



## **Faculty of Mechanical Engineering**

# **GREENING THE EXISTING BUILDING (CHANCELLERY BUILDING - UNIVERSITY TEKNIKAL MALAYSIA MELAKA)**

**Mustafa Khudhur Hussein Al-Ani**

**Master of Mechanical Engineering**

**(Energy Engineering)**

**2016**

**GREENING THE EXISTING BUILDING (CHANCELLERY BUILDING -  
UNIVERSITY TEKNIKAL MALAYSIA MELAKA)**

**MUSTAFA KHUDHUR HUSSEIN AL-ANI**

**A master project report submitted  
in fulfillment of the requirements for the degree of Master of  
Mechanical Engineering (Energy Engineering)**


**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2016**

## DECLARATION

I declare that this report entitles “Greening the Existing Building (Chancellery Building - University Teknikal Malaysia Melaka)” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

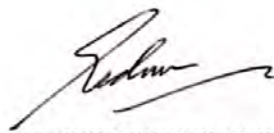
Signature :  .....

Author : Mustafa Khudhur Hussein Al-Ani

Date : 21-7-2016 .....

## APPROVAL

I hereby declare that I have read this report and in my opinion, this report is sufficient in terms of scope and quality for the award of Master of Engineering in Mechanical Engineering (Energy Engineering).

Signature :  .....

Supervisor : Dr. Reduan Bin Mat Dan

Date : 21 JULY 2016

**DR. REDUAN BIN MAT DAN**  
KETUA JABATAN (LOJI & PENYELENGGARAAN)  
FAKULTI KEJURUTERAAN MEKANIKAL  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA



## **DEDICATION**

This report work is dedicated to my beloved mother and father, whose have been a constant source of support and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life. This work is also dedicated to my brother who has always helped and support me. I also dedicate this thesis to my wife, without whose helpful support it would not have been possible, and my wonderful children, Aws and Mohanad.

## ABSTRACT

Buildings contribute significantly to the environmental and economic issues, as they consume a high amount of energy and water. As a building consumes energy, it contributes to emissions of carbon dioxide which lead to environmental pollution. These factors have a negative impact on the environment and the economy among other issues. Green building practices and approaches can considerably reduce or eliminate negative ecological and economic impacts. This study aims to “greening the existing building” (Chancellery Building - University Teknikal Malaysia Melaka) and achieve the “Certified” rating level according to the GBI classification, taking into consideration estimated cost. The green building audit results show the total current building rating level is only 18 off 100 points based on the major six criteria. Including Energy Efficiency (EE), Indoor Environment Quality (EQ), Sustainable Site Planning & Management (SM), Materials & Resources (MR), Water Efficiency (WE), and Innovation (IN), this shows the existing Chancellery building achieves a low rating level when evaluated according to the GBI rating system. To achieve a “Certified Rating Level” of (50 points) this study proposes improvements of existing building’s criteria (Retrofitting). The economic analysis involves the estimation of costs included in “Greening Existing Building” and the potential savings acquired from “Retrofitting”. The estimated cost of greening the proposed building is RM 800,764. This demonstrates the “Greening Existing Building” requires several improvements aspects which are considered very costly to attain. Additionally, the potential savings includes cutting costs from Lighting System and Building Integrated Photo Voltage. The potential savings from Lighting System is (67345.9 RM/year) and the payback period is (1.68 years). Also, the potential saving from Building Integrated Photo Voltage is (30492RM/year) and the payback period is (4.9 years).

