ATTRIBUTES OF GREEN BUILDING RATING TOOL (GBRT) FOR MALAYSIA

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ACKNOWLEDGEMENT

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Appreciation also goes to the author's beloved parents, family, friends and everyone involved directly or indirectly towards the compilation of this thesis.

"Life is a learning process".

Thank you. Alhamdulillah.
ABSTRACT

Movement towards sustainable development in building industry has been growing around the world including Malaysia. Throughout the duration of this study, Malaysia is having two main green building rating tools namely Green Building Index (GBI) and Green Real Estate (Green RE) which are using prescriptive approach in its building assessment procedure. Looking at the objectives of green building, it seems not sufficient to just rely on this approach. However some of the international rating tools such as Leadership in Energy and Environmental Design (LEED) Pilot, National Australia Built Environment Rating System (NABERS) and Green Building Tool (GB Tool) had incorporated performance approach in assessing the performance of building. Thus, this study was conducted to gather experts’ opinions on the attributes of rating tool for Malaysia environment. Three rounds of Delphi survey were carried out to gather expert’s preferences from Malaysia Green Building Confederation (MGBC) regarding the importance assessment elements and criteria together with the most suitable assessment approach to be included in Green Building Rating Tool (GBRT). The 1st round was aimed for ascertaining the relevancy of the preliminary information gathered from literature review. Then, the 2nd round was carried out for determining the importance level of the assessment elements and criteria also with the most suitable assessment approach. The 3rd round was aimed for determining the level of agreement on the results of previous round. Collected data was analyzed using probability distribution of central tendency (mode, median and Inter Quartile Range (IQR) value). Results of the analysis found out that the experts had agreed that the suggested 8 assessment elements (Energy Efficiency, Indoor Environmental Quality, Sustainable Site Management, Water Efficiency, Waste Management, Materials & Resources, Innovation and Pollution & Emission) and the related 16 assessment criteria are relevant to be incorporated to Malaysia green building rating tool. The experts also preferred to combine both the prescriptive and performance approaches in carrying the assessment in determining rating of green building. These results were integrated into the attributes for GBRT.
ABSTRAK

CONTENTS

TITLE PAGE i
DECLARATION ii
ACKNOWLEDGEMENT iii
ABSTRACT iv
ABSTRAK v
TABLE OF CONTENTS vi
LIST OF TABLE xi
LIST OF FIGURES xiii
LIST OF SYMBOLS AND ABBREVIATIONS xiv
LIST OF APPENDICES xvi

CHAPTER 1 INTRODUCTION 1

1.1 Background of Research 1

1.2 Problem Statement 2

1.3 Research Aim and Objectives 4

1.4 Scope of the Research 4

1.5 Significance of the Research 4
###CHAPTER 2  CLIMATE CHANGE AND GREEN BUILDING RATING TOOL (GBRT)

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>2.2</td>
<td>Climate Change</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Causes of Climate Change</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Consequences of Climate Change</td>
</tr>
<tr>
<td>2.3</td>
<td>Contribution of Buildings to Climate Change</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Sustainable Building</td>
</tr>
<tr>
<td>2.4</td>
<td>Green Building Rating Tool (GBRT)</td>
</tr>
<tr>
<td>2.5</td>
<td>Green Building Rating Tool (GBRT) Approaches</td>
</tr>
<tr>
<td>2.5.1</td>
<td>Prescriptive Approach</td>
</tr>
<tr>
<td>2.5.2</td>
<td>Performance Approach</td>
</tr>
<tr>
<td>2.6</td>
<td>Comparison of Prescriptive and Performance Based GBRT</td>
</tr>
<tr>
<td>2.6.1</td>
<td>Advantages and Disadvantages of Prescriptive Approach</td>
</tr>
</tbody>
</table>
2.6.2 Advantages and Disadvantages of Performance Approach

2.7 Important Features of GBRT

2.7.1 Overview of GBRT

2.7.2 Assessment Element of GBRT

2.7.3 Assessment Criteria of GBRT

2.8 Summary

CHAPTER 3 METHODOLOGY

3.1 Introduction

3.2 Questionnaire Design

3.3 Delphi Method

3.3.1 First Round of Delphi (Relevance)

3.3.2 Second Round of Delphi (Importance)

3.3.3 Third Round of Delphi (Consensus)

3.4 Delphi Method of Data Collection

3.4.1 Pilot Study

3.4.2 Selection of Experts

3.4.3 Survey Administration
3.4.4 Analysis Method 44
3.5 Summary 46

CHAPTER 4 ANALYSIS AND RESULT 48

4.1 Introduction 48
4.2 Respondent of Delphi Survey 48
4.3 First Round of Delphi Survey 49
4.3.1 Assessment Preferences 50
4.3.2 Outcome of First Round of Delphi Survey 51
4.4 Second Round of Delphi Survey 52
4.4.1 Assessment Elements 52
4.4.2 Assessment Approach 54
4.4.3 Assessment Criteria 55
4.4.4 Outcome of Second Round of Delphi Survey 58
4.5 Third Round of Delphi Survey 58
4.5.1 Assessment Elements 58
4.5.2 Assessment Criteria 60
4.5.3 Outcome of Third Round of Delphi Survey 61
4.6 Recommendations of Attributes for GBRT 63
4.7 Conclusion

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

5.2 Conclusion of the Research

5.2.1 Objective 1: To Identify the Different Assessment Approaches and Features of GBRT

5.2.2 Objective 2: To Determine the Significant Level of GBRT Assessment Approaches and Features Based On Expert’s Preferences

