Arab Academy for Science, Technology & Maritime Transport (AASTMT)

College of Engineering and Technology (Cairo)
Construction and Building Engineering Department

Master of Construction and Building Engineering

Evaluation of the Arab Academy for Science, Technology & Maritime Transport (AASTMT) Building to be Oriented towards a Green Building

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بسم الله الرحمن الرحيم

يَرْفَعِ اللهُ الّذِينَ آمَنُوا مِنكُمْ والّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللهُ بِمَا تَعْمَلُونَ خَبِيرٌ

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This thesis is dedicated to my beloved country in hopes that it can contribute towards the establishment and development of the local Green Building market.

ABSTRACT

Major challenges are encountering mankind these days, one of which is the lack of nonrenewable resources which imposes a need to implement creative solutions to fulfill the daily basic needs and provide a maximum possible reserve for future generations. In addition, the world economy is becoming increasingly constrained by energy cost, energy availability, and energy-related environmental regulations. Many countries, especially the developing nations like Egypt, are looking to shore up their energy supply structure and identify measures to address energy demand issues. With the continued challenge of climate change, more countries are implementing measures that will reduce energy consumption and GHG emissions. The Arab Academy for science, technology, & maritime transport, Cairo branch buildings (A, B, and GS) were used as a case study. The research has focused on detecting some tiers to retrofit those buildings to be environmentally green. Those tiers include energy consumption, operating cost, and greenhouse gas emissions. Data were collected and analyzed for the three buildings which showed that it is possible to reduce energy consumption by about 29%. This will result in reducing operating cost and the greenhouse gas emissions, mainly CO_2, by 28.97%.The application of Green building practices and recommendations inside the buildings will enhance the productivity of the employees. BIM application (Revit) was used to build a 3D model for the buildings and to run natural lighting analyses to determine the amount of natural light entering the buildings accurately in order to increase the reliance inside the buildings and reduce the demand on the artificial lights and decrease the operating costs.

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LIST OF ACRONYMS/ABBREVIATIONS

3R	**:**	Reduce, Reuse, and Recycle
AASTMT	**:**	Arab Academy for Science and Technology and Maritime Transport
ASHRAE	**:**	American Society of Heating, Refrigerating, and Air-conditioning Engineers
BREEAM	**:**	Building Research Establishment Environmental Assessment Methodology
GBCI	**:**	Green Building Certification Institute
GCB	**:**	Green Commercial Building
GPRS	**:**	Green Pyramid Rating System
HVAC	**:**	Heating Ventilation and Air-Conditioning
LCA	**:**	Life cycle assessment
LEED	**:**	Leadership in Energy and Environmental Design
NAHB	**:**	National Association of Home Builders
NBI	**:**	New Building Institute
RPI	**:**	Responsible Property Investment
USDOE	**:**	United States Department of Energy
USEPA	**:**	United States Environmental Protection Agency
USGBC	**:**	United States Green Building Council
VOC	**:**	Volatile Organic Compounds

CHAPTER ONE

INTRODUCTION

CHAPTER ONE
INTRODUCTION

1.1 Background

Growing world population and rapid urbanization go hand in hand with a greater exploitation of the world's limited resources. Egypt is no exception. This leads to a large demand and consumption in energy, land, water, and other resources.
Buildings worldwide, according to World Business Council for Sustainable Development (WBCSD), account for 40% of global energy consumption; and the resulting carbon footprint (consisting of 40% CO_2 emissions) significantly exceeds those of all transportation combined (WBCSD, 2010).

Egypt is a development country which has a moderate climate over the year and limited non-renewable resources. Securing energy demand on continuous bases is a vital element for sustained development plans. For the past two decades, the Egyptian government has been working feverishly to improve the Egyptian environment, minimize the energy consumption, and cost (El Din, 2011). For Egyptian stakeholders are seeking for methods to reduce energy consumption by developing energy efficiency building codes which started by a critical first step in that process. Identifying alternative paths towards energy efficiency has been a second step.

The purpose of this research is to complete an analyses of the elements of a green building. This is also known as sustainable buildings which represent friendly structures that significantly reduce their impact on the environment .This topic becomes more relevant as the cost for energy and natural resources continue to increase. The financial benefits of green buildings include lower energy, waste, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health and the savings continue throughout the life cycle of green buildings because they are less expensive to operate. A green building is designed to reduce or eliminate the impact on human health and the natural environment. This is accomplished by incorporating materials and operational elements that are environmentally responsible and resource efficient throughout the life cycle of the building.

The life cycle of a green building is defined as the life expectancy of any components that make up the structure and impact on the operation of the structure over an established period of time. Life cycle can also consist of the overall impact to society in terms of a green environmentally friendly building and any associated environmental contribution that could be done. An important aspect of a green structure is its "Carbon Footprint." A carbon footprint is the release of carbon dioxide from energy use. Energy use includes that used for the manufacture and products used in construction of a building. This use also includes the energy used in the operation of a building such as heating, cooling, lighting as well as other aspects. The use of carbon foot printing has only recently started to be used as part of the design and operational efficiency (Zigenfus, 2008).

Using green building materials and products promotes conservation of dwindling nonrenewable resources internationally. In addition, integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials.

1.2 Problem Identification

The world is heading towards reducing the natural resources degradation and increasing the reliance on the renewable energy sources, and limiting the negative effect on the surrounding environment, global warming and climate change problem. Consequently, governments and organizations have been seeking for solutions to reduce the pressure on the remaining natural resources.

AASTMT contains various electrical systems in terms of lights, air conditioners, computers, heaters, etc. These consume a great amount of energy and hence cost a lot in addition to consumption of the available non-renewable resources. There are many policies that could be adopted inside the academy which should help in preserving the environment and reducing the operating costs.

1.3 Research objective

The main purpose of this research is to analyze the exiting situation of the Arab Academy for Science, Technology and Maritime Transport (AASTMT: A,B,GS) buildings in terms of sustainability, their adverse effect on their users and the surrounding environment, and the possibility of orienting them towards being categorized as green buildings

This research shall focus on evaluating the buildings to be oriented towards a green building and Energy consumption, Operating cost, and Greenhouse gas emissions.

The objectives of Evaluation of the Arab Academy for Science, Technology &Maritime Transport (AASTMT) Building to be oriented towards a Green Building were:

(1) To identify and research green and sustainable design building features.

(2) To evaluate the applicability of green features in buildings (A, B, and GS).

(3) To conduct a lifecycle cost analyses associated with the implementation of each green feature.

(4)Evaluate how do current policies make use of the key stakeholders in the green building system to encourage the development.

(5) To make preliminary recommendations to the stakeholders regarding the implementation and effectiveness of each green building feature at AASTMT.

1.4 Methodology

The evaluation of the buildings was done via two rating systems called:

- LEED (Leadership in Energy and Environmental Design) developed by the United States Green Building Council (USGBC).
- The newly developed rating system from the National Home Builders Association (NAHB).

Both qualitative and quantitative data were collected via multiple methods and were analyzed under the market transformation theory framework presented as follows:

- Literature review, to include a greater description for the purpose of the study.
- Field survey was done for the AASTMT buildings elements through data collection, and observation.
- Mathematical equations were used to compute GHG's emotions, energy consumptions, and operating cost.
- BIM software -natural lighting analyses-, it was used to calculate the amount of natural lighting interring the building throw making a 3D model for the buildings and analyzing it.
- Comparisons between the green building concepts to clarify them.
- Analyses, conclusion, and recommendations.

1.5 Thesis Outlines

This thesis contains five chapters as follows:

Chapter (1) "Introduction":

Introduces the problem definition, the objective and methodology of the work and thesis outlines.

Chapter (2) "Literature Review":

Includes a review of the literature about green building and sustainable policies.

Chapter (3) "Green Building Standards":

Is devoted to present the different standard in green building and show the difference between them.

Chapter (4) "Case Study":

Is devoted to analyze the collected data and put strategies to apply the green building practices.

Chapter (5) "Results and Analyses":

It devoted to review the found results and the recommended suggestions in terms of green building and sustainability.

Chapter (6) "Conclusions":

Presents the obtained results and the overall conclusions and recommendations for future studies.