## ABSTRAK

*Bangunan menyumbang kepada masalah alam sekitar dan ekonomi secara ketara, kerana infrastruktur ini menggunakan sumber tenaga dan air yang tinggi. Penggunaan tenaga ini turut menyumbang kepada pelepasan karbon dioksida di mana membawa kepada pencemaran alam sekitar. Persoalannya adalah bagaimana kesan terhadap alam sekitar dan ekonomi hasil dari faktor-faktor yang dinyatakan dapat dikurangkan. Pendekatan dan praktis bangunan hijau dapat mengurangkan atau menghapuskan impak ekologi dan ekonomi. Kajian ini bertujuan untuk “penghijauan bangunan sedia ada” (Bangunan Canselori – Universiti Teknikal Malaysia Melaka) dan mencapai tahap penilaian persijilan berdasarkan klasifikasi GBI berserta kos dipertimbangkan. Keputusan yang diperolehi dari Audit Tenaga menunjukkan jumlah paras penilaian bagi Bangunan Canselori pada Energy Efficiency (EE), Indoor Environment Quality (EQ), Sustainable Site Planning & Management (SM), Material & Resources (MR), Water Efficiency (WE), and Innovation (IN) hanya pada 18 dari 100 markah. “PENGHIJAUAN BANGUNAN SEDIA ADA” melibatkan cadangan penambahbaikan terhadap kriteria bangunan (Retrofit) untuk mencapai paras penilaian persijilan (50 markah). Analisis ekonomi melibatkan penganggaran kos Penghijauan Bangunan Sedia Ada dan penjimatan yang berpotensi dari Retrofit. Kos yang dianggarkan bagi Penghijauan Bangunan Sedia Ada adalah (RM 800,764). Tambahan pula, penjimatan yang berpotensi juga termasuk dengan penjimatan dari Sistem Lampu dan BIPV. Potensi penjimatan dari Sistem Lampu adalah (RM 67345.90/tahun) dan tempoh pembayaran balik adalah (1.68 tahun). Di samping itu, potensi penjimatan untuk BIPV adalah (RM 30492/tahun) dan tempoh bayaran balik adalah (4.9 tahun).*

## ACKNOWLEDGEMENT

Foremost, I am highly grateful to God for His blessing that continues to flow into my life, and because of You, I made this through against all odds. Also, I would like to take this opportunity to express my sincere acknowledgment to my supervisor Dr. Reduan Bin Mat Dan from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support, and encouragement towards the completion of this report.

Special thanks to all my colleagues, my beloved mother, father, and siblings for their moral support in completing this degree. Lastly, thank you to everyone who had been associated with the crucial parts of realization of this project.

Finally, I would like to thank my country (IRAQ) that grants me financial support to complete my study.



## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	<b>i</b>
<b>APPROVAL</b>	<b>ii</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>ABSTRAK</b>	<b>v</b>
<b>ACKNOWLEDGEMENT</b>	<b>vi</b>
<b>TABLE OF CONTENTS</b>	<b>vii</b>
<b>LIST OF TABLES</b>	<b>xi</b>
<b>LIST OF FIGURES</b>	<b>xiv</b>
<b>LIST OF SYMBOLS</b>	<b>xvi</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xviii</b>
<b>LIST OF APPENDICES</b>	<b>xx</b>

### **CHAPTER**

<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Background of Study	1
1.2 Problem Statement	3
1.3 Objectives of the Study	3
1.4 Scope of the Study	4
1.5 Significant of Study	4
1.6 Structure of the Report	5
<b>2. LITERATURE REVIEW</b>	<b>6</b>
2.1 Introduction	6
2.2 Green Building Concept	6
2.3 Green Building Rating Tools Review	6
2.4 Green Building Index (GBI)	7
2.5 Non-Residential Existing Building Rating Tools	8
2.6 GBI Assessment Criteria for (NREB)	8
2.7 Energy Efficiency (EE)	8