5.2.3 Objective 3: To Propose a Guideline of GBRT For Malaysia

5.3 Limitations of the Research

5.4 Recommendations for Further Research

REFERENCES

APPENDICES
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Green Building Rating Tool in 26 countries</td>
<td>19</td>
</tr>
<tr>
<td>2.2</td>
<td>Ranking of assessment elements according to different GBRT</td>
<td>30</td>
</tr>
<tr>
<td>2.3</td>
<td>Mapping of GBRT compliance to 16 criteria set by AIA</td>
<td>33</td>
</tr>
<tr>
<td>2.4</td>
<td>Major assessment elements in GBRT</td>
<td>34</td>
</tr>
<tr>
<td>3.1</td>
<td>Distribution of the respondents in the pilot study</td>
<td>40</td>
</tr>
<tr>
<td>3.2</td>
<td>Distribution of the expert’s profession</td>
<td>43</td>
</tr>
<tr>
<td>3.3</td>
<td>Measures of central tendency in a sample</td>
<td>45</td>
</tr>
<tr>
<td>4.1</td>
<td>Cross-tabulation of experts’ profession by years of working experience</td>
<td>49</td>
</tr>
<tr>
<td>4.2</td>
<td>Frequency of agreement to incorporate assessment elements in GBRT</td>
<td>50</td>
</tr>
<tr>
<td>4.3</td>
<td>Frequency of agreement to incorporate assessment criteria in GBRT</td>
<td>51</td>
</tr>
<tr>
<td>4.4</td>
<td>Frequency importance for the assessment elements</td>
<td>52</td>
</tr>
<tr>
<td>4.5</td>
<td>Median and IQR of importance for the assessment elements</td>
<td>54</td>
</tr>
<tr>
<td>4.6</td>
<td>Frequency and mode preference of assessment approach</td>
<td>55</td>
</tr>
<tr>
<td>4.7</td>
<td>Frequency importance for the assessment criteria</td>
<td>56</td>
</tr>
<tr>
<td>4.8</td>
<td>Median and IQR of importance for the assessment criteria</td>
<td>57</td>
</tr>
<tr>
<td>4.9</td>
<td>Frequency consensus for the assessment elements</td>
<td>59</td>
</tr>
<tr>
<td>4.10</td>
<td>Median and IQR consensus for the assessment elements</td>
<td>59</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>4.11</td>
<td>Frequency consensus for the assessment criteria</td>
<td>60</td>
</tr>
<tr>
<td>4.12</td>
<td>Median and IQR consensus for the assessment criteria</td>
<td>61</td>
</tr>
<tr>
<td>4.13</td>
<td>Median and IQR value of assessment elements between second and third round of Delphi</td>
<td>62</td>
</tr>
<tr>
<td>4.14</td>
<td>Median and IQR value of assessment criteria between second and third round of Delphi</td>
<td>62</td>
</tr>
<tr>
<td>4.15</td>
<td>Attributes for GBRT</td>
<td>64</td>
</tr>
<tr>
<td>5.1</td>
<td>Main assessment approaches of GBRT</td>
<td>67</td>
</tr>
<tr>
<td>5.2</td>
<td>Main assessment elements in GBRT</td>
<td>68</td>
</tr>
<tr>
<td>5.3</td>
<td>Ranking of assessment elements and most suitable approach</td>
<td>68</td>
</tr>
<tr>
<td>5.4</td>
<td>Ranking of assessment criteria</td>
<td>69</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Structure of the research methodology</td>
<td>6</td>
</tr>
<tr>
<td>2.1</td>
<td>Model of sustainable development</td>
<td>17</td>
</tr>
<tr>
<td>2.2</td>
<td>Timeline of the development of building rating tools in different countries</td>
<td>18</td>
</tr>
<tr>
<td>3.1</td>
<td>Process of the survey</td>
<td>35</td>
</tr>
<tr>
<td>3.2</td>
<td>Procedure of survey</td>
<td>47</td>
</tr>
<tr>
<td>4.1</td>
<td>The distribution of median and quartiles</td>
<td>53</td>
</tr>
<tr>
<td>5.1</td>
<td>The construction of GBRT attributes</td>
<td>69</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>°C</td>
<td>Degree Celsius</td>
<td></td>
</tr>
<tr>
<td>ACEM</td>
<td>Association of Consulting Engineers Malaysia</td>
<td></td>
</tr>
<tr>
<td>AIA</td>
<td>American Institute of Architects</td>
<td></td>
</tr>
<tr>
<td>BREEAM</td>
<td>Building Research Establishment Environmental Assessment Method</td>
<td></td>
</tr>
<tr>
<td>CASBEE</td>
<td>Comprehensive Assessment System for Building Environmental Efficiency</td>
<td></td>
</tr>
<tr>
<td>CIDB</td>
<td>Construction Industry Development Board</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
<td></td>
</tr>
<tr>
<td>ECS</td>
<td>Energy Charter Secretariat</td>
<td></td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
<td></td>
</tr>
<tr>
<td>GASSIC</td>
<td>Green Assessment System in Construction</td>
<td></td>
</tr>
<tr>
<td>GBI</td>
<td>Green Building Index</td>
<td></td>
</tr>
<tr>
<td>GBRT</td>
<td>Green Building Rating Tool</td>
<td></td>
</tr>
<tr>
<td>GB Tool</td>
<td>Green Building Tool</td>
<td></td>
</tr>
<tr>
<td>GEO</td>
<td>Green Energy Office</td>
<td></td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gases</td>
<td></td>
</tr>
<tr>
<td>Green PASS</td>
<td>Green Performance Assessment System</td>
<td></td>
</tr>
<tr>
<td>Green RE</td>
<td>Green Real Estate</td>
<td></td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air-Conditioning</td>
<td></td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>HERS</td>
<td>Home Energy Rating System</td>
<td></td>
</tr>
<tr>
<td>HESS</td>
<td>High Efficiency Systems Strategy</td>
<td></td>
</tr>
<tr>
<td>IgCC</td>
<td>International Green Construction Code</td>
<td></td>
</tr>
<tr>
<td>iSBE</td>
<td>International Initiative for a Sustainable Built Environment</td>
<td></td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
<td></td>
</tr>
<tr>
<td>IQR</td>
<td>Inter Quartile Range</td>
<td></td>
</tr>
<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design</td>
<td></td>
</tr>
<tr>
<td>LCCF</td>
<td>Low Carbon Cities Framework and Assessment System</td>
<td></td>
</tr>
<tr>
<td>MGBC</td>
<td>Malaysia Green Building Confederation</td>
<td></td>
</tr>
<tr>
<td>MIA</td>
<td>Malaysian Institute of Architects</td>
<td></td>
</tr>
<tr>
<td>MyCREST</td>
<td>Malaysian Carbon Reduction and Environmental Sustainable Tool</td>
<td></td>
</tr>
<tr>
<td>NABERS</td>
<td>National Australia Built Environment Rating System</td>
<td></td>
</tr>
<tr>
<td>NASA</td>
<td>Aeronautics and Space Administration</td>
<td></td>
</tr>
<tr>
<td>NGTP</td>
<td>National Green Technology Policy</td>
<td></td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
<td></td>
</tr>
<tr>
<td>NSIDC</td>
<td>National Snow and Ice Data Centre</td>
<td></td>
</tr>
<tr>
<td>PWD</td>
<td>Public Work Department</td>
<td></td>
</tr>
<tr>
<td>REHDA</td>
<td>Real Estate and Housing Development Association</td>
<td></td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
<td></td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
<td></td>
</tr>
<tr>
<td>WBCSD</td>
<td>World Business Council for Sustainable Development</td>
<td></td>
</tr>
<tr>
<td>WEC</td>
<td>World Energy Council</td>
<td></td>
</tr>
<tr>
<td>WGBC</td>
<td>World Green Building Council</td>
<td></td>
</tr>
</tbody>
</table>
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AIA Full List of Assessment Criteria (16)</td>
<td>87</td>
</tr>
<tr>
<td>B</td>
<td>Invitation and Response from for Participation in the Survey Exercise</td>
<td>88</td>
</tr>
<tr>
<td>C1</td>
<td>First Round of Delphi Survey Questionnaire Form</td>
<td>91</td>
</tr>
<tr>
<td>C2</td>
<td>Second Round of Delphi Survey Questionnaire Form</td>
<td>93</td>
</tr>
<tr>
<td>C3</td>
<td>Third Round of Delphi Survey Questionnaire Form</td>
<td>95</td>
</tr>
<tr>
<td>D1</td>
<td>First Round of Delphi Survey Results</td>
<td>97</td>
</tr>
<tr>
<td>D2</td>
<td>Second Round of Delphi Survey Results</td>
<td>98</td>
</tr>
<tr>
<td>D3</td>
<td>Third Round of Delphi Survey Results</td>
<td>99</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background of the research