List of references

Appendices A and B

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The background information (including pressure and driving forces) on green building development in Egypt was gathered. This helped to understand the current situation in Egypt, and played a significant role in narrowing down the research scope as well as selecting the case of this study.

An intensive literature review was prepared aiming to build the theoretical context relating to green building and market transformation in order to achieve a comprehensive view of the whole system and the market transformation process.

2.2 Green building

The development of green building practice can be traced back to 1970s, along with energy crisis (Wilson, 2006, EPA, 2010); while the term of "green building" and its concept came later. The definition varies by the green building evaluation system or program (Yoshida and Sugiura, 2010).

In some evaluation systems or programs, the term of green building is merely defined by one single factor, such as energy efficiency. For example, the European Commission initiates the Green Building Program in 2004. The program aims at "improving the energy efficiency and expanding the integration of renewable energies in non-residential buildings in Europe on a voluntary basis" (European Commission, 2004). It is even narrower than the Egyptian official definition of green building.

Usually in this circumstance, green building is regarded the same as "Sustainable Building". For example, according to US EPA, green, or sustainable, building refers to "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort" (EPA, 2010). In Japan, CASBEE2 uses the term "Sustainable Building "defined by the Architectural Institute of Japan-AIJ (Sunikka-Blank and Iwafune, 2011) as a building considering the three pillars of sustainability (environmental, social and economic) referring to a building that saves a maximum amount of resources (including energy, land, water, and materials), protect the environment, and minimize pollution throughout its life cycle; provides people with healthy, comfortable and high efficient space, and exist harmoniously with local environment and culture.

It is worth mentioning that during the development of green building worldwide, there exist several relevant terms. Some of them address one single factor of green building; while some highlight the technical aspects to achieve green building.

There are two representative ones listed as follows:

1. **Energy-efficient building**: it is part of the origin of green building. An energy-efficient building retains the best environment while minimizing the consumption and waste of energy (Crook, 2006). Similar ones are low-energy building, zero-energy home, energy plus house, passive house, zero-carbon house, etc. (European Commission, 2009). They all stress the factor of energy in building, regardless of life cycle.
2. **Eco-architecture**: it is “in harmony with nature, including its immediate environs”. It “makes every effort to minimize the use of energy at each stage of the building’s life cycle, including that embodied in the extraction and transportation of materials, their fabrication, their assembly into the building and ultimately the ease and value of their recycling when the building’s life is over” (Broadbent and Brebbia, 2006). This term addresses more on the harmony with nature and considers energy, material, as well as life cycle aspects.

According to the different researchers the term “green” was defined in the following lines:

- Green is really about the construction and operation of a building to be ecology friendly. Or a better way to describe green is environmentally sustainable to reduce or eliminate the need for resources (Zigenfus, 2008).
- Green buildings appear to be the future for Swedish real estate companies. There is a great potential in the environmental benefits in this area is obvious (Sundbom, 2011).
- The green building movement is an evolving and unique process. Once the organizational mindset had changed and committed to implementing sustainable goals the process becomes an easy task (vanderweil, 2008).
- Residential green building programs have different goals, but they all tend to measure similar categories of concern namely, energy efficiency, water efficiency, wise use of materials and resources,…etc. (Miller, 2010).
- There are many factors involved in the process of state-funded construction, so to compare the actual number of completed projects in each state has emerged as an inadequate measure of accomplishment as LEED and MSGB (JANAK, 2009).
- Homes can become a tool for changing behaviors and the world. The need for an integrated design and construction process and the diversity of possible solutions requires stakeholders to participate in new ways (Scheuer, 2007).
- The contractors need to know all of the information related with the green construction so that they can understand the benefits of the green construction, and hence applying it in their operation (Abdel Aziz, 2011).
- There is a significant positive relationship between the greenness and the residential property prices.The builders want to mention and market the buildings as green earn the extra profit (Aroul, 2009).
- Green building development in Shanghai is at a crossed stage of both market formation and expansion. Stimulating developers’ green motivation is considered to be a key to promote the green building development in present system (Liu, 2012).

- The main barriers Dubai's construction market faced while applying sustainable construction practices was the lack of information, no clarity was provided on the scope of the policy and long payback periods for these investments (Maguina, 2011).
- One of potential contributions to support improvements of the existing GB rating systems could be to provide quantitative measures of IAQ that can be then associated with energy efficiency strategies and human health outcomes (Srebric, 2010).

2.3 Energy consumption

Renewable energy is any technology that exclusively relies on an energy source that is naturally regenerated over a short time and derived directly from the sun, indirectly from the sun, or from moving water or other natural movements and mechanisms of the environment. Renewable energy technologies include those that rely on energy derived directly from the sun, wind, geothermal, hydroelectric, wave or tidal energy, or on biomass or biomass based waste products, including landfill gas. (Waltonselectric.com) Renewable energy is the best choice for securing energy demand to the next generations with clean environment. Egypt is a rich country with renewable resources which can be used for power generation on a commercial scale (El Din, 2011).

The energy efficiency of a building can be influenced by how the space is utilized. In order to maximize energy efficiency within the building, heat losses must be kept to a minimum by using insulation (Elsadig, 2005). The implementation of solar energy solutions combined with energy efficient design can lessen the burden of the building on the energy sector (Kramer, 2008). A case study showed how a simple occupancy based lighting control system can save electrical energy and has a short payback period (Benediktsson, 2009).

2.4 Water and Waste Water Quality

The water which leaves the treatment center will be of the highest quality for renovated wastewater. The implementation of water reuse would be much less expensive (Grant, and others, 2002). According to (Varghese, 2007), on 76 % of the projects where grey water reuse systems were utilized, capital cost of the project was affected by the implementation. Savings reaped from not using as much potable water were notable and there was less sewage to be treated

2.5 Operating Cost

The motivator for many institutions, with a policy in place, is assured lower building operational costs. This appears to reinforce the value of having a policy or state legislation as a tool for undertaking sustainable practices (Cupido, 2011). There is a need to change the attitude of that green buildings cost more. The focus should be on the life cycle costs of a building and what the benefits of building green add to the equation (Andersson and others, 2010).

The research reveals that green building is less about product and more about process. The use of an integrated design process is absolutely critical to cost effective green building (Mcdonald, 2005). The invisible cost of environmental pollution is a heavy cost to the society; it may be even more expensive than adopting sustainable technology (Yunqing, 2011). In the long term, green commercial building will earn more profit than typical commercial building even it started off with higher construction cost (Vinyangkoon, 2012).

2.6 Application of 3R

The importance of analyzing the issue of waste picking is that it represents the intersection of two increasingly pertinent topics of concern to our societies; poverty and waste. The important shift in waste picking from an atomized undertaking to an organizational base provides a platform where the poor can become social actors within the local governance framework (Turcotte, 2009). Refers to (Ho, 2002) countries can adopt different waste management strategies but only when consumerism decreases can true waste minimization and true sustainable waste management be achieved . Waste reduction through waste reuse is a primary function of the public at the stage of waste generation (Kirunda, 2009).

The solid waste management has been developed after operation the Zahrat Al-Finjan landfill on an environmentally sound through construction a controlled sanitary landfill, and improving the solid waste management services (Al Sa'di, 2009).

The design and planning of a successful waste management scheme in Cameroon has to involve the community from the beginning, and has to be part of a holistic development program (Sylvester, 2002).

2.7 Sustainable Materials

Green building materials are rapidly developing and expanding sector in the construction materials market. What constitutes a "green" material varies widely depending on the source. While no official government standard exists to provide definable guidelines, the Federal Trade Commission is working on such a plan (Gupta, and others). According to Milani (2005) in a transition to an ecological economy, awareness about materials is perhaps more important than energy awareness. The materials can be a fulcrum to leverage change in the economy as a whole. Some sustainable building materials depend on new technology, and it requires testing over time. Advice from other architects and building occupants who are using these new technologies can assist in determining their long range effectiveness (Kim, and Rigdon, 1998). The sustainability index is a combination of economic, social, technical and environmental criteria into an indexing algorithm to rank building material on their contribution to sustainability (Akadiri, 2011).

Low-income housing projects can be vastly improved by considering options for alternative design and materials. Technical sustainability, such as energy efficiency, life-cycle analyses of materials …etc. should receive more attention (Ballerino, 2002).