2.7.1 Design & Performance	8
2.7.2 Commissioning	12
2.7.3 Monitoring & Maintenance	13
2.8 Indoor Environmental Quality (EQ)	14
2.8.1 Air Quality	14
2.8.2 Thermal Comfort	16
2.8.3 Lighting, Visual & Acoustic Comfort	17
2.8.4 Verification	19
2.9 Sustainable Site Planning & Management (SM)	20
2.9.1 Facility Management	20
2.9.2 Transportation	21
2.9.3 Reduce Heat Island Effect	21
2.10 Materials & Resources (MR)	23
2.10.1 Reused and Recycled Materials	23
2.10.2 Sustainable Materials & Resources and Policy	24
2.10.3 Waste Management	24
2.10.4 Green Products	25
2.11 Water Efficiency (WE)	25
2.11.1 Water Harvesting & Recycling	25
2.11.2 Increased Efficiency	27
2.12 Innovation (IN)	28
2.12.1 Innovation & Environmental Initiatives	28
2.12.2 Green Building Index Facilitator	28
2.13 Standards Related to GBI Assessment Criteria	28
2.14 Energy Audit	29
2.14.1 Type of Energy Audit	30
2.15 GBI Certified Buildings	31
2.16 Previous Studies	33
2.17 Summary of Previous Studies	42
<b>3. METHODOLOGY</b>	<b>47</b>
3.1 Introduction	47
3.2 Description of the Building	47
3.2.1 Chancellery Building - Universiti Teknikal Malaysia Melaka	47

3.2.2 The ACMV system Description	51
3.3 The Flowchart of Methodology	57
3.4 Energy Audit Procedure	59
3.4.1 Data Collection	59
3.4.2 Walk-through Tour	59
3.4.3 Check List According to (GBI)	59
3.4.4 Calculation of Building Criteria	59
3.4.5 Physical Measurement	60
3.5 Measurement Equipment for Energy Audit	63
3.5.1 TSI 7545 Indoor Air Quality Meter	63
3.5.2 RS AVM-0.1 Anemometer	64
3.5.3 CENTER 337 Light Meter	65
3.5.4 RION NA-28 Sound Level Meter	65
3.6 Improvement of Building Criteria (Retrofit)	66
<b>4. RESULTS AND DISCUSSION</b>	<b>68</b>
4.1 Introduction	68
4.2 Results of Energy Audit according to the Green Building Index (GBI/NREB)	68
4.2.1 Results of Energy Efficiency (EE)	68
4.2.2 Results of Indoor Environment Quality (EQ)	75
4.2.3 Results of Sustainable Site Planning & Management (SM)	99
4.2.4 Results of Materials & Resources (MR)	100
4.2.5 Results of Water Efficiency (WE)	101
4.2.6 Results of Innovation (IN)	102
4.3 Summary of Energy Audit's Results	102
<b>5. GREENING THE EXISTING BUILDING</b>	<b>104</b>
5.1 Introduction	104
5.2 Potential improvement (Retrofitting)	104
5.2.1 Energy Efficiency (EE)	104
5.2.2 Indoor Environment Quality (EQ)	113
5.2.3 Management and Sustainable Site Planning	115
5.2.4 Materials & Resources (MR)	116
5.2.5 Water Efficiency (WE)	118

5.2.6 Innovation (IN)	121
5.3 Summary of the Potential improvement (Retrofitting)	123
5.4 Economic Analysis	126
5.4.1 Cost of Greening Existing Building (Retrofit)	126
5.4.2 Potential Saving from Retrof	131
<b>6. CONCLUSIONS AND FUTURE WORK</b>	<b>136</b>
6.1 Conclusion	136
6.2 Future Work	139
6.3 Summary	139
<b>REFERENCES</b>	<b>140</b>
<b>APPENDICES</b>	<b>146</b>

## LIST OF TABLES

TABLE	TITLE	PAGE
2.1	GBI Assessment Criteria for (NREB)	8
2.2	Standards related with Building Assessment Criteria	29
2.3	GBI Certified Buildings	32
2.4	Assessment of Credits	36
2.5	Earned Points	36
2.6	Cost Calculation	37
2.7	Summary of Previous Works and Studies	43
3.1	Details of Chilled Water System	51
3.2	Details of Pump sets	52
3.3	Details of Cooling Tower sets	53
3.4	Details of Air cooled split units	54
3.5	Details of AHUs	55
3.6	Details of FCUs	56
4.1	Results of Energy Efficiency (EE)	69
4.2	properties of plastered Brick wall	71
4.3	properties of Aluminum Composite Cladding without insulation wall	72
4.4	Electrical Consumption during the period (January 2015 – December 2015)	73
4.5	Results of (EQ)	75
4.6	The Overall Average values of IAQ for whole Building	86
4.7	Values of the average fresh air flow (cfm) for each building blocks , Occupancy Number and People Outdoor Air Rate (Rp) cfm/person	88
4.8	Comparisons Results with MS 1525: 2007 and Industry Code of Practice On Indoor Air Quality 2010	90

