuar who offered assistance and advice during the preparation of this thesis. I'd also like to thank Zaiton Anuar for your encouragement, support and kindness. And, of course million thanks to Hani for solid moral support and cheering me on every night as I pondered and wrote. To the sweetest people, Florianna Michael thanks for your thoughtful and energetic soul - reminding me to think "big".

I feel very blessed with all your love and support throughout this thesis completion. Who knew writing could be so much fun?

ABSTRACT

The reduction in energy usage is proven able to minimize the carbon dioxide emission. Therefore, by promoting energy efficiency at Rest and Service areas (RSAs) along the highway is able to decreasing the carbon dioxide emission. This study aims to compare the energy consumption of the RSA that utilized HVAC and non-HVAC. Thus, the study extends to determine the potential retrofitting of RSAs that responsive to energy reduction. Data collection conducted at the RSA in Johor Region. It found that energy consumption at Machap Northbound RSA was found very high compared to the other RSAs in Johor Region that not utilized full HVAC. It was proven that the usage of full HVAC system increasing the energy consumption at the RSA. Simultaneously, the carbon emission is also directional proportion to the energy consumption at the RSAs. Some retrofitting could be applied for energy efficiency in order to support the overall energy reduction at the RSAs. In conclusion, energy efficient RSAs can be achieved by promoting good energy management, applying best energy saving appliance and implementing passive design strategy.

ABSTRAK

Pengurangan penggunaan tenaga letrik terbukti dapat mengurangkan pembebasan gas karbon dioksida. Maka, dengan menggalakkan penggunaan tenaga letrik secara efisien di kawasan Rehat & Rawat (R&R) di sepanjang lebuh raya dapat mengurangkan pembebasan gas karbon dioksida. Kajian ini bertujuan untuk membandingkan penggunaan tenaga letrik di kawasan R&R yang menggunakan penghawa dingin (HVAC) dan yang tidak menggunakan penghawa dingin (non-HVAC). Sehubungan dengan itu, potensi penambahbaikan yang berpotensi untuk kawasan R&R yang lebih responsif kepada pengurangan tenaga letrik telah dikenalpasti. Pengumpulan data dijalankan di kawasan R&R Lebuhraya PLUS di bahagian Johor sahaja. Didapati penggunaan tenaga letrik di kawasan R&R Machap Utara agak tinggi berbanding kawasan R&R (bahagian Johor) yang tidak menggunakan penghawa dingin. Ini membuktikan penggunaan sistem penghawa dingin di kawasan R&R akan meningkatkan penggunaan tenaga untuk sesebuah bangunan. Maka, kadar pembebasan gas karbon dioksida juga meningkat naik, ia berkadar langsung dengan pengunaan tenaga letrik di kawasan R&R. Usaha untuk penambahbaikan penggunaan tenaga letrik yang lebih efisien dalam membantu mengurangkan pengunaan tenaga letrik secara menyeluruh di kawasan R&R patut dilaksanakan. Secara keseluruhannya, dapat disimpulkan bahawa penggunaan tenaga letrik yang efisien di kawasan R&R boleh dicapai melalui penggunaan pengurusan tenaga letrik yang baik, penggunaan alatan letrik yang jimat tenaga dan menggunakan strategi rekabentuk pasif.

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		ii
	DEDICATION		iii
	ACKNOWLEDMENT		iv
	ABSTRACT		v
	ABSTRAK		vi
	TABLE OF CONTENTS		vii
	LIST OF TABLES		xii
	LIST OF FIGURES		xiii
	LIST OF APPENDICES		xv
1	**INTRODUCTION**		
	1.1	**Introduction**	1
	1.2	**Problem Statement**	3
	1.3	**Research Aim**	4
	1.4	**Research Objectives**	4
	1.5	**Scope of Study**	5
	1.6	**Brief Research Methodology**	5
		1.6.1 Preliminary Stage of Study	5
		1.6.2 Data Collection and Analysis	5
		1.6.3 Conclusion Stage	6
	1.7	**Expected Findings**	6
	1.8	**Significant of the Study**	7