2.8 Indoor Air Quality, Health and Productivity Impacts

A natural ventilation concept is based on the characteristics of the site and highly integrated with the building structure and can have considerable architectural consequences (Kleiven, 2003). It is critical that sustainable development results not just in resource conservation, but also in increasing productivity and occupant well-being (Prakash, 2005).

It has to be realized that high insulation levels have to be combined with vapor control layers and ventilation systems to reduce heat loss on the one hand and to provide moisture protection on the other (De Groot, 2009). It was observed that occupants in green buildings are on average more satisfied with their air quality and thermal comfort (Fard, 2006). According to Kats (2003) a larger portion of benefits are represented by productivity and health, and the percentages of benefits from the other categories reduce correspondingly.

2.9 Policy Instrument

According to Liu (2012) policy instrument is the object of this research. It refers to the tools or measures used by the governments to exercise their power through public policy (Vedung, 1998). Here, based on the classification system from UNEP (2007), UNFCCC (1999), IEA (2005) and Klinckenberg and Sunikka (2006), the policy instruments are classified in the following categories:

- Regulatory instruments refer to laws and implementation regulations that are mandatory to fulfill by targeted participants. Regulatory instruments applicable to the case of green building include building codes, appliance standards, mandatory audits, etc.
- Market-based instruments are usually based on market mechanisms and contain elements of voluntary action or participation, though usually initiated or promoted by regulatory instruments (UNEP, 2007).
- Energy performance contracting and tradable certificates for energy efficiency improvements (e.g. LEED) are two examples of such instruments potentially applicable to the case of green building.
- Fiscal instruments provide financial incentives or disincentives to alter the economic conditions of targeted participants (Mundaca, 2008). For instance, taxation, tax exemptions/reductions, subsidies, soft loans, so on and so forth. They are often mandated and/or implemented through legal means (ibid.).
- Informative instruments aim at providing information, knowledge, and examples of successful implementation in order to achieve social change, such as customers' behavior. This is based on the rationale that asymmetric information makes it difficult for market agents to make rational choices (ibid.). Such instruments include certificate programs, labeling schemes, public demonstration programs, education, information campaigns, training programs, etc.

2.10 Global Warming

Global warming is defined as an increase in the average temperature of the Earth's atmosphere, especially a sustained increase great enough to cause changes in the global climate. The term global warming is synonymous with Enhanced greenhouse effect, implying an increase in the amount of greenhouse gases in the earth's atmosphere, leading to entrapment of more and more solar radiations, and thus increasing the overall temperature of the earth (Chauhan, 2010).

2.10.1 Effect of Global warming on the earth's climate

Detailed researches of climatic events of the past 150 years have revealed that the temperatures have risen all over the globe, with the warming occurring in two phases. The first phase was from 1919 to 1940, with an average temperature gain of 0.35°C, and the second phase was from 1970 to the present, exhibiting temperature gains of 0.55°C. Records show that the past 25 years have been the warmest time of the past 5 centuries. The global warming has resulted in the warming of the oceans, rising of the sea levels, melting of glaciers, and diminished snow cover in the Northern Hemisphere (Chauhan, 2010).

The recent catastrophic climatic events like the massive floods in Pakistan and India, the Hurricane Katrina in the United States, the prolonged droughts in Australia, China, Pakistan, India and Texas, are all the results of increased temperatures due to global warming. During the 21st century, climatic disasters occurred five times as frequently and killed or affected seventy times as many people. Between 2000 and 2004, an average of 26 climatic disasters was reported each year. Thus, the immense geological changes will continue their destruction unabated if steps to mitigate global warming are not taken (Chauhan, 2010).

2.10.2 The greenhouse effect and global warming

The sun produces radiation mainly in the ultraviolet (UV), visible (vis) and infrared (IR) regions of the electromagnetic spectrum. When these reach the Earth, part is reflected back into space and part of it is absorbed by the Earth's surface. The part which is absorbed heats up the Earth which in turn then radiates some of its energy out into space.

The frequency at which any object emits radiation depends on its temperature. The Earth, being that much cooler than the Sun, emits energy at a lower frequency and therefore longer wavelength – in the IR region.

A steady state is reached where the Earth is absorbing and radiating energy at the same rate, resulting in a fairly constant average temperature. If there were no greenhouse effect at all then the surface temperature would be about 256K or -17˚C (about the temperature of a domestic freezer) and life as we know it could not exist because water, the which is fundamental to life, would be a solid.

However, the IR radiation emitted by the Earth can be absorbed by gases in the troposphere and become trapped. The radiation is then re-emitted in all directions; some back towards the Earth, which is known as the 'greenhouse effect'.

This leads to an increase in temperature and global warming, making the average surface temperature of the Earth about 286K or 13˚C. (Wong, V., 2008).

It is an essential part of keeping our planet hospitable and helps to sustain life. The gases which absorb and then re-emit IR are known as 'greenhouse gases. (Wong, V., 2008) as illustrated in **Figure 2-1.**

2.11 Greenhouse Gas Emissions

2.11.1 Emission Factors for Greenhouse Gas Inventories.

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO_2). Gases are converted to CO_2e by multiplying by their global warming potential by the emission factors listed in this document have not been converted to CO_2. To do so, the emissions are multiplied by the corresponding GWP as listed in **Table 2-1**.

Table (2-1) Global Warming Potentials (GWPs)

Gas	100-year GWP
CH_4	25
N_2O	298

Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007.

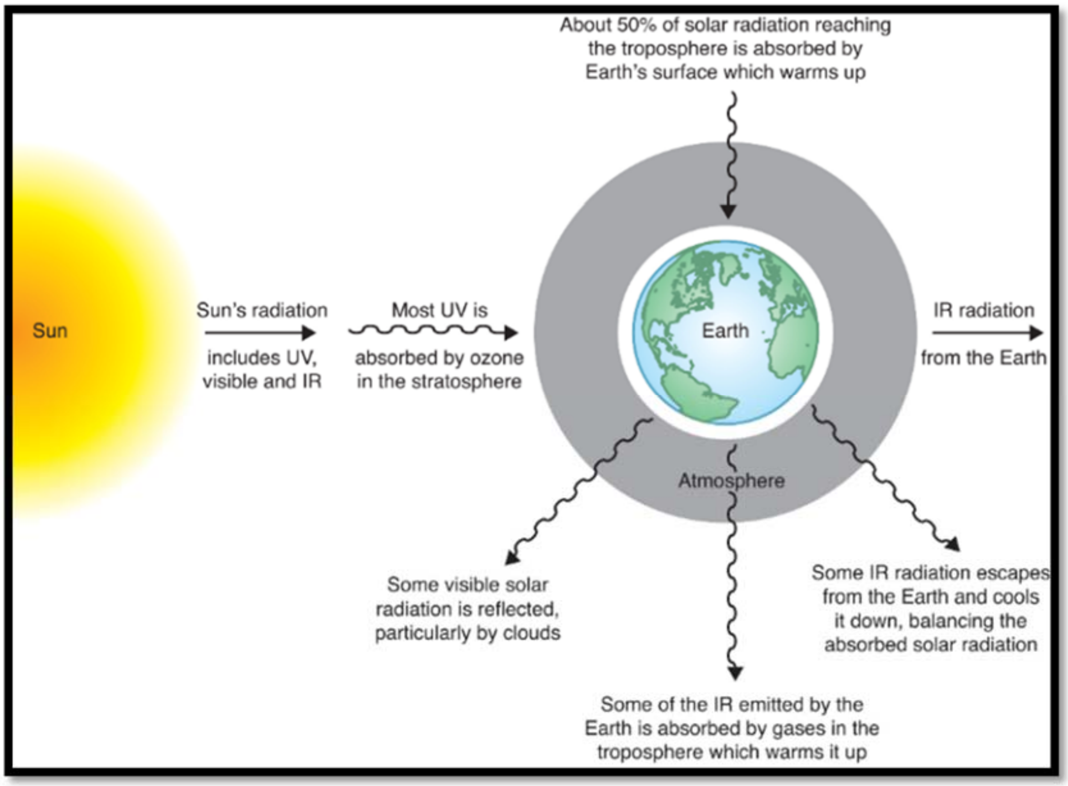

Figure (2-1) Energy balance of the earth.