The push towards green building is growing around the world including developing countries such as Malaysia, India, Mexico, Brazil, Indonesia, South Africa and Argentina. According to Smart Market Report (2013), 28% of the world’s architects, contractors, engineers, building owner and building consultants emphasis on sustainable building constructions. This number reportedly to grow in the future, and it seems that green elements have become business opportunity into the building sector. Through the application of various green elements into building constructions, it can reduce the carbon footprint by building operation and can reduce operation cost, in the long run other than increase the capital value of the building itself.

Building sector plays a major role in the issue of climate change and with green buildings, it could become the key factor in reducing it in the future. The effects of climate change are apparent. Based on global greenhouse gas emission from 2010, electricity and heat production is the largest single source of global greenhouse gas emissions with 25 percent. Industrial and commercial buildings are the major users of electricity and heat producer (IPCC, 2014). With that statement, it needed much attention to be put towards building sector in reducing the impacts towards the environment in near future. That is the way where green building comes to the rescue.

Major personnel in the construction sector and the public have been aware of the potential of green building in the future of building construction in Malaysia. It is
proven by the development of National Green Technology Policy (NGTP, 2009) and Low Carbon Cities Framework and Assessment System (LCCF, 2011) by the Ministry of Energy, Green Technology and Water, Malaysia. This policy assembles under the aspects of energy, environment, economy and social, which have short, mid and long-term goals. The national goal of this policy is to provide direction and motivation for Malaysians to continuously enjoy good quality living and a healthy environment.

1.2 Problems statement

In the seriousness to tackle climate change effects which impact the global community, sustainable development such as green building to reduce the energy consumption of the building seems achievable and necessary change. It was claimed that benchmarking, assessment and knowledge sharing should be the effort that needs to be focused on in developing countries for sustainable development and construction (CIDB Malaysia, 2007 and Yeoh, 2005). Malaysia mostly relies on Green Building Index (GBI) to drive the building industry towards sustainable development. The most established green building rating tool in Malaysia as widely recognised in the literature is the GBI (Mohd Annuar, Osmond and Prasad, 2014). GBI was launched in 2009 and since then, it has received huge acceptance from building stakeholders with 667 registered buildings as of January 15, 2016 (Green Building Index, 2016). Alongside GBI, a number of green building rating tools and policies have evolved, such as the Green Real Estate (GreenRE), Malaysian Carbon Reduction and Environmental Sustainable Tool (MyCREST), Green Assessment System in Construction (GASSIC) and Public Work Department (PWD) Green Rating Scheme.

40 percent of total energy consumed is attributable to buildings, and that green buildings typically reduce consumption by 50 to 70% (Kerswill, 2014). A report by CIDB (Sazali, 2012) revealed that current Low-Carbon Buildings does not perform as expected. Comparing buildings certified by GBI (prescriptive-based) and a performance-based tool (Green PASS), there are major differences in the percent reduction of Carbon dioxide equivalent (CO2e). CO2e allows other greenhouse gas emission to be expressed in terms of CO2 based on their relative Global Warming Potential (GWP). The building of Energy Commission at Putrajaya had received
Platinum GBI rating but received 4 Diamonds rating by Green PASS. It shows that GBI highest Platinum design building only demonstrated 70% reduction in CO2e. Furthermore, Green Energy Office (GEO) at Bangi was certified by GBI but demonstrated 83% CO2e reduction (5 Diamonds). This shows that GBI as the main GBRT in Malaysia failed to recognize the environmental performance established by GEO building.

Prescriptive approach GBRT implemented at the early stages of building cycle while performance approach GBRT applied in the whole life cycle of a building. Looking at the objectives of green building, which are to create structures and using processes that are environmentally responsible and resource-efficient throughout a building’s life-cycle (Environment and Ecology, 2016), but it seems not sufficient to just rely on this approach to determine the real performance of a building. Other countries such as United States, United Kingdom, Australia and Japan have recognized the need for performance-based standards in addressing green construction to provide a framework linking sustainability with performance in order to mitigate climate change. Well established green building rating tools have addressed the life cycle approach of performance-based GBRT as the basis of its’ criteria such as BREEAM-UK and LEED-US (Mohd Annuar, Osmond and Prasad, 2014) have come out and suggested a performance-based GBRT to evaluate building to determine its sustainability.

Furthermore, there are findings implied that assessment frameworks in developing and developed countries should be different because of different in economic development and environmental interest (Mohd Annuar, Osmond and Prasad, 2014). GBI was developed from the framework of BREEAM-UK and LEED-US. Other GBRT in Malaysia also based on earlier tools from outside of the country. In the developed countries, it has a reasonable standard of living in which the sustainability agenda is around to maintain that standards of living, at the same time reducing resources and energy. While in developing countries, protection of the environment has become a necessity in order to maintain healthy wellbeing as well as sustaining the economic growth (Pereira, Tiong & Komoo, 2010).

Thus, the researcher realised that an effort to formulate the attributes of GBRT from Malaysia building experts’ preferences that promote sustainable construction in an integrated manner with other construction industry standards is necessary and is the subject pursued in this research.
1.3 Research aim and objectives:

The aim of this research is to formulate Green Building Rating Tool (GBRT) attributes. To achieve this aim, the following objectives are to be carried out:

1. To identify the different assessment approaches and features of GBRT attributes;
2. To determine the agreement level on assessment approaches and features of GBRT attributes based on local expert’s preferences;
3. To develop the attributes of GBRT for Malaysia.

1.4 Scope of the research

In this research, it will focus on two approaches of GBRT, which are prescriptive-based approach and performance-based approach. Comparison of seven international GBRT is conducted. This study investigates the assessment elements and assessment criteria together with the assessment approach to be incorporated in GBRT attributes. The respondents are from the local building experts, the member of Malaysia Green Building Confederation (MGBC).

1.5 Significance of the research

This research will contribute to the following items:

1. To get feedback about the characteristics of GBRT from the experts. So it will provide a better understanding between the stakeholders in supporting sustainability in their projects;
2. To come out with a checklist of requirements for GBRT, for the government to use it as a guide in planning system to promote sustainable development;
3. To make a contribution to the development of green building assessment tool by sharing knowledge in the field of sustainable development;
4. For the community, this research can act as an educational medium to increase the level of knowledge on environmental issues and sustainability among Malaysians.
1.6 Research methodology

This research adopted mixed-method research approach; a qualitative stage followed by a quantitative stage. The structure of the research methodology is presented in Figure 1.1.