4.9	Comparisons results of (Rp) and (CO <sub>2</sub> ) with ASHARE Standard 62.1: 2007	91
4.10	Average Relative Humidity (%)	92
4.11	(D.F) Measurement and Calculation Details	93
4.12	Details of Measurement the Daylighting Glare Control	95
4.13	Overall average Electric Lighting Illumination Levels	96
4.14	Average Internal Noise Levels	98
4.15	Results of (SM)	99
4.16	Results of Materials & Resources (MR)	100
4.17	Results of Water Efficiency (WE)	101
4.18	Results of Innovation (IN)	102
4.19	Summary of Energy Audit's Results	103
5.1	Lighting Motion Sensors	105
5.2	Electrical sub-metering	105
5.3	BIPV Installation details	106
5.4	Lighting consumption percentage from the total consumption	107
5.5	The proposed Lighting consumption percentage from total consumption	107
5.6	Energy Saving By Retrofit the Lighting System	109
5.7	The proposed power generated from (BIPV)	110
5.8	Energy Saving from (BIPV)	111
5.9	power saving from the Lighting System retrofit and the Proposed Power generated from (BIPV)	111
5.10	Carbon Dioxide Monitoring & Control Installation details	114
5.11	Details of Installing Rainwater Harvesting Complete System	120
5.12	Water Sub-Meters Installation Details	120
5.13	Details of using self – cleaning façade paint	121
5.14	Details of installation of Electrochromic glazed façade	122
5.15	Proposed Improvement Summary	124
5.16	Summary of Building Rating Level according to the GBI Classification	125
5.17	Estimated cost of Greening the Chancellery Building	126
5.18	Expected Saving from Retrofit Lighting System	132
5.19	Expected saving and Payback Period from Retrofit Lighting System	132

5.20	Expected saving from installing BIPV	133
5.21	Expected saving and Payback Period from installing BIPV	134
5.22	Total Expected saving from retrofit the lighting system and installing BIPV	134
5.23	Total Expected saving and Payback Period from retrofit The lighting system and installing BIPV	135

## LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Thermal Comfort Factors	17
2.2	The Significant Elements to be used on Retrofitting UTM Existing Building	34
3.1	Location of Chancellery building	48
3.2	Building Blocks	50
3.3	Chilled Water System	51
3.4	Pump set	52
3.5	Cooling Tower sets	54
3.6	The Process Flow of this study	58
3.7	Measurements of IAQ parameters	61
3.8	Measurement of Average Fresh Air Flow (cfm)	61
3.9	Measurement of Electric Lighting Levels (lux)	62
3.10	Measurement of Internal Noise Levels	63
3.11	TSI 7545 Indoor Air Quality Meter	64
3.12	RS AVM-0.1 Anemometer	64
3.13	CENTER 337 Light Meter	65
3.14	RION NA-28 Sound Level Meter	66
4.1	Chancellery Block	70
4.2	Electricity Consumption from (January 2015) to (December 2015)	74
4.3	Physical Measurement Parameters in the Chancellery block (LG floor)	77
4.4	Physical Measurement Parameters in the Chancellery block (G floor)	78
4.5	Physical Measurement Parameters in the Chancellery block (1 floor)	79
4.6	Physical Measurement Parameters in the Chancellery block (2 floor)	80