The greenhouse gas emissions can be calculated for the different types of fuel as listed **Tables (2-2) to (2-11)**

Table (2-2) Stationary Combustion Emission Factor

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO2 per mmBtu	g CH4 per mmBtu	g N2O per mmBtu	kg CO2 per short ton	g CH4 per short ton	g N2O per short ton	
Coal and Coke								
Anthracite Coal	25.09	103.69	11	1.6	2,602	276	40	short tons
Bituminous Coal	24.93	93.28	11	1.6	2,325	274	40	short tons
Sub-bituminous Coal	17.25	97.17	11	1.6	1,676	190	28	short tons

Table (2-2) Stationary Combustion Emission Factor continue:

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO2 per mmBtu	g CH4 per mmBtu	g N2O per mmBtu	kg CO2 per short ton	g CH4 per short ton	g N2O per short ton	
Lignite Coal	14.21	97.72	11	1.6	1,389	156	23	short tons
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34	short tons
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32	short tons
Mixed (Industrial Coking)	26.28	93.9	11	1.6	2,468	289	42	short tons
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36	short tons
Coal Coke	24.8	113.67	11	1.6	2,819	273	40	short tons
Fossil Fuel-derived Fuels (Solid)								
Municipal Solid Waste	9.95	90.7	32	4.2	902	318	42	short tons
Petroleum Coke (Solid)	30	102.41	32	4.2	3,072	960	126	short tons
Plastics	38	75	32	4.2	2,850	1,216	160	short tons
Tires	28	85.97	32	4.2	2,407	896	118	short tons
Biomass Fuels (Solid)								
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35	short tons
Peat	8	111.84	32	4.2	895	256	34	short tons
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44	short tons
Wood and Wood Residuals	17.48	93.8	7.2	3.6	1,640	126	63	short tons
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	
Natural Gas								
Natural Gas (per scf)	0.001026	53.06	1	0.1	0.05444	0.00103	0.0001	scf
Fossil-derived Fuels (Gaseous)								
Blast Furnace Gas	0.000092	274.32	0.022	0.1	0.02524	0.000002	0.000009	scf
	mmBtu per short ton	kg CO2 per mmBtu	g CH4 per mmBtu	g N2O per mmBtu	kg CO2 per short ton	g CH4 per short ton	g N2O per short ton	
Coke Oven Gas	0.000599	46.85	0.48	0.1	0.02806	0.000288	0.00006	scf
Fuel Gas	0.001388	59	3	0.6	0.08189	0.004164	0.000833	scf
Propane Gas	0.002516	61.46	0.022	0.1	0.15463	0.000055	0.000252	scf

Table (2-2) Stationary Combustion Emission Factor continue:

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO2 per mmBtu	g CH4 per mmBtu	g N2O per mmBtu	kg CO2 per short ton	g CH4 per short ton	g N2O per short ton	
Biomass Fuels (Gaseous)								
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306	scf
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413	scf
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	
Petroleum Products								
Asphalt and Road Oil	0.158	75.36	3	0.6	11.91	0.47	0.09	gallon
Aviation Gasoline	0.12	69.25	3	0.6	8.31	0.36	0.07	gallon
Butane	0.103	64.77	3	0.6	6.67	0.31	0.06	gallon
Butylene	0.105	68.72	3	0.6	7.22	0.32	0.06	gallon
Crude Oil	0.138	74.54	3	0.6	10.29	0.41	0.08	gallon
Distillate Fuel Oil No. 1	0.139	73.25	3	0.6	10.18	0.42	0.08	gallon
Distillate Fuel Oil No. 2	0.138	73.96	3	0.6	10.21	0.41	0.08	gallon
Distillate Fuel Oil No. 4	0.146	75.04	3	0.6	10.96	0.44	0.09	gallon
Ethane	0.068	59.6	3	0.6	4.05	0.2	0.04	gallon
Ethylene	0.058	65.96	3	0.6	3.83	0.17	0.03	gallon
Heavy Gas Oils	0.148	74.92	3	0.6	11.09	0.44	0.09	gallon
Isobutane	0.099	64.94	3	0.6	6.43	0.3	0.06	gallon
Isobutylene	0.103	68.86	3	0.6	7.09	0.31	0.06	gallon
Kerosene	0.135	75.2	3	0.6	10.15	0.41	0.08	gallon
Kerosene-type Jet Fuel	0.135	72.22	3	0.6	9.75	0.41	0.08	gallon
Liquefied Petroleum Gases (LPG)	0.092	61.71	3	0.6	5.68	0.28	0.06	gallon
Lubricants	0.144	74.27	3	0.6	10.69	0.43	0.09	gallon
Motor Gasoline	0.125	70.22	3	0.6	8.78	0.38	0.08	gallon
Naphtha (<401 deg F)	0.125	68.02	3	0.6	8.5	0.38	0.08	gallon

Table (2-2) Stationary Combustion Emission Factor continue:

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO2 per mmBtu	g CH4 per mmBtu	g N2O per mmBtu	kg CO2 per short ton	g CH4 per short ton	g N2O per short ton	
Natural Gasoline	0.11	66.88	3	0.6	7.36	0.33	0.07	gallon
Other Oil (>401 deg F)	0.139	76.22	3	0.6	10.59	0.42	0.08	gallon
Pentanes Plus	0.11	70.02	3	0.6	7.7	0.33	0.07	gallon
Petrochemical Feedstocks	0.125	71.02	3	0.6	8.88	0.38	0.08	gallon
Petroleum Coke	0.143	102.41	3	0.6	14.64	0.43	0.09	gallon
Propane	0.091	62.87	3	0.6	5.72	0.27	0.05	gallon
Propylene	0.091	65.95	3	0.6	6	0.27	0.05	gallon
Residual Fuel Oil No. 5	0.14	72.93	3	0.6	10.21	0.42	0.08	gallon
Residual Fuel Oil No. 6	0.15	75.1	3	0.6	11.27	0.45	0.09	gallon
Special Naphtha	0.125	72.34	3	0.6	9.04	0.38	0.08	gallon
Still Gas	0.143	66.72	3	0.6	9.54	0.43	0.09	gallon
Unfinished Oils	0.139	74.54	3	0.6	10.36	0.42	0.08	gallon
Used Oil	0.138	74	3	0.6	10.21	0.41	0.08	gallon
Biomass Fuels (Liquid)								
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01	gallon
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01	gallon
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01	gallon
Vegetable Oil	0.12	81.55	1.1	0.11	9.79	0.13	0.01	gallon
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu				
Steam and Hot Water								
Steam and Hot Water		66.33	1.25	0.125				mmBtu

Source: Solid, gaseous, liquid and biomass fuels: Federal Register (2009) EPA; 40 CFR. (69)

Table (2-3) Mobile Combustion CO_2 Emission Factors

Fuel Type	kg CO_2 per unit	Unit
Aviation Gasoline	8.31	gallon
Biodiesel (100%)	9.45	gallon
Compressed Natural Gas (CNG)	0.0545	scf
Diesel Fuel	10.21	gallon
Ethane	4.05	gallon
Ethanol (100%)	5.75	gallon
Jet Fuel (kerosene type)	9.75	gallon
Liquefied Natural Gas (LNG)	4.46	gallon
Liquefied Petroleum Gases (LPG)	5.68	gallon
Methanol	4.1	gallon
Motor Gasoline	8.78	gallon
Propane	5.72	gallon
Residual Fuel Oil	11.27	gallon

Source: Federal Register (2009) EPA; 40 CFR. (70)

Table (2-4) Mobile Combustion CH_4 and N_2O Emission Factors for On-road Gasoline Vehicles.