<table>
<thead>
<tr>
<th>OBJECTIVES</th>
<th>METHODOLOGY</th>
<th>ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) To identify the different assessment approaches and features of GBRT attributes</td>
<td>• Conduct literature review</td>
<td>• Determine the different approaches of GBRT</td>
</tr>
<tr>
<td></td>
<td>• Mapped the frequency of the attributes</td>
<td>• Point out the advantages and disadvantages of both approaches</td>
</tr>
<tr>
<td></td>
<td>• Mapped of GBRT compliance to 16 criteria set by AIA</td>
<td>• Determine the major assessment elements of GBRT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Chapter 3 (Methodology)</td>
</tr>
</tbody>
</table>

**Literature Review**

2) To determine the agreement level on assessment approaches and features of GBRT attributes based on local expert’s preferences | • Survey with experts to rank assessment elements, criteria and the most suitable approach (Delphi Method) | • Analyze using median and Inter Quartile Range (IQR) |
| | | • Chapter 5 (Analysis and Results) |

**Field Studies**

3) To develop the attributes of GBRT for Malaysia | • Come out with the suitable requirements of GBRT for Malaysia | • Define main categories and indicators of the assessment tool using the ranking indicators |
| | | • Chapter 5 (Analysis and Results) |

**Data Analysis**

Figure 1.1: Structure of the research methodology
The purpose of the qualitative stage was to identify the essential assessment aspects to be incorporated in GBRT. The qualitative stage was conducted by literature review. The outcome of the qualitative stage then brought to the quantitative stage, where the assessment features (assessment elements and criteria) were assigned with the respective level of importance from the 14 local experts of Malaysia Green Building Confederations (MGBC) members. Three rounds of Delphi survey were implemented in this study to formulate the requirements for developing the assessment criteria.

1.7 Structure of the thesis

The descriptions of the chapters in the thesis are as follows:

Chapter 1 (Introduction): This chapter explains the background of the study, which contains the problem statement, the aim and objectives, the scope, the significant contribution and the method employed for the study.

Chapter 2 (Sustainability and Green Building Rating Tool, GBRT): This chapter builds preliminary information for the research by reviewing the literature on the key aspects of GBRT. It reviews selected GBRT that being used and also the different assessment approaches integrated into its building assessment. It enables identifying important assessment elements and criteria that were incorporated in the assessment tools.

Chapter 3 (Methodology): This methodology’s chapter presents the approach adopted for this study, which applied Delphi method in carrying out data collection using questionnaire form. It also describes the analysis used on the gathered data to find results for this study.

Chapter 4 (Analysis and Results): This chapter presents the data collection and analysis on the collected data. The data was collected through the questionnaire survey, which was intended to gather opinions from experts who are involved or related to green building works. The results of the analysis of the collected data from the questionnaire survey works are also presented and discussed.
Chapter 5 (Conclusion): This chapter concludes the findings of this research based on the objectives that are mentioned in Chapter 1. The achieved aim of the research to develop the attributes of GBRT for Malaysia based on local experts is highlighted. Limitations of this study and recommendations for further research are suggested in this chapter.
CHAPTER 2

CLIMATE CHANGE AND GREEN BUILDING RATING TOOL

2.1 Introduction

This section discusses climate change issues and its relationship to the concept of sustainability, which includes sustainable building, design and operations. To improve the knowledge on the level of sustainable building, countries have introduced GBRT. Thus, seven GBRT attributes that being used in six countries and the different assessment approaches are discussed. It then outlines the major assessment approaches, which are prescriptive and performance approach in the implementation of sustainable development. Furthermore, the review enables identifying important assessment elements and criteria that were incorporated in the assessment tools. Finally, the important requirements that were included in this research are highlighted in the summary.

2.2 Climate change

Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years (Agrafioti, 2011). National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA) have both confirmed that 2015 was the hottest year ever recorded globally (Climate Reality Project, 2016). It was the highest among all years in the 1880 to 2015 record, which topping the previous record set on 2014. That might seems not much, but the numbers says it otherwise. During 2014, the average temperature across global land and ocean surfaces was
0.16°C, while in 2015 the average temperature rise to 0.90°C (Lindsey, 2016). The report also mentioned that it was the biggest margin by which the annual global temperature record has been broken. It was not surprising as there was some scientific reports concluded that there was 97% probability that 2015 would set a new global temperature record (Arguez et al., 2015). If the trend still on the same pace, global temperature will rise above 2015 record for the next few years.

The global temperature is increasing because of human activities like burning fossil fuel, which caused carbon pollution and other greenhouse gases into the earth atmosphere. Other than caused by manmade warming, the planet is warming because of the natural condition called El Niño. According to NOAA (2016a), El Niño is the complex weather patterns resulting from variations in ocean temperatures in the Equatorial Pacific. Weather around the planet can be influenced by the warmer and colder than average ocean temperatures in one part of the world. Measured on seasonal timescales, the Niño3.4 index broke the record in December 2015, with 2.38°C above average, surpassing December 1997’s 2.24 °C (Becker, 2016). The Niño3.4 index compares ocean surface temperatures in the east-central Pacific to the long-term average. El Niño is the consequences of a complex circulation in the ocean and atmosphere that happens every four to seven years. The most reliable global impacts are dryness over Indonesia and northern South America, below-average rains during the Indian Monsoon and excess rainfall in southeastern South America, eastern Africa and across the southern United States (NOAA, 2016b). Furthermore, increase the risk of coral bleaching and endangered the populations of marine plants in the eastern tropical Pacific (Karnauskas, 2015). Although El Niño cause temporary escalation in average global temperatures, research imply that strong El Niño events might occur frequently (Cai, 2013). While, El Niño caused temperatures change from year to year, but the earth is increasingly warming and it’s due to human activity.

97% or more of scientists agree that climate-warming impacts are very likely due to human activities based on multiple published studies (Cook et al., 2013; Aderegg, 2010; Doran and Zimmerman, 2009; Oreskes, 2004). There are 16 warmest years recorded globally in the 20th century. Of these 16 years, 1998 was the only one that happened before 2000. For which, on that year like 2015, strong El Niño happened. It shows that even without an El Niño, incoming years would have been the hottest year on record. The trends will continue because of the ongoing of fossil
fuel burning. These records put pressure on governments to urgently act on climate change and to reduce greenhouse gases (GHG).

2.2.1 Causes of climate change

According to Intergovernmental Panel on Climate Change (IPCC), global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. The largest growth in GHG emissions between that year has come from energy supply, transport and industry, while residential and commercial buildings, forestry and agriculture sectors have been growing at a lower rate (IPCC Fourth assessment report, 2007). Most climate scientists agree the central cause of the current global warming trends is human development of “greenhouse effect” (United States Global Change Research Program, 2009; IPCC Fourth Assessment Report, 2007; Oreskes, 2004).