2 **LITERATURE REVIEW**

2.1 Introduction 8

2.2 Sustainable Revolution 9

2.2.1 Sustainable Construction and Design 10

2.3 Green Building 11

2.3.1 Concept of Green Building 11

2.3.1.1 Definition of Green Building 12

2.3.1.2 Principles of Green Building 13

2.3.2 Potential Retrofitting 18

2.3.3 Rating System for Green Building 22

2.3.3.1 BREEAM 23

2.3.3.2 LEED 25

2.3.3.3 Green Star 26

2.3.3.4 Green Mark 28

2.3.3.5 Green Building Index (GBI) 31

2.4 Energy Efficiency 34

2.4.1 Solar Energy System 35

2.4.2 Building Envelope 35

2.5 Obstruction in Green Building 36

2.5.1 Capital and Operating Budget 36

2.5.2 Lack of Research Investments 37

2.5.3 Product Information And Sourcing 38

2.5.4 Tradition 38

2.6 Greening the public building: RSA 39

2.6.1 Benefits to the Agency 40

2.6.2 Benefits to Future 41

2.6.2.1 Financial Performance 42

2.6.3 Example of Green Building 42

2.6.3.1 Case study: 100 Pine Street, San 42

		Francisco	
	2.6.3.2	Case study: Lewis & Clark State Office Building, Jefferson City	44
2.7	**Greening the RSA**		46
	2.7.1	Factors Influencing Energy Usage at RSA	47
	2.7.2	Materials/ Appliance Applied	47
	2.7.2.1	Solar Panel	48
	2.7.2.2	Green Roof	48
	2.7.2.3	Lighting	49
	2.7.2.4	Windows and Door	50
	2.7.3	Indoor Environment	50
	2.7.3.1	Heating, ventilating and air-conditioning (HVAC) systems	50
2.8	**Conclusion**		51
3	**METHODOLOGY**		
3.1	**Introduction**		52
3.2	**Background of the Study Area**		53
3.3	**Rational of Study Area Selection**		54
3.4	**Sample Size Determination**		56
3.5	**Sample Distribution**		56
	3.5.1	Method of Data Collection	57
	3.5.1.1	Primary Data Collection	59
	3.5.1.2	Secondary Data Collection	60
	3.5.1.3	Questionnaire	60
	3.5.1.4	Data Analysis	61
	3.5.1.5	Carbon Dioxide Emission Factors	61
	3.5.1.6	Likert's Scale	62
	3.5.1.7	Average Index	63
3.6	**Conclusion**		64

4	**DATA ANALYSIS, RESULTS AND DISCUSSION**		
	4.1	**Introduction**	65
		4.1.1 Demographic Information	66
	4.2	**Objective 1: To identify current energy consumption at the RSAs and carbon emission**	66
		4.2.1 Carbon Dioxide Emission	69
	4.3	**Objective 2: To identify causes lead to energy wastage**	70
		4.3.1 Pagoh RSA (Northbound & Southbound), Machap Southbound and Gelang Patah (Northbound & Southbound)	70
		4.3.2 Machap Northbound RSA	72
	4.4	**Objective 3: To identify potential retrofit to reduce energy consumption for RSAs**	74
		4.4.1 Pagoh RSA (Northbound & Southbound), Machap Southbound and Gelang Patah (Northbound & Southbound)	74
		4.4.2 Machap Northbound RSA	76
	4.5	**Objective 4: To propose action in order to retrofit the existing RSA**	78
		4.5.1 Active Response	78
	4.6	**Overall Conclusion**	80
5	**CONCLUSION AND RECOMMENDATION**		
	5.1	**Introduction**	81
	5.2	**Current Energy Consumption at the RSAs**	82

and Carbon Emission

5.3 Causes Lead to Energy Wastage 83

5.4 Potential Retrofit To Reduce Energy Consumption For RSAs 84

5.5 Propose Action in order to Retrofit The Existing RSA 85

5.6 Recommendation 86

5.6.1 Energy Management 86

5.6.2 Equipment 88

5.7 Limitation of Study 92

5.8 Recommendation for Futher Study 92

REFERENCES

APPENDICES

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Comparison of Non-Green Buildings and Green Buildings	13
2.2	The Green Star Rating Scale	28
2.3	Green Mark Points for New Buildings	30
2.4	Green Mark Points for Existing Buildings	30
2.5	Economic Benefits of ENERGY STAR and LEED Buildings	40
3.1	Number of Sample Questionnaire been Distributed for Every RSAs	56
4.1	Active Response from Professional Point of View	79
5.1	Energy Consumption and Estimated Carbon Dioxide Emission at RSA	82
5.2	Estimation of Overall Energy Usage According to Type of the RSA along the PLUS Expressway	83
5.3	Average Index Value For Significant Causes Lead to Energy Wastage at the RSAs	84
5.4	Average Index Value for Significant Potential Retrofit to be taken to Reduce Energy Wastage	85