Vehicle Type	Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Passenger Cars	1973-74	0.1696	0.0197
	1975	0.1423	0.0443
	1976-77	0.1406	0.0458
	1978-79	0.1389	0.0473
	1980	0.1326	0.0499
	1981	0.0802	0.0626
	1982	0.0795	0.0627
	1983	0.0782	0.063
	1984-93	0.0704	0.0647
	1994	0.0531	0.056
	1995	0.0358	0.0473
	1996	0.0272	0.0426
	1997	0.0268	0.0422
	1998	0.0249	0.0393
	1999	0.0216	0.0337
	2000	0.0178	0.0273
	2001	0.011	0.0158
	2002	0.0107	0.0153
	2003	0.0114	0.0135
	2004	0.0145	0.0083
	2005	0.0147	0.0079
	2006	0.0161	0.0057
	2007	0.017	0.0041
	2008	0.0172	0.0038
	2009-present	0.0173	0.0036

Table (2-4) Mobile Combustion CH_4 and N_2O Emission Factors for On-road Gasoline Vehicles continue:

Vehicle Type	Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Light-duty Trucks (Vans, Pickup Trucks, SUVs)	1973-74	0.1908	0.0218
	1975	0.1634	0.0513
	1976	0.1594	0.0555
	1977-78	0.1614	0.0534
	1979-80	0.1594	0.0555
	1981	0.1479	0.066
	1982	0.1442	0.0681
	1983	0.1368	0.0722
	1984	0.1294	0.0764
	1985	0.122	0.0806
	1986	0.1146	0.0848
	1987-93	0.0813	0.1035
	1994	0.0646	0.0982
	1995	0.0517	0.0908
	1996	0.0452	0.0871
	1997	0.0452	0.0871
	1998	0.0391	0.0728
	1999	0.0321	0.0564
	2000	0.0346	0.0621
	2001	0.0151	0.0164
	2002	0.0178	0.0228
	2003	0.0155	0.0114
	2004	0.0152	0.0132
	2005	0.0157	0.0101
	2006	0.0159	0.0089
	2007	0.0161	0.0079
	2008-present	0.0163	0.0066
Gasoline Heavy-duty Vehicles	<1981	0.4604	0.0497
	1982-84	0.4492	0.0538
	1985-86	0.409	0.0515
	1987	0.3675	0.0849
	1988-1989	0.3492	0.0933
	1990-1995	0.3246	0.1142
	1996	0.1278	0.168
	1997	0.0924	0.1726
	1998	0.0641	0.1693
	1999	0.0578	0.1435
	2000	0.0493	0.1092
	2001	0.0528	0.1235
	2002	0.0546	0.1307
	2003	0.0533	0.124
	2004	0.0341	0.0285
	2005	0.0326	0.0177
	2006	0.0327	0.0171
	2007	0.033	0.0153
	2008-present	0.0333	0.0134

Source: Federal Register (2009) EPA; 40 CFR

Table (2-5) Mobile Combustion CH_4 and N_2O Emission Factors for On-road Diesel and Alternative Fuel Vehicles

Vehicle Type	Vehicle Year	CH_4 Factor(g / mile)	N_2O Factor(g / mile)
Diesel Passenger Cars	1960-1982	0.0006	0.0012
	1983-1995	0.0005	0.001
	1996-present	0.0005	0.001
Diesel Light-duty Trucks	1960-1982	0.0011	0.0017
	1983-1995	0.0009	0.0014
	1996-present	0.001	0.0015
Diesel Medium- and Heavy-duty Vehicles	1960-present	0.0051	0.0048
Gasoline Motorcycles	1960-1995	0.0899	0.0087
	1996-present	0.0672	0.0069
CNG Light-duty Vehicles		0.737	0.05
CNG Heavy-duty Vehicles		1.966	0.175
CNG Buses		1.966	0.175
LPG Light-duty Vehicles		0.037	0.067
LPG Heavy-duty Vehicles		0.066	0.175
LNG Heavy-duty Vehicles		1.966	0.175
Ethanol Light-duty Vehicles		0.055	0.067
Ethanol Heavy-duty Vehicles		0.197	0.175
Ethanol Buses		0.197	0.175

Source: EPA (2014) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. All values are calculated from Tables A-104 through A-106.

Table (2-6) Mobile Combustion CH_4 and N_2O Emission Factors for Non-road Vehicles

Vehicle Type	CH_4 Factor (g / gallon)	N_2O Factor (g / gallon)
LPG Non-Highway Vehicles	0.5	0.22
Residual Oil Ships and Boats	0.11	0.57
Diesel Ships and Boats	0.06	0.45
Gasoline Ships and Boats	0.64	0.22
Diesel Locomotives	0.8	0.26
Gasoline Agricultural Equip.	1.26	0.22
Diesel Agricultural Equip.	1.44	0.26
Gasoline Construction Equip.	0.5	0.22
Diesel Construction Equip.	0.57	0.26
Jet Fuel Aircraft	0	0.3
Aviation Gasoline Aircraft	7.06	0.11
Biodiesel Vehicles	0.57	0.26
Other Diesel Sources	0.57	0.26
Other Gasoline Sources	0.5	0.22

Source: EPA (2014) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. All values are calculated from Table A-107.

Note: LPG non-highway vehicles assumed equal to other gasoline sources. Biodiesel vehicles assumed equal to other diesel sources.

Table (2-7) Electricity Emission Factors

	Total output emission factors			Non-baseload emission factors		
eGRID Sub region	CO_2 Factor (lb /MWh)	CH_4 Factor (lb /MWh)	N_2O Factor (lb/MWh)	CO_2 Factor (lb /MWh)	CH_4 Factor (lb /MWh)	N_2O Factor (lb /MWh)
AKGD (ASCC Alaska Grid)	1,256.87	0.02608	0.00718	1,387.37	0.03405	0.00693
AKMS (ASCC Miscellaneous)	448.57	0.01874	0.00368	1,427.76	0.05997	0.0118
AZNM (WECC Southwest)	1,177.61	0.01921	0.01572	1,210.44	0.02188	0.00986
CAMX (WECC California)	610.82	0.02849	0.00603	932.82	0.03591	0.00455
ERCT (ERCOT All)	1,218.17	0.01685	0.01407	1,181.70	0.02012	0.00763
FRCC (FRCC All)	1,196.71	0.03891	0.01375	1,277.42	0.03873	0.01083
HIMS (HICC Miscellaneous)	1,330.16	0.07398	0.01388	1,690.72	0.10405	0.01912
HIOA (HICC Oahu)	1,621.86	0.0993	0.02241	1,588.23	0.11948	0.0201
MROE (MRO East)	1,610.80	0.02429	0.02752	1,755.66	0.03153	0.02799
MROW (MRO West)	1,536.36	0.02853	0.02629	2,054.55	0.05986	0.03553
NEWE (NPCC New England)	722.07	0.07176	0.01298	1,106.82	0.06155	0.01207
NWPP (WECC Northwest)	842.58	0.01605	0.01307	1,340.34	0.04138	0.01784
NYCW (NPCC NYC/Westchester)	622.42	0.02381	0.0028	1,131.63	0.02358	0.00244
NYLI (NPCC Long Island)	1,336.11	0.08149	0.01028	1,445.94	0.03403	0.00391
NYUP (NPCC Upstate NY)	545.79	0.0163	0.00724	1,253.77	0.03683	0.01367
RFCE (RFC East)	1,001.72	0.02707	0.01533	1,562.72	0.03593	0.02002
RFCM (RFC Michigan)	1,629.38	0.03046	0.02684	1,744.52	0.03231	0.026
RFCW (RFC West)	1,503.47	0.0182	0.02475	1,982.87	0.0245	0.03107
RMPA (WECC Rockies)	1,896.74	0.02266	0.02921	1,808.03	0.02456	0.02289
SPNO (SPP North)	1,799.45	0.02081	0.02862	1,951.83	0.02515	0.0269
SPSO (SPP South)	1,580.60	0.0232	0.02085	1,436.29	0.02794	0.0121
SRMV (SERC Mississippi Valley)	1,029.82	0.02066	0.01076	1,222.40	0.02771	0.00663
SRMW (SERC Midwest)	1,810.83	0.02048	0.02957	1,964.98	0.02393	0.02965
SRSO (SERC South)	1,354.09	0.02282	0.02089	1,574.37	0.02652	0.02149
SRTV (SERC Tennessee Valley)	1,389.20	0.0177	0.02241	1,873.83	0.02499	0.02888
SRVC (SERC Virginia/Carolina)	1,073.65	0.02169	0.01764	1,624.71	0.03642	0.02306
US Average	1,232.35	0.02414	0.01826	1,520.20	0.03127	0.01834

Source: EPA Year 2010 eGRID 9th edition Version 1.0 February 2014.