Greenhouse gases in the atmosphere block heat from the earth from escaping thus caused global climate change. According to United States Environmental Protection Agency (EPA), gases that contribute to greenhouse effect include Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O) and Fluorinated gases (United States Environmental Protection Agency, 2015). Carbon dioxide is the main GHG released through human activities. Carbon dioxide naturally present in the atmosphere as part of earth’s carbon cycle, but human actions is changing the carbon cycle between the atmospheres, oceans, soil, animals and plants. Although carbon dioxide productions come from a range of natural sources, human activities responsible for the increase carbon dioxide to the atmosphere since the industrial revolution (National Academy of Sciences, 2010). The burning of fossil fuels (oil, coal and natural gas) for energy and transportation is the primary human activity that release carbon dioxide to the atmosphere.

Methane is a hydrocarbon gas emitted from activities such as agriculture, decomposition of wastes in landfills, energy use and biomass burning. Methane is a far more active GHG than carbon dioxide, but less abundant in the atmosphere (Trenberth et al, 2007). Although methane have a shorter lifetime than carbon dioxide, it is more efficient at trapping radiation. Another powerful GHG, nitrous oxide is naturally present in the atmosphere as part of the nitrogen cycle. Average nitrous oxide’s lifetime is 114 years before being removed by a sink or demolished
through chemical reactions. Globally, about 40% of total nitrous oxide emissions come from human activities such as agriculture, transportation and industry activities (Inventory of United States Greenhouse Gas Emissions and Sinks, 2015). In agriculture, nitrogen oxide released through the application of synthetic fertilizers and during the breakdown of nitrogen in livestock manure and urine. Nitrogen oxide also emitted when transportation fuels are burned and as a byproduct during the production of synthetic commercial fertilizer, fibers and other synthetic products.

Different from other GHG, fluorinated gases only come from human-related activities. Fluorinated gases can also have long period of lifetime and destroyed by sunlight in the far layer of atmosphere. There are four main of fluorinated gases, which are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3) (United States Environmental Protection Agency, 2015). Hydrofluorocarbons are used in refrigerants, solvents, fire retardants and aerosol propellants. Hydrofluorocarbons and perfluorocarbons are two main gases in air conditioning systems both in vehicles and building. If these gases were released into the atmosphere, it will deplete the atmospheric layers. Aluminium production and semiconductor manufacturing produced perfluorocarbons as byproduct. Sulfur hexafluoride is used in electrical transmission equipment. Different from water vapor and ozone, these fluorinated gases have a slow atmospheric lifetime, and some of these releases will affect the climate for many years or centuries.

The increased emissions of the GHG may likely to effects the natural environments on earth. Earth will become warmer which will lead to evaporation and precipitation. The increase in temperature will warm the ocean and melt the glaciers and other ice, furthermore lead to sea level rise. Higher temperature and ever-changing climate pattern may alter the areas for crops and disturb the natural plant populations. Based on the Fourth Assessment Report, the Intergovernmental Panel on Climate Change (2007), under the supports of United Nations, a group of 1,300 independent scientific experts from countries all over the world stated that there are more than 90 percent probability that human activities over the past 250 years have increase the temperature of the earth. It also stated that with the dependent on industrial activities, it has raised atmospheric carbon dioxide levels from 280 parts per million to 400 parts per million in the last 150 years. They also summarised that over the past 50 years, there is more than 90 percent probability than manmade GHG
have caused the increased in earth temperatures. Although it could be assumed that the sun’s energy would cause climate change, multiple investigations implied that solar radiance changes couldn’t plausibly account for more than 10 percent of global warming (IPCC, 2013; Lean, 2010; Lockwood, 2009). Moreover, 70% of the sunlight that reaches the planet is absorbed (National Research Council, 2010).

2.2.2 Consequences of climate change

Domino effect of global climate change effects has been observed across the world. Consequences that scientist had anticipated in the past would result from global climate change have occurred. The net damage costs of climate change are likely to be significant and to increase over time, which indicated by several published reports (Intergovernmental Panel on Climate Change Fourth Assessment Report, 2007). Global climate will continue to change. It depends on the amount of heat-trapping gases released globally. As temperature rise, wildfires are rising and wildfire season is getting longer. Increase heat waves caused serious health risks such as heat exhaustion and heat stroke. Trees also died from heat and drought.

One of the main consequences is, the earth temperature increased and will continue to increase. Temperature data from four international science institutions; NASA Goddard Institute for Space Studies; Met Office Hadley Centre; NOAA National Climatic Data Center and Japanese Meteorological Agency, reflected that rapid warming in the past few decades (Earth Science Communications Team, 2016). Additionally, recorded temperature has been the warmest on last decades. Droughts and heat waves everywhere is expected to become worst.

Then sea level rises as the result of melting land ice and the expansion of seawater. From 1880 to 2009, the global sea level increases eight inches and increment of 0.8 inch per decade from 1972 to 2008 (Church and White, 2011; Church et al., 2011). The oceans absorbed 85 percent of the extra heat trapped by the atmosphere since 1880 (Cazenave and Llovel, 2010; Levitus et al., 2009; Levitus et al., 2005; Levitus et al., 2001). As the temperature of the oceans warms, it expands and caused global sea level rise. As a result of higher temperature, the land ice such as glaciers, ice caps and ice sheets is shrinking (Trenberth et al., 2007). The melting of the ice adding water to the oceans and cause the rising of global sea level (EPA, 2012; Cogley 2009; Meier et al., 2007; Kaser et al., 2006). The loss of ice added
nearly half an inch to global sea level from 2003 to 2007, which contributed to 75 percent to 80 percent of the total escalation (Cazenave and Llovel, 2010). Seawater expanded as it temperature increase. Artic sea ice reaches its minimum each September and deteriorating at a rate of 13.4 percent per decade, relative to the 1981 to 2010 average (National Snow and Ice Data Centre, 2016). Increase in global sea level increase the risk of flooding.

2.3 Contribution of buildings to climate change

In a summary report by United Nation Environment Programme (UNEP), buildings in developed and developing countries are accountable for more than 40 percent of global energy used, and as much as one third of global GHG emissions (UNEP, 2009). In 2004, it was estimated that building-related GHG emissions to be around 8.6 million metric tons CO₂ equivalent (Levine et al., 2007). This number is expected to increase as the rate of growth between 1971 and 2004 are 1.7% per year for residential buildings and 2.5% per year for commercial buildings (Levine et al., 2007). In the report it was also predicted that the number could almost double to reach 15.6 billion metric tons CO₂ equivalent by 2030. Furthermore, due to the applications for cooling, refrigeration and the use of halocarbons and insulation materials, the building sector is also responsible for significant emissions of other GHG.