LIST OF FIGURE

FIGURE NO.	TITLE	PAGE
1.1	Rest and Service Area (RSA)	2
2.1	Sustainable Development	9
2.2	100 Pine Street, San Francisco, California	44
2.3	Lewis & Clark State Office Building, Jefferson, Missouri	45
2.4	The Windows on the North and South Sides of the Building	46
3.1	Location of the Rest and Service Areas in Johor Region	53
3.4	Machap Northbound RSA	55
3.5	Pagoh Northbound RSA	55
3.2	Flow of Research Methodology	58
3.3	Likert's Scale Flow Chart	62
4.1	Energy Consumption at RSAs	67
4.2	Cost for Energy Consumption at RSAs	68
4.3	Carbon Dioxide Emission at RSAs	69
4.4	Percentage of Users' Opinion on Electrical Wastage at the RSAs at Pagoh (NB & SB), Machap SB and Gelang Patah (NB & SB) RSA	70
4.5	Average Index Value of Users' Opinion on Causes Lead to Energy Wastage at the Pagoh (NB & SB), Machap SB and Gelang Patah (NB & SB) RSA	71
4.6	Percentage of Users' Opinion on Electrical Wastage at the Machap Northbound RSA	72
4.7	Average Value Index of Users' Opinion on Causes Lead to Energy Wastage at the Machap Nortbound Rsas	73
4.8	Percentage of Users' Opinion on the Need of the RSA Retrofitting and Application of Energy	74

	Efficiency Elements at Pagoh RSA (Northbound & Southbound), Machap Southbound and Gelang Patah (Northbound & Southbound)	
4.9	Average Index Value for the Best Potential Retrofitting at Pagoh RSA (Northbound & Southbound), Machap Southbound and Gelang Patah (Northbound & Southbound)	75
4.10	Percentage Of Users' Opinion on the Need of the RSA Retrofitting and Application of Energy Efficiency Elements at the Machap Northbound RSA	76
4.11	Average Index Value for the Best Potential Retrofitting at the Machap Northbound RSAs	77
4.12	Percentage of RSAs that Applying the Elements of Energy Efficiency in Johor Region	78
5.1	Variable Refrigerate Flow (VRF) System	87
5.2	Programmable Logic Controller (PLC) System	87
5.3	LED Lighting Bulb	88
5.4	Compact Fluorescent Lights Passive Design Strategy	89
5.5	Water Fountain Helps to Humidify The Surrounding	90
5.6	Plants Help to Give Shade and Beautify the Area	91

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Sample of Questionnaire for RSA Users	90
B	Sample of Questionnaire for Profesionnal	91

CHAPTER 1

INTRODUCTION

This topic discusses in detail the important part in conducting a research; for example, problem statements, aims and objectives, scope to be covered and the research methodology. The rationale of the selection of the study area also been emphasized.

1.1 Introduction

Rest and Service Areas or also known as the RSAs or R&R are the well maintained facilities that provided for traveler a stop point during their long distance trip (refer Figure 1.1). For the comfortable and safety purpose, RSAs usually located every 80 to100 kilometers. RSA helps the visitor to refresh and resting themselves especially for those who travel for a long distance. Therefore, it is a must for this place to be able evoking the sense of comfortable as well as security. One of the best ways to generate this feeling is by enhancing the environment. The provisions of the RSAs are very helping especially in reducing accident rate and other problems on the highway. Normally, RSAs in Malaysia offering several basic needs for the visitors

such as children's playground, petrol stations, 'surau', auto-teller machines (ATM), ‘wakaf’ (rest shelters), public telephones and air-conditioned restaurants. Overall, there are 24 RSAs on the PLUS Expressways. There are located at Gelang Patah, Machap, Pagoh, Ayer Keroh, Mambau, Seremban, Dengkil, Rawang, Tapah, Sungai Perak, Gunung Semanggol, and Gurun. The RSAs can be found at both Northbound and Southbound.

Figure 1.1 Rest and Service Area (RSA)

The energy efficient of existing building can be achieved by retrofit; for example, installing low maintenance and cost-effective product. Some products and services might in initial be more expensive, but the savings over time are compelling. In general, energy efficiency is the goal of efforts to reduce the amount of energy required to provide comfortable indoor climate. Operational energy reduction can easily be implemented. A proper design of the building is the starting point for green building. A high performance building’s design will be able to reduce the energy

consumption via the good natural ventilation strategy and quality of day lighting. In addition, the soft-landscape will enhance the green environment of the RSAs by cooling the surrounding. The native landscape is perfectly adaptable to the local environment and therefore needs no irrigation or fertilizer. This can minimize the maintenance cost and solved multiple problems.