4.7	Physical Measurement Parameters in the Chancellery block (3 floor)	81
4.8	Physical Measurement Parameters in the Plaza block (LG floor)	82
4.9	Physical Measurement Parameters in the HEPA block (LG floor)	83
4.10	Physical Measurement Parameters in the HEPA block (G floor)	84
4.11	Average IAQ Parameters at the whole Building	85
4.12	Average Fresh Air Flow (cfm) for each building blocks, Occupancy Number and People Outdoor Air Rate (Rp) cfm/person	87
4.13	Average value of Li (lux) and Daylight Factor (D.F) for each orientations	93
4.14	Results of Daylight Glare Control	94
4.15	Average Electric Lighting Illumination Levels	96
4.16	Average Internal Noise Levels	98
5.1	Energy Saving By Retrofit the Lighting System	108
5.2	Energy Saving from (BIPV)	110
5.3	Power saving from the Lighting System retrofit and the Proposed power generated from (BIPV)	112
5.4	Simple Green Industrial Cleaner	115
5.5	Green Vehicle Priority	116
5.6	Average Monthly Precipitation of Rainfall for Melaka / Malaysia	118
5.7	Example of Installing Rainwater Harvesting Complete System	119
5.8	Comparison of the Building Assessment Criteria before and After Proposed Greening Existing Building	125
5.9	Comparison between building assessment criteria cost	131

## LIST OF SYMBOLS

°C	-	Degrees Celsius
cfm	-	Cubic feet per minute
m	-	Meter
ft	-	feet
hr.	-	Hour
KW	-	kilowatt
KWh	-	kilowatt per hour
KW/m <sup>2</sup> /year	-	kilowatt / hour / meter square / year
W/m <sup>2</sup>	-	Watt per meter square
%	-	Percentage
RH	-	Relative Humidity
rpm	-	Revolutions per Minute
CO	-	Carbon Monoxide
CO <sub>2</sub>	-	Carbon Dioxide
Ppm	-	Parts per Million
m/s	-	velocity
OTTV	-	Overall Thermal Transfer
WWR	-	Window-to-gross exterior wall area ratio
U	-	Thermal transmittance
SC	-	Shading coefficient
CF	-	Correction factor
$\alpha$	-	Solar absorption factor
K	-	Thermal Conductivity
R	-	Thermal Resistance

t	-	Thickness
Lux	-	Lighting illuminance
DF	-	Daylighting Factor
$L_o$	-	Outdoor illuminance
$L_i$	-	Indoor illuminance
dB	-	Decibel
$L_{Aeq}$	-	Average sound level, equivalent continuous sound level
L	-	Liter

## LIST OF ABBREVIATIONS

ACMV	- Air Conditioning and Mechanical Ventilation
AHU	- Air Handling Unit
ASHRAE	- American Society of Heating, Refrigerating, and Air Conditioning
ACE	- Air Change Effectiveness
BEI	- Building Energy Intensity
BAS	- Building Automation System
BIPV	- Building Integrated Photo Voltaic
BREEAM	- Building Research Establishment Environmental Assessment Methodology (UK)
CASBEE	- Comprehensive Assessment System for Built Environment Efficiency
CxS	- Commissioning Specialist
EE	- Energy Efficiency
EQ	- Environment Quality
EA	- Energy Audit
EMS	- Energy Management Control System
ETS	- Environmental Tobacco Smoke Control
FCU	- Fan Coil Unit
FRP	- Fiberglass Reinforced Plastic
GBCI	- Green Building Certification Institute
GBI	- Green Building Index
HVAC	- Heating, Ventilation, and Air Conditioning
HED	- House Energy Doctor
HUKM	- Hospital Universiti Kebangsaan Malaysia
IBS	- Industrialized Building System