Building sector has potential for significantly decreasing GHG emissions relatively independent of the cost per ton of CO₂ equivalent achieved (IPCC Fourth Assessment Report, 2007). It the report, it is possible for both buildings in developed and developing countries to reduce the GHG emissions. With the available and incoming technologies, the energy utilizations can be reduced with potential net profit throughout the building life span. Using a Life Cycle Approach to connect emission to the different stages of building life cycle, Graham (2003) found out that the greatest proportion of energy is used during the building operational stage. Previous studies also suggest that over 80 percent of GHG was released during operational phase to meet the energy needs such as heating, ventilation, and air conditioning (HVAC), lighting, water heating, telecommunications and entertainment (Junnila, 2004; Adalberth, Almgren and Petersen, 2001). Therefore, countries can accomplish most reduction in GHG emissions by aiming the
operational phase of building life cycle. According to Graham (2003), the life cycle phases of buildings are as follow:

1. Feasibility: Pre-design and development planning; then
2. Building design; then
3. Construction; then
4. Operation; then
5. Reuse and refurbishment (deconstruction and recycle of components or materials; then
6. Demolition, reuse and recycling (Material recover for recycle on other building developments or for reprocessing by other industries)

Energy consumptions during the operational stage of a building depend on several factors, such as function of the building, climate, location, building design and behavior of its occupants. Although the residential sector accounts for most of the major share of total energy consumption, the energy consumption in non-residential buildings such as offices, public buildings and hospital is also noteworthy and increasing. China is projected to increase the numbers of office building twice as much as U.S. by 2020 (Lawrence Berkeley National Laboratories, 2007). For countries with hotter climates, less energy is used for space heating but more may be used cooling. Other percentage of the energy consumed in building life cycle is for materials manufacturing and construction, transportation, maintenance, renovation and demolition. In developing countries, policies encouraged building owner to integrate energy efficiency and GHG emission considerations into the design phase of buildings.

Most developed and developing countries have taken the steps towards reducing GHG emissions from the building industry. But due to some difficulties, these steps have limited influence on actual emission levels. Study by the World Business Council for Sustainable Development (WBCSD) and other studies stated that it is challenging to save energy in buildings (WBCSD, 2007 and 2009; UNEP, 2007a; IPCC, 2007; Deringer, Iyer and Yu Joe Huang, 2004; Westling, 2003). It is easy to reach large emission reductions per unit at the top end of the range of buildings, but becomes challenging, as the size of the buildings gets smaller (Hinostroza et al., 2007; UNEP 2008). According to previous studies it was reported
that some of the barriers are as follow (UNEP, 2009; Levine et al., 2007; Carbon Trust, 2005):

1. Many small reduction opportunities spread across millions of buildings;
2. Different stakeholders are involved at the different phases in a building’s life cycle;
3. Stakeholders have distinct economic interest in terms of valuing investments in energy efficiency measures;
4. Energy efficiency investments are perceived to be expensive and uncertain;
5. There is still deficiency of understanding about how to implement energy efficiency measures.

Government should lead the way to tackle climate change issues and highlight building sector in their strategies. A credible and comparable energy performance standards should be developed to assist building stakeholders to reduce GHG emissions from building sector. Building sector should have precise and comprehensive data in the processing of real performance of a building. The lack of data such as climate and temperature, age and size of building, construction materials or actual use of natural ventilation, has been cited a major setback to estimate GHG emission reduction potential in previous studies (Odon, 2008). To access energy performance and application of energy efficiency policies, professionals should have the appropriate skills-base. Baden et al (2006) has recommended a list of training needs for the development of professional to verify a building’s performance which are qualification of raters, development of code of standards for the on-site and performance testing confirmation, quality assurance requirements description and insurance requirements description. The government should have the frameworks and systems for consultations with all major building stakeholders to implement their energy efficiency strategies. The implementation of subsidies is very common to overcome the major barrier of high cost of sustainable development (ECS, 2002; WEC 2008). The cooperation between the government, building and construction industry, civil society organizations, non-governmental organisation (NGO), research and educational institute and also the public are required to accomplish the mutual objective of reducing GHG emissions from the building. Government initiatives to encourage energy efficiency in public buildings can significantly lower energy usage
and show new technologies while delivering incentive to the private sector to join in. (Harris et al., 2004).

2.3.1 Sustainable building

The potential for achieving significant GHG emission reductions could be achieved through the development of sustainable building in developed and developing countries. In Malaysia, the increasing number of building and energy demand has a great impact on national development (Ahmad Sukri Ahmad et al., 2012). 94 percent of electricity generated in Malaysia is by fossil fuels and it will remain over the next decade (Mohammad et al., 2014). Furthermore, the total electricity generated and consumed in Malaysia is expected to increase (Chua and Tick Hui, 2010). Previous study by Rozana and her teams presented that 40 percent of GHG emissions was contributed from Malaysia existing buildings and its communities (Zakaria et al., 2012). In term of carbon and GHG emission, Malaysia has been listed as the 26th nation (Islam et al., 2013). Thus the government was aware about the problems and formed the National Green Technology Policy (NGTP, 2009) and Low Carbon Cities Framework and Assessment System (LCCF, 2011) by the Ministry of Energy, Green Technology and Water Malaysia, which promote sustainable building developments.

Based on the survey conducted by the world Energy Council (WCE) of 70 countries, around 66 percent of the countries have a national energy efficiency organization and over 90 percent have a Ministry department for energy efficiency (WEC, 2008). UNEP (2009) has proposed five main policy targets to reduce emissions from new and existing buildings, which are as follow:

1. Increase the energy efficiency of buildings;
2. Increase the energy efficiency of appliances that use energy;
3. Encourage energy generation and distribution corporations to support emission reductions in the building industry;
4. Transform the attitudes and behavior towards energy consumption;
5. Promote the use of renewable energy as an alternative to fossil fuels.

A program called Top Runner Program in Japan, required all new products to deliver the energy efficiency level suggested have displayed improvements of 50 percent for some products (Geller et al., 2006). Often, sustainable development is
presented as an interconnected ring of environment, social and economy as Figure 2.1 (Barton, 2000; Lutzkendorf & Lorenz, 2007). It is important to consider these three aspects in built development to achieve sustainability. Building’s construction, renovation and maintenance contribute 10 to 40 percent of countries’ Gross Domestic Product (GDP) (UNEP, 2008). While, renewable energy production in China and Spain, energy efficiency programs for buildings in France and Germany and in the bio-energy and recycling industry in Brazil created hundreds of thousands of new job. (Sanchez and Poshecn, 2009). According to Pew Charitable Funds, employment in clean energy economy grew by more than 9 percent between 1997 and 2007 (Pew Charitable Trust, 2009). Proper building monitoring has yielded energy savings of up to 38 percent in cooling and 62 percent in heating and overall energy saving of higher than 30 percent (Levine et al., 2007).