Table (2-8) Business Travel Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Passenger Car A	0.368	0.018	0.013	vehicle-mile
Light-duty Truck B	0.501	0.024	0.019	vehicle-mile
Motorcycle	0.197	0.07	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak) C	0.144	0.0085	0.0032	passenger-mile
Commuter Rail D	0.174	0.0084	0.0035	passenger-mile
Transit Rail (i.e. Subway, Tram) E	0.133	0.0026	0.002	passenger-mile
Bus	0.058	0.0007	0.0004	passenger-mile
Air Travel - Short Haul (< 300 miles)	0.275	0.0091	0.0087	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles)	0.162	0.0008	0.0052	passenger-mile
Air Travel - Long Haul (>= 2300 miles)	0.191	0.0008	0.006	passenger-mile

* Fuel consumption was converted to emissions by using fuel and electricity emission factors presented in the tables above.

Table (2-9) Product Transport Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-duty Truck	1.456	0.018	0.011	vehicle-mile
Passenger Car A	0.368	0.018	0.013	vehicle-mile
Light-duty Truck B	0.501	0.024	0.019	vehicle-mile
Medium- and Heavy-duty Truck	0.296	0.0036	0.0022	ton-mile
Rail	0.026	0.002	0.0007	ton-mile
Waterborne Craft	0.042	0.0004	0.0027	ton-mile
Aircraft	1.301	0	0.04	ton-mile

Table (2-10) Global Warming Potentials (GWPs)

Gas	100-year GWP
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134	1,100
HFC-134a	1,430
HFC-143	353
HFC-143a	4,470
HFC-152	53

Table (2-10) Global Warming Potentials (GWPs) continue:

Gas	100-year GWP
HFC-152a	124
HFC-161	12
HFC-227ea	3,220
HFC-236cb	1,340
HFC-236ea	1,370
HFC-236fa	9,810
HFC-245ca	693
HFC-245fa	1,030
HFC-365mfc	794
HFC-43-10mee	1,640
SF6	22,800
NF3	17,200
CF4	7,390
C2F6	12,200
C3F8	8,830
c-C4F8	10,300
C4F10	8,860
C5F12	9,160
C6F14	9,300
C10F18	>7,500

Source: 100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007.

Table (2-11) GWPs for Blended Refrigerants

ASHRAE #	100-year GWP	Blend Composition
R-401A	16	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a
R-401B	14	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a
R-401C	19	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a
R-402A	2,100	38% HCFC-22 , 6% HFC-125 , 2% propane
R-402B	1,330	6% HCFC-22 , 38% HFC-125 , 2% propane
R-403B	3,444	56% HCFC-22 , 39% PFC-218 , 5% propane
R-404A	3,922	44% HFC-125 , 4% HFC-134a , 52% HFC 143a
R-406A	0	55% HCFC-22 , 41% HCFC-142b , 4% isobutane
R-407A	2,107	20% HFC-32 , 40% HFC-125 , 40% HFC-134a
R-407B	2,804	10% HFC-32 , 70% HFC-125 , 20% HFC-134a
R-407C	1,774	23% HFC-32 , 25% HFC-125 , 52% HFC-134a
R-407D	1,627	15% HFC-32 , 15% HFC-125 , 70% HFC-134a
R-407E	1,552	25% HFC-32 , 15% HFC-125 , 60% HFC-134a
R-408A	2,301	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a
R-409A	0	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b
R-410A	2,088	50% HFC-32 , 50% HFC-125
R-410B	2,229	45% HFC-32 , 55% HFC-125
R-411A	14	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene
R-411B	4	94% HCFC-22 , 3% HFC-152a , 3% propylene
R-413A	2,053	88% HFC-134a , 9% PFC-218 , 3% isobutane

Table (2-11) GWPs for Blended Refrigerants continue:

ASHRAE #	100-year GWP	Blend Composition
R-414A	0	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142b
R-414B	0	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b
R-417A	2,346	46.6% HFC-125 , 5% HFC-134a , 3.4% butane
R-422A	3,143	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane
R-422D	2,729	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane
R-423A	2,280	47.5% HFC-227ea , 52.5% HFC-134a ,
R-424A	2,440	50.5% HFC-125, 47% HFC-134a, 2.5% butane/pentane
R-426A	1,508	5.1% HFC-125, 93% HFC-134a, 1.9% butane/pentane
R-428A	3,607	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane
R-434A	3,245	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% isobutane
R-500	32	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22
R-502	0	48.8% HCFC-22 , 51.2% CFC-115
R-504	325	48.2% HFC-32 , 51.8% CFC-115
R-507	3,985	5% HFC-125 , 5% HFC143a
R-508A	13,214	39% HFC-23 , 61% PFC-116
R-508B	13,396	46% HFC-23 , 54% PFC-116

Source: 100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. (73)

2.11.2 Relationship between electricity generation and CO_2 gas emissions

The amount of carbon dioxide produced (CO_2) can be calculated per kilowatt hour (kWh) for specific fuels and specific types of generators by multiplying the) (in pounds of CO_2 per million Btu) by the heat rate of a generator (in Btu per kWh generated), and dividing the result by 1,000,000.

Below are the number of pounds of CO_2 produced by a steam-electric generator for different fuels using the above formula and the average heat rates for steam-electric generators for calculating the amount of CO_2 produced per kWh.**as shown at Table (2-12)**

Table (2-12) the amount of carbon dioxide produced by a steam-electric generator for different fuels

Fuel	Lbs of CO_2 per Million Btu	Heat Rate (Btu per kWh)	LbsCO_2 per kWh
Coal			
Bituminous	205.300	10,107	2.08
Sub-bituminous	212.700	10,107	2.16
Lignite	215.400	10,107	2.18
Natural gas	117.080	10,416	1.22
Distillate Oil (No. 2)	161.386	10,416	1.68
Residual Oil (No. 6)	173.906	10,416	1.81

2.12 Quantitative, Qualitative, and Mixed research

Quantitative research: research that relies primarily on the collection of quantitative data. (Quantitative research will follow all of the paradigm characteristics of quantitative research **as shown in Table 2-12**)

Qualitative research: research that relies on the collection of qualitative data. (Qualitative research will follow all of the paradigm characteristics of qualitative research **as shown in Table 2-12)**

Mixed research: research that involves the mixing of quantitative and qualitative methods or paradigm characteristics. (Tashakkori and Teddlie, 2003) **as shown in Table 2.13**

Table (2-13) Common types of variables classified by level measurement and by role of variables

	Quantitative research	Mixed research	Qualitative research
Scientific method	Deductive "top-down" the researcher test hypotheses and theory with data	Deductive and inductive	Inductive "bottom-up" the researcher generates new hypotheses and grounded theory from data collected during fieldwork
View of human behavior	Behavior is regular and predictable	Behavior is some-what predictable	Behavior is fluid, dynamic, situational, social, contextual and personal
Most common research objectives	Description, explanation, and prediction	Multiple objectives	Description, exploration, and discovery
Focus	Narrow-angle lens, testing specific hypotheses	Multi lens focus	Wide-angle and "deep-angle" lens, examining the breadth and depth of phenomena to learn more about them
Nature of observation	Attempt to study behavior under controlled conditions	Study behavior in more than one context or condition	Study behavior in natural environments. Study the context in which behavior occurs
Nature of reality	Objective (different observers agree on what is observed)	Commonsense realism and pragmatic view of world (i.e., what works is what is "real" or true)	Subjective, personal, and socially constructed
Form of data collected	Collect quantitative data based on precise measurement using structured and validated data collection instruments (e.g., closed-ended items, rating scales, behavioral responses)	Multiple forms	Collect qualitative data (e.g.,in-depth interview, participant observation, field notes, and open-ended questions) the researcher is the primary data collection instrument
Nature of data	Variables	Mixture of variables, words, and images	Words, images, categories
Data analyses	Identify statistical relationships	Quantitative and qualitative	Search for patterns, themes, and holistic features
Results	Generalizable findings	Corroborated findings may generalize	Particularistic findings representation of insider(i.e., "emic") viewpoint
Form of final report	Statistical report (e.g., with correlations, comparisons of means, and reporting of statistical significances of findings	Eclectic and pragmatic	Narrative report with contextual description and direct quotations from research participants

Source: Handbook of Mixed Methods in Social and Behavioral Research (Tashakkori and Teddlie, 2003)

2.13 ASHRAE (www.ashrae.org)

American Society for Heating, Refrigerating and Air Conditioning Engineers was founded in 1894 at a meeting of engineers in New York City, formerly headquartered at 345 East 47th Street, and have held an annual meeting since 1895. Until 1954 it was known as the American Society of Heating and Ventilating Engineers (ASHVE); in that year it changed its name to the American Society of Heating and Air-Conditioning Engineers (ASHAE). Its current name and organization came from the 1959 merger of ASHAE and the American
Society of Refrigerating Engineers (ASRE). The result, ASHRAE, despite having 'American' in its name, is an influential international organization amongst other international activities, it helps organize international events.