IEQ	- Indoor Environmental Quality
IAQ	- Indoor Air Quality
IN	- Innovation
ISO	- International Organization for Standardization
LEED	- Leadership in Energy and Environmental Design
LED	- Light-Emitting Diodes
MR	- Materials and Resources
MS	- Malaysian Standard
MDF	- Medium Density Fiberboard
MCC	- Motor Control Center
NREB	- Non-Residential Existing Building
NRNC	- Non-Residential New Construction
NLA	- Net Lettable Area
OTTV	- Overall Thermal Transfer Value
OFEE	- Office of the Federal Environmental Executive
OPD	- Ozone Depleting Potential
PU	- polyurethane
RE	- Renewable Energy
Rn	- Radon
REB	- Residential Existing Building
RNC	- Residential New Construction
RP	- People Outdoor Air Rate
SRI	- Solar Reflectance Index
SM	- Sustainable Site Planning and Management
USGBC	- U.S. Green Building Council
UHI	- Urban Heat Island
UTeM	- Universiti Teknikal Malaysia Melaka
UTM	- Universiti Teknologi Malaysia
VOCs	- Volatile organic compounds
WE	- Water Efficiency

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	GBI Assessment Criteria for Non-Residential Existing Building (NREB) & Project Information Submission Form	147
B	Building's Layout	161
C	Master Project's Gantt – Chart	170
D	Overall Thermal Transfer value Calculation & Building Energy Intensity	172
E	Measurements Data of Indoor Environmental Quality (IEQ)	178
F	Building Energy Intensity Improvement	188
G	Utility Bill	197
H	Proposed Installation Equipment	204

## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Study

“Greening buildings” is considered one of the solutions proposed to address global climate changes and economic issues due to unbalanced energy consumption in various types of infrastructure. The global annual energy consumption of buildings is of high impact as it accounts for more than 68% of the total electricity consumption and 39% of the aggregate energy consumed. Moreover, the use of water in buildings is more than 12% of the aggregate water consumption (EPA, 2009). Buildings are considered one of the causes of the global warming phenomenon since it accounts for over 40% of total carbon dioxide (CO<sub>2</sub>) emissions. While currently, United States, Canada, Western Europe, and Japan are the major contributors to greenhouse gas emissions, this situation is going to change radically in the upcoming years. Carbon dioxide emissions from China, India, and the rest of Asia, Russia and Brazil are dramatically increasing which arise the need for global participation in reducing the carbon footprint. That can be defined as the environmental impact of produced greenhouse gasses, measured in the units of carbon dioxide of urban buildings over the next 30 years (Yudelson, 2007). The practices of green buildings can significantly decrease or eradicate negative impacts on the environment by utilizing high-performance, cutting-edge designs, constructions, and operations practices. Green operations and management decrease operating costs, boost building marketability, increase workers’ productivity and decrease potential accountability resulting from indoor air quality (IAQ) issues (Green Building Council, 2009).

“Leadership in Energy and Environmental Design (LEED)”, a private third-party building certification program managed by the “Green Building Certification Institute” (“GBCI”) and established by the “U.S. Green Building Council” (“USGBC”) aims to accomplish the “triple bottom line,” that promotes the incorporation of sustainable design techniques and strategies for the benefit of the environment, society, and the economy. At each LEED rating system, building categories, requirements and credits are developed with this aim in mind. Four levels of LEED certification are stated: “Platinum (more than 80 points) ; Gold (60 to 79 points); Silver (50 to 59 points); and Certified (40-49 points)” (Joshua Winefsky, 2016).

The “Green Building Index (GBI)” is the recognized “Rating Tool” for green buildings in Malaysia. Which encourages sustainability in the built environment and increase awareness of these matters among related stakeholders, including developers, contractors and architects. The evaluation of residential and commercial properties using the “GBI Rating Tool” depend on six main criteria: “Indoor Environment Quality (EQ), Sustainable site planning & Management (SM), Energy Efficiency (EE), Materials and Resources (MR), Innovation (IN), and Water Efficiency (WE)”. Alternatively, buildings are divided into the following categories: “Non-Residential New Construction (NRNC), Non-Residential Existing Building (NREB), Residential New Construction (RNC), and Residential Existing Building (REB)”. There are four levels of GBI certification: “(more than 86 points) Platinum; (76 to 85 points) Gold; (66 to 75 points) Silver; and (50 to 65 points) Certified” (GBI Malaysia, 2011).

This study aims to “Greening” the Non-Residential Existing Building (Chancellery Building - Universiti Teknikal Malaysia Melaka).