![Figure 2.1: Model of sustainable development (Barton, 2000; Lutzkendorf and Lorenz, 2007)](image)

Reducing GHG and other emissions from sustainable buildings industry will bring multiple benefits to environment, economy and to society. According to Kristensen (2007), a study found that modification during the operational stages of several sustainable buildings in Kuala Lumpur, Malaysia reduced total energy consumed by 20 to 30 percent. In developed countries such as U.S sustainable building reduced initial site energy use by 37 percent (Torcellini et al., 2006). GHG improvement strategies for building industry can contribute to the growth of new trades and employments. These initiatives as well can stimulate social development goals such as improved housing and access to clean energy and water. This is the opportunity for decision makers in governments to grab the prospects to build the foundation for sustainable development in the countries.
2.4 Green Building Rating Tool (GBRT)

According to United States Environmental Protection Agency (2012), green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building life cycle from the design to construction, operation, maintenance, renovation and deconstruction. It involves the whole life cycle of a building to maintain its performance while complements with the building design concern of economy, durability, utility and comfort. Green building also called sustainable building or high performance building.

GBRT is a tool or system that examines the performance or expected performance of a whole building and translates that into an overall assessment that allow for comparison against other buildings (Fowler & Rauch, 2006). It is a tool developed to assess a building, which will produce an output that show if the building is performing according to the threshold level. There are two different approaches of GBRT which are Prescriptive-based and Performance-based approach (Viera, 2014; Spataro, Bjork & Masteller, 2011). These approaches have a distinctive ways to assess buildings. The timeline of the development of building rating tools in different countries is shows in Figure 2.2.

![Figure 2.2: Timeline of the development of building rating tools in different countries (Reed et al., 2009)](image)

There are many GBRT had been formulated, as early as 1990 with the released of Building Research Establishment Environmental Assessment Method (BREEAM) in United Kingdom. Since then, building rating systems were evolved into different countries and largely based on the initial rating systems (Reed et al., 2009). These
assessment tools are able to rate and determine the green performance of a building. Some of the other assessment tools that are being used in 26 countries (Reed et al., 2009) are shown in Table 2.1.

Table 2.1: Green Building Rating Tool in 26 countries (Reed, et al, 2009)

<table>
<thead>
<tr>
<th>Continent</th>
<th>Country</th>
<th>Green Building Rating Tool (GBRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>LEED / Green Globes / BREEAM / GB Tool / BEPAC (Building Environmental Performance Assessment Criteria)</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>LEED</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>LEED</td>
</tr>
<tr>
<td>EUROPE</td>
<td>Germany</td>
<td>DGNB / Office Score</td>
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<tr>
<td></td>
<td>UK</td>
<td>BREEAM / ENVEST</td>
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<td></td>
<td>France</td>
<td>HQE</td>
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<td></td>
<td>Finland</td>
<td>PromisE</td>
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<tr>
<td></td>
<td>Netherlands</td>
<td>BREEAM</td>
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<td></td>
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<td></td>
<td>Portugal</td>
<td>SBPTool</td>
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<td></td>
<td>Swiss</td>
<td>SPIN / Minenergie</td>
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<tr>
<td></td>
<td>Spain</td>
<td>VERDE</td>
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<tr>
<td>ASIA</td>
<td>India</td>
<td>LEED / TGBRS</td>
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<tr>
<td></td>
<td>China</td>
<td>LEED</td>
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<tr>
<td></td>
<td>Singapore</td>
<td>Green Mark</td>
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<tr>
<td></td>
<td>Vietnam</td>
<td>LOTUS Rating Tool</td>
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<td></td>
<td>Thailand</td>
<td>TREES</td>
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<tr>
<td></td>
<td>Hong Kong</td>
<td>BEAM</td>
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<td></td>
<td>Philippines</td>
<td>VERDE</td>
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<tr>
<td></td>
<td>Indonesia</td>
<td>Greenship</td>
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<tr>
<td></td>
<td>Japan</td>
<td>CASBEE</td>
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<tr>
<td></td>
<td>Malaysia</td>
<td>GBI/GreenRE/GreenPASS/PH/MyCREST</td>
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<tr>
<td>Africa</td>
<td>South Africa</td>
<td>Green Star</td>
</tr>
<tr>
<td>Oceania</td>
<td>Australia</td>
<td>Green Star (2002) / NABERS / City of Sydney Multi Unit Residential / AGIC / STEPS / SDS / EnviroDevelopment / NatHERS</td>
</tr>
<tr>
<td></td>
<td>New Zealand</td>
<td>Green Star</td>
</tr>
</tbody>
</table>

Based on Table 2.1, it shows various GBRT were used in different continent of the world. United States, Canada and Australia have more recognized building assessment tools used in the country. LEED is widely used and accepted by other country other than Unites States, such as Canada, Mexico, Brazil, India and China. Developed countries such as United States, Australia, Germany, Canada and Singapore have all have developed their own GBRT because of high awareness to promote sustainability in their building sector. It is standard for developing countries to adopt readily developed tools to be used in its country. This method of adoption
although save time and cost for development of a new tool, the different priorities between developed and developing countries should be addressed.

In Malaysia, with the statistics showed that buildings consume a total of 48% of the electricity generated in the country and the demand for electricity is expected to rise (Hassan, et al, 2014), the development of National Green Technology Policy (NGTP, 2009) and Low Carbon Cities Framework and Assessment System (LCCF, 2011) by the Ministry of Energy, Green Technology and Water, Malaysia is deemed essential. Consequently in 2009, GBI was developed through the collaboration of Malaysian Institute of Architects (MIA) and the Association of Consulting Engineers Malaysia (ACEM). GBI is Malaysia’s first green rating tool and specifically established for Malaysia tropical climate, environmental context and cultural and social needs. As of October 2015, there are 650 registered projects by GBI (Green Building Index, 2016). In 2013, the Real Estate and Housing Development Association of Malaysia (REHDA) launched Green Real Estate (GreenRE) to drive forward the initiatives of sustainable development in Malaysia. Beside GBI and Green RE, currently in Malaysia there are other tools or systems that available such as Green Mark, LEED, Green Rating (Penarafan Hijau), Sustainable Low Carbon Building Performance Framework and Malaysian Carbon Reduction and Environmental Sustainable Tool (MyCREST).