2.13.1 ASHRAE Research: Improving the Quality of Life

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is the world's foremost technical society in the fields of heating, ventilation, air conditioning, and refrigeration. Its members worldwide are individuals who share ideas, identify needs, support research, and write the industry's standards for testing and practice. The result is that engineers are better able to keep indoor environment safe and productive while protecting and preserving the outdoors for generations to come. One of the ways that ASHRAE supports its members' and industry's need for information is through ASHRAE Research. Thousands of individuals and companies support ASHRAE Research annually, enabling ASHRAE to report new data about material properties and building physics and to promote the application of innovative technologies. Chapters in the ASHRAE Handbook are updated through the experience of members of ASHRAE Technical Committees and through results of ASHRAE Research reported at ASHRAE meetings and published in ASHRAE special publications and in ASHRAE Transactions.

2.13.2 ASHRAE Objective

ASHRAE develops standards for both its members and others professionally concerned with refrigeration processes and the design and maintenance of indoor environments. ASHRAE writes standards for the purpose of establishing consensus for:
Methods of test for use in commerce
Performance criteria for use as facilitators with which to guide the industry.
ASHRAE publishes the following three types of voluntary consensus standards:
1) Method of Measurement or Test.
2) Standard Design.
3) Standard Practice. ASHRAE does not write.
"rating standards" unless a suitable rating standard will not otherwise be available i.e. to say that ASHRAE provides standard methods and procedures but does not provide comparing ratings for different performances Consensus standards are developed and published to define minimum values or acceptable performance, whereas other documents, such as design guides, may be developed and published to encourage enhanced performance.

ASHRAE is accredited by the American National Standards Institute (ANSI) and follows ANSI's requirements for due process and standards development.

2.13.3 Examples of ASHRAE Standards

- Standard 34 – Designation and Safety Classification of Refrigerants
- standard 55 – Thermal Environmental Conditions for Human Occupancy
- Standard 62.1 – Ventilation for Acceptable Indoor Air Quality (versions: 2001 and earlier as "62", 2004 and beyond as "62.1")
- Standard 62.2 – Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings
- Standard 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings – The IESNA is a joint sponsor of this standard.
- Standard 90.2 - Energy- Efficient Design of Low rise Residential Buildings
- Standard 135 – BACnet - A Data Communication Protocol for Building Automation and Control Networks
- Standard 189.1 – Standard for the Design of High Performance, Green Buildings except Low-Rise Residential Buildings

These, and many other ASHRAE Standards, are periodically reviewed, revised and published, so the year of publication of a particular standard is important for code compliance.
The ASHRAE Journal is a monthly magazine published by ASHRAE. It includes peer-reviewed articles on the practical application of HVAC&R technology, information on upcoming meetings and product shows, classified and display advertising, and editorials. Members of ASHRAE receive the magazine and the current year's volume of the ASHRAE Handbook as membership benefits. ASHRAE also publishes many books, ASHRAE Transactions, and the International Journal of HVAC&R Research.
As of now Port Authority is interested in complying with Standard 90.1.

Purpose of Standard 90.1

To establish minimum energy efficiency requirements of buildings other than low rise residential buildings for:
Design, Construction and Plan for operation and maintenance.
Utilization of onsite renewable energy resources.

2.14 Green roof

Green roof temperatures depend on the roof's composition, moisture content of the growing medium, geographic location, solar exposure, and other site-specific factors. Through shading and evapotranspiration, most green roof surfaces stay cooler than conventional rooftops under summertime conditions. Numerous communities and research centers have compared surface temperatures between green and conventional roofs.

Reduced surface temperatures help buildings stay cooler because less heat flows through the roof and into the building. In addition, lower green roof temperatures result in less heat transfer to the air above the roof, which can help keep urban air temperatures lower as well. Some analyses have attempted to quantify the potential temperature reductions over a broad area from widespread adoption of green roof technology. A modeling study for Toronto, Canada, for example, predicted that adding green roofs to 50 percent of the available surfaces downtown would cool the entire city by 0.2 to 1.4°F (0.1 to 0.8°C).

Irrigating these roofs could further reduce temperatures by about 3.5°F (2°C) and extend a 1 to 2°F (0.5-1°C) cooled area over a larger geographic region.

As shown in Figure 2-2 the simulation showed that, especially with sufficient moisture for evaporative cooling, green roofs could play a role in reducing atmospheric urban heat islands. (Amandeep Gupta and others)

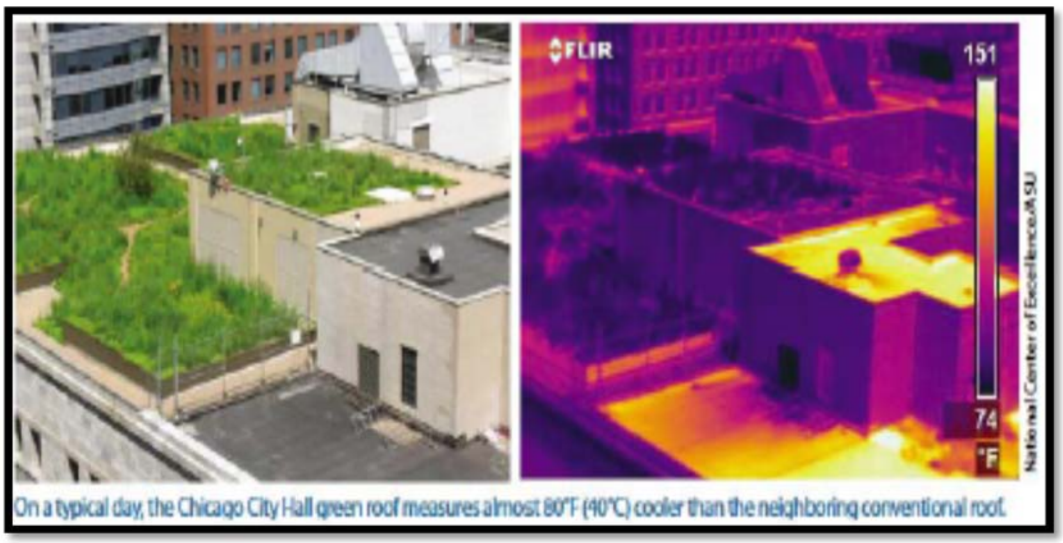

Figure (2-2) the effect of green roof on the temperature

CHAPTER THREE

GREEN BUILDING STANDARDS

CHAPTER THREE
GREEN BUILDING STANDARDS

3.1 Introduction

A review of the green building standards (LEED, BREEM, GPRS, and ASHRAE) presenting the different definitions, terms and comparing them to clarify the advantages and disadvantages of each one are presented in order to get a better understanding for the green building and sustainability standards.

3.2 LEED (www.usgbc.org/leed)

LEED (Leadership in Energy and Environmental Design), is a certification and standard-setting programme designed to improve the environmental sustainability of buildings and encourage the spread of "Green Buildings." The success of this program could be instrumental in achieving US energy and emission reduction goals; buildings contribute a significant percentage of both US energy and carbon dioxide emissions. The current version of LEED should be commended for its entrepreneurial progress; it has undoubtedly contributed to considerable reductions in energy use and emissions. However, in order for LEED to achieve its full potential and evolve from a benchmark into a mandate, two key areas of improvement need to be addressed: Point Alignment: The current version of LEED was designed to be a helpful benchmark for commissioners who desired to build environmentally sustainable buildings. It was not intended to be a mandate for all new buildings. As a result, the point allocations are somewhat unsystematic and not directly correlated to energy and emission reduction. To ensure that the LEED program achieves the highest potential environmental improvements, we argue that the current point system needs to be redesigned such that the points align with actual energy savings over the lifecycle of the technology. Ultimately, the energy savings and appropriate point allocation should be calculated and weighted using Life Cycle Analyses (LCA) (LEED Certification for Buildings, 2007).