The concentration of the energy supply on fossil fuels has a drastic effect on the ecosystems and the overall environment. The use of fossil energy sources had led to a rapid rise in the emission of carbon dioxide and other greenhouse gases into the atmosphere. Estimated that 'at present urban agglomerations accounts account for up to seventy per cent of all carbon dioxide emission worldwide' (Scheer, 2002). This study will explore the ways in which the building design can drastically impact the consumable energy including improvement on the comfortable aspect. Besides that, the use of natural landscape as the shade, cooling effect and to beautify the site also will become one of the main purposes for this study.

1.2 Problem Statement

The main target for RSAs provision is to provide a better place for traveler to relax and refreshing themselves. However, it is a disregard when these good turn will give negative side effect to the surrounding environment. For example, the numbers of air conditioner installed in the RSAs may comfort the visitor; however, it will release the carbon dioxide (CO_2) that will contribute to the global warming. It is better if a win-win situation can be introduced.

In addition, the rest and service areas have to be more attractive in term of the landscape. It is because a relaxing area should be a pleasant place to be. In spite of this, there are a lot of the problems related to the landscape at the RSAs. It is disappointing because no action taken to solve the problems.

In this study, there are several problem statements highlighted include:

i. Lighting and air ventilation are depends on electrical appliance that used energy.
ii. The indoor air is too depending on the electrical energy increasing the energy consumption at the RSAs.
iii. Natural air ventilation for the building is not working very well and contributes to the increase in the energy consumption.
iv. Waste of electrical energy is frequently occurred because sometime it caters only for a few users.
v. Landscape materials are not well response to shade the RSAs, therefore more energy needed to cooling the building

1.3 Research Aim

This study aims to determine the potential retrofitting of RSAs that responsive to energy reduction by comparing the usage of energy in RSA of full HVAC and non-responsive.

1.4 Research Objectives

This study achieves the following objectives concern due to the importance of energy efficiency in building. The objectives are as follow:

i. To identify current energy usage at the RSAs.
ii. To identify causes lead to energy wastage.

iii. To identify potential retrofit to reduce energy consumption for RSAs.
iv. To estimate consumption of energy and carbon emission of RSAs.
v. To propose action in order to retrofit the existing RSA.

1.5 Scope of Study

There are four scopes in this study. There are listed as below:

i. The study focused only on the estimation of energy consumption for RSAs.
ii. This study only deals with the existing RSA and the potential retrofit process.
iii. The RSAs that been taken into account are the RSAs at PLUS Highway in Johor Region.
iv. The study compared the RSAs with full HVAC system and non-HVAC system.

1.6 Brief Research Methodology

This study was conducted at selected RSAs on the PLUS Expressway. Research methodology explains the stages in conducting the research. The detail research methodology is explained in Chapter 3. The research stages cover:

1.6.1 Preliminary Stage of Study

At this stage, a critical discussion and reading on the energy efficiency and energy reduction been done.

1.6.2 Data Collection and Analysis

Data were collected through questionnaire and also from observation. The data collection is divided into two phases. The first phase is conducted on RSAs' user from different background. Whilst, the second phase survey is conducted via email that been synchronize by the PLUS Expressway officer.

The main purpose is to know the users perspective on the causes that lead to energy wastage and potential retrofit in target to reduce energy consumption for the RSAs. The second phase survey is focusing on the professional group, it is conducted in order to know their point of view on actions to retrofit the existing RSAs been considered in line with the users response.

1.6.3 Conclusion Stage

Based on the data from the analysis, some recommendation has been made for the further action. The recommendations are discussed in Chapter 5.

1.7 Expected Findings

At the end of this study, several results are expected and hope will benefit for the future use. The study is expected to meet the objectives:

i. The RSAs are able to apply green technology idea to support the overall energy reduction initiative.
ii. Being able to highlight the potential of the existing RSAs in reducing the energy consumption especially after applying the green building concept.
iii. The landscape will use the native and soft landscape as the core landscape at the RSAs.

1.8 Significant of the Study

This study is important in order to promote the greening of the existing building in Malaysia especially in term of energy efficiency. Furthermore, the study can lead to a sustainable environment and promise a better living for the future generation.