2.5 Green Building Rating Tool (GBRT) approaches

These various GBRT around the globe used different approach to conduct its building assessment to achieve its ratings. There are two approaches of GBRT that being used, which are prescriptive and performance approach. Classifying whether a GBRT is a prescriptive or performance approach comes on how it is being implemented and when it is being implemented during the building assessment. Prescriptive approach tells the designer what should be done while performance approach set a goal and leave it to the designer how the goal is to be achieved (Malin, 2000). The green building assessment tools are implemented across the life cycle of a building, but prescriptive approach relates mostly to the design and construction phases while performance approach are focused on the construction and operation phases (Mohd Annuar, Osmond & Prasad, 2014). This section discusses more in detail about both approaches.
2.5.1 Prescriptive approach

Prescriptive indicators are used to specify a certain set of actions that must be taken to satisfy the criteria or credit (Carmody, Weber & Jacobson, 2009). Prescriptive approach assess building by comparing the design and construction of the building with a list of specification of green elements based on the standards and allocate points based on the compliancy. Using prescriptive approach, it relies mostly on the assumption that chosen elements will be designed, installed and performed accordingly to determine compliance and this process usually takes part during the design and construction processes. It not focuses on the overall life cycle of a building, where most of energy consumption took place in the operation phase of a building.

Prescriptive approach is an option describes exactly what is required in terms of the design and performance of the building according to the standard. Building industry players need to follow the instructions that has been laid out according to the approach guideline (Freeman, 2013). He added that this approach more suitable in more simple building design without having complex Heating, Ventilation and Air Conditioning (HVAC), lighting and water system. There has been a noticeable shift away from prescriptive measures and toward systematic, performance-based assessment using Life Cycle Assessment (Werner & Richter, 2007). Accordingly, it is more appropriate to have a more suitable approach to access complex building, which calculates the true performance of the building.

2.5.2 Performance approach

GBRT using performance approach assesses the whole building real performance rather than comparing the compliance of a building towards a certain standards. Performance indicators are used to measure the outcome of a set of actions (Carmody, Weber & Jacobson, 2009). To manage a building, we need certain measurements of the real performance of the buildings to make sure it performs efficiently. Performance-based GBRT relies on data monitoring and reporting of performance to determined compliance. Taking into account of achieving energy efficient building, this approach shows the real performance of a building during
their critical stage of life cycle, which is operation. The electricity and water bills are few indicators to the building manager or building owner for measuring the performance of their buildings. “The best systems measure performance rather than prescribe solutions, or are based on life cycle assessment” (British Colombia Wood, 2015). Performance of a building should be monitored throughout its life cycle to maintain an efficient system, which promote sustainability.

Performance-based GBRT use different approach in assessing building than prescriptive-based. Prescriptive approach only describes design rules on exactly how buildings are to be designed and presume that those designs and installments will perform as accordance with the expected outcome. In the other hand, performance approach set standards for the whole building performance. Other than National Australia Built Environment Rating System (NABERS), there are also other tools implementing this approach such as Sustainable Building Tool (SB Tool), Home Energy Rating System (HERS), Living Building Challenge, International Green Construction Code (IGCC) and Eqo-Quantum. With this approach, building manager can carry out continuous monitoring of compliance through performance data and encourages continuous commissioning of their buildings.

A prescriptive standard tells you what to do, while performance standard tells you what your goal is (Green Building Advisor, 2015). Performance and prescriptive approach are two distinctive approaches. These different approaches give alternatives to designers or architects in designing new buildings. Thus, it gives diverse advantages and disadvantages with the same aim to promote sustainable building management in the building industry.

2.6 Comparison of Prescriptive and Performance based GBRT

This section will highlight comparison between two different approaches of GBRT, which are prescriptive and performance approach. Both approaches have their own advantages and disadvantage.

2.6.1 Advantages and disadvantages of Prescriptive-based approach

The advantages of prescriptive approach might attract major building developers and owner to apply it to rate their buildings for green certificate. With its simple process,
which provides a clear description of accepted energy efficiency measures and the compliance is easily verify by the inspectors it might be the option to go to (Spataro, Bjork & Masteller, 2011). The early tools like BREEAM and LEED become the common used framework for new tools such as Green Globes (US) and GBI (Malaysia). It is being adopted in the sense that building owners and designers know what to expect based on the previous tools.

For prescriptive approach, all the guidelines and elements for green building have been laid out according to the standards, but building developers have limited usage of current green building technology and innovation. It causes lack of flexibility for designers and developers (Rosenberg & Hart, 2014). Their choices are narrow down to the baseline that was generated from prescriptive code components. This approach may cause lag in technological advancement towards the application on the building construction. With the compliance only can be checked during the design and assessment process, the building can be poorly operated and managed (Senick, 2014).

2.6.2 Advantages and disadvantages of Performance-based approach

Using performance approach, new technology can be implemented in the new or existing buildings to allow more flexible approach to design innovation (Spataro, Bjork & Masteller, 2011). With various options to implement green elements into the building, building owners or building developers can choose the latest and best options. With a clear goals and objectives, transparency is not a problem. The regulators are encouraged to implement performance-based into its rating tool to really comprehend the performance of the building (Jacobs, 2011).

But, it seems that the implementation of performance approach is expensive, as it requires special software and a trained energy modeler. Moreover, it is time consuming, as it requires meeting specified energy use intensity (Senick, 2014). Thus make it unfavorable amongst building owners and developers. The use of special software, energy modeler and time surge the cost for certain building to be rated as sustainable or green building.

Although both approaches have its own advantages and disadvantages, it shows that it is not sufficient to just rely on prescriptive approach assessment system to achieve the objective of green building to mitigate climate change. The trend of
applying prescriptive-based green building certification is a major start-up in adopting building performance. A standard should lie on the principle that address building performance beyond those captured by rating systems or guidelines for making an efficient construction industry. For this matter, an incorporation of performance-based assessment system should receive more attention in the building construction as it can address the requirement for sustainable building requirements.

2.7 Important features of GBRT

This part discusses the details of GBRT and the important features in GBRT attributes that were included in this research, which are the assessment elements and criteria. Previous studies related to this investigation are discusses to get more ideas and views to conduct this research. From there, all the important features are gathered as the preliminary information for the survey process.

2.7.1 Overview of the GBRT

This section discusses 7 GBRT that being used in 6 countries. The GBRT that was selected for this research are BREEAM (U.K.), LEED (U.S.), Green Star (Australia), GBI (Malaysia), Green Mark (Singapore), NABERS and SB Tool (Canada). The GBRT were commonly used in the global market and also its respective country.

Building Research Establishment Environmental Assessment Method (BREEAM) developed by the Building Research Establishment in 1990 (BREEAM, 2007). It is the earliest rating tool. Since then, it has been internationally adopted and become the framework of new developing tools. Australia (Green Star), Hong Kong (HK-BEAM) and New Zealand also used the BREEAM methodology in developing their own building assessment systems (Ding, 2008 and Grace 2000). In 2005, the Green Building Institute adapted the Canadian Version of BREEAM for a U.S. market and named it Green Globes (Smith et al., 2006). It provides a framework for sustainable design and a measure of the overall sustainability of the building on a scale that can be benchmarked against any building across the globe. It carried out assessment in two stages, which are at design stage and a post construction stage. Then the final certificate and rating is awarded. BREEAM can be used to assess any type of buildings in the world using the National Scheme Operators (BREEAM,
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