3.2.1 Background

LEED was designed by the U.S. Green Building Council (USGBC) in 1998. Since then it has grown and been modified substantially, with the current version being labelled LEED 2.2. Currently there are over 14,000 projects with LEED certification and many government agencies have been promoting LEED by implementing its standards in their own buildings. For example, a recent legislative initiative aims to require LEED certification in all newly built public schools.

From an environmental standpoint LEED's goal of reducing the environmental impact of buildings is extremely important. In North America, where LEED is most predominant, buildings account for 20% of all energy usage (National Academy of Sciences, 2008). Buildings also account for 72% of all electricity and 54% of all natural gas consumption. They also contribute 37% of North American carbon dioxide emissions to put this into context; this means that US buildings alone emit more carbon dioxide than any other entire country except China. To encourage reductions in these environmental impacts of buildings, a system of standards monitoring energy reduction and increase “greenness” of buildings is necessary.

The introduction of LEED was a first step in developing these standards; it was designed to be used as a benchmark to be used by building commissioners who wished to be more environmentally friendly. This effort has been largely successful; by 2006, 642 million square feet of building space had achieved LEED certification (Housing Commission Documents, 2007). These buildings have been proven to use significantly less energy and emit less carbon dioxide than non-certified buildings. However, with success and expansion have come new challenges. Because LEED is emerging as a mandated industry standard, it must be re-evaluated; its initial ‘benchmark’ design needs to be adjusted to account for builders who may not be as motivated. Furthermore, it needs to be made as effective as possible; despite the increase in LEED certifications, emissions from buildings have, since 1990, continued to grow at about 2.1% a year (McMahon, 2007).

3.2.2 Overview of the LEED Certification Process

LEED (2.2) certification is known as a “menu-based system”. Each building-commissioner can choose from a list of projects and items (such as installing on-site renewable energy facilities or improving insulation) to implement in the construction (or renovation) of the building. The building is then awarded points for these projects/items. With the exception of seven prerequisite requirements (to which no points are awarded but which must be installed to become LEED certified) and two “special” items (which have a range of attainable credits) all projects/items are awarded one point. Depending on the level of points a building receives,
Varying levels of LEED certification are possible. These are presented in **Table (3-1)** (LEED Certification for Buildings, 2007).

Table (3-1) LEED Certification types and the corresponding points

LEED Certification type	Min-Max points necessary
Certified	26-32points
Silver	33-38points
Gold	39-51points
Platinum	52-69points

As the table indicates, there are a total of 69 attainable points. The projects/items from which these points can be earned are organised into 6 different categories. These are:

- Sustainable sites (1 prerequisite and 14 possible point): This category is designed to focus on the sustainability of buildings by reducing the impact of the buildings to the surrounding environment and by encouraging less environmentally damaging modes of transport. For example, points are awarded for locations close to public transportation.
- Water Efficiency (5 possible points): This category is included to encourage more efficient use of water and waste treatment. For example, points would be awarded for installing low-flow water fixtures.

- Energy and Atmosphere (3 prerequisites, 17 possible points, one item with 1-10 point range and one item with 1-3 point range. 4 more items worth 1 point each): This is the largest and most important category and will be the main focus of this paper. This category deals with a variety of issues, ranging from improvements in commissioning (ensuring the building operates as planned), to items dealing with the way the building optimises its energy. The methodology is two-fold; there are points awarded for the use of 'green' and on-site renewable energies, as well as points for technologies that reduce emissions and refrigerants.
- Materials and Resources (1 prerequisite and 13 possible points): This category deals primarily with building maintenance. Its purpose is to encourage the use of sustainable and environmentally friendly materials in new constructions and renovations. For example, points in this category are awarded for providing on-site recycling facilities.
- Indoor Environmental Quality (2 prerequisites and 15 possible points): Points in this category are designed to improve health conditions in the building and to reduce indoor pollution. Points are awarded for a range of items; these range from following certain ventilation standards to use of low-emitting substances for interior design (such as more environmentally friendly forms of paint) to windows with better exposure to light and outside views.
- Innovation and Design (5 possible points): This category awards points to buildings that adhere to certain LEED innovation and design codes, including one for inclusion of LEED certified member(s) on the building-project team. Applicants who wish to become LEED certified can submit an application (by mail or online) during the design, construction or operational (post-completion) phase of the building, after which a panel from USGBC will review the building and award it points accordingly (LEED Certification for Buildings, 2007).

USGBC requires that the building be inspected at least every 5 years to maintain certification, but recommends doing so annually. LEED also has slightly different auxiliary versions for specific types of buildings.

While the general guidelines mentioned above are primarily used for commercial buildings (which are currently the main LEED adopters). For example, in January 2008 USGBC released a LEED for Homes Rating system that is principally the same as the general LEED 2.2 but has some modifications to accommodate specific factors relevant in residential buildings as shown in **Table (3-2)** (LEED for Homes Rating System, 2008).

Table (3-2) the modified point system

Credit category	Prerequisites (mandatory) measures	Minimum point requirements	Maximum points available
Innovation design process (ID)	3	0	11
Location &linkages (LL)	0	0	10
Sustainable sites (SS)	2	5	22
Water efficiency (WE)	0	3	15
Energy & atmosphere (E135A)	2	0	38
38Materials & resources (MR)	3	2	16
Indoor environment quality (EQ)	7	6	21
Awareness & education (AE)	1	0	3
total	18	16	136

As shown in the table, two new categories are added: Location and Linkages and Awareness and Education. Location and Linkages awards points according to where the house is built and the access it has to other environmentally friendly infrastructures and commuter transport and sources. Awareness and Education grants points for educating tenants and building managers on environmental sustainability (LEED for Homes Rating System, 2008).

3.2.3 Benefits of LEED

LEED has been linked to both economic and environmental benefits. Several studies have shown that LEED buildings are considered more valuable than non-LEED buildings, both in actual property and rental prices. LEED buildings are perceived to be more fashionable among environmentally conscious buyers and renters and this is a reputation component that can add prestige to the building. Because of this and their lower energy costs, LEED buildings command a sales premium of $171 per square foot and a rental premium of $11.28 per square foot when compared to non-LEED. They also have a 3.8% higher occupancy rate. Perhaps even more importantly, research has also determined that on average a LEED building saves 25-50% in energy, confirming its environmentally friendlier status (Turner & Frankel, 2008 and CoStar, 2007). Another possible, albeit less verified, benefit is that certain materials that award LEED points also tend to increase the life potential of the building, leading to fewer needs of renovation and maintenance. (Green Buildings, 2007)

Finally, it has also been claimed that the work and living environment within LEED buildings is healthier and contributes to higher productivity among individuals inside it. This is difficult to verify; such conditions are rather difficult to isolate from other variables.

Nonetheless, it can be reasonably assumed that some health benefits are derived from the reduction in toxic substances throughout the building (LEED Certification for Buildings, 2007).

3.2.4 Costs of LEED

Despite these benefits and increasing enthusiasm for LEED, obstacles to LEED expansion remain. In fact, a large number of LEED projects are frequently abandoned or halted before LEED certification is awarded. This is due to increased construction and administrative costs that are difficult to quantify but may discourage potential contractors and building commissioners from implementing the changes needed to obtain LEED certification. There are, primarily, costs for installing and/or constructing the items necessary to gain LEED points towards certification. Because the LEED system is a point-based system, these can be a variety of different materials or installations, ranging from types of paint and insulation to different methods of deriving on-site energy (such as solar panels). One study estimates these costs to add anywhere between 2-6% to the initial construction cost of buildings. As mentioned before, LEED buildings sell at a premium that may more than compensate for these expenses. However, this is only part of the actual cost of obtaining LEED certification. The less quantifiable costs come from increased administrative challenges. These can be categorised into commissioning, documentation/administrative tasks and energy modelling and design. As shown in **Figure (3-1)** one study estimates that energy modelling is not a very significant cost (about 0.1% increase in construction costs), but that the other three categories may increase construction costs by 3-5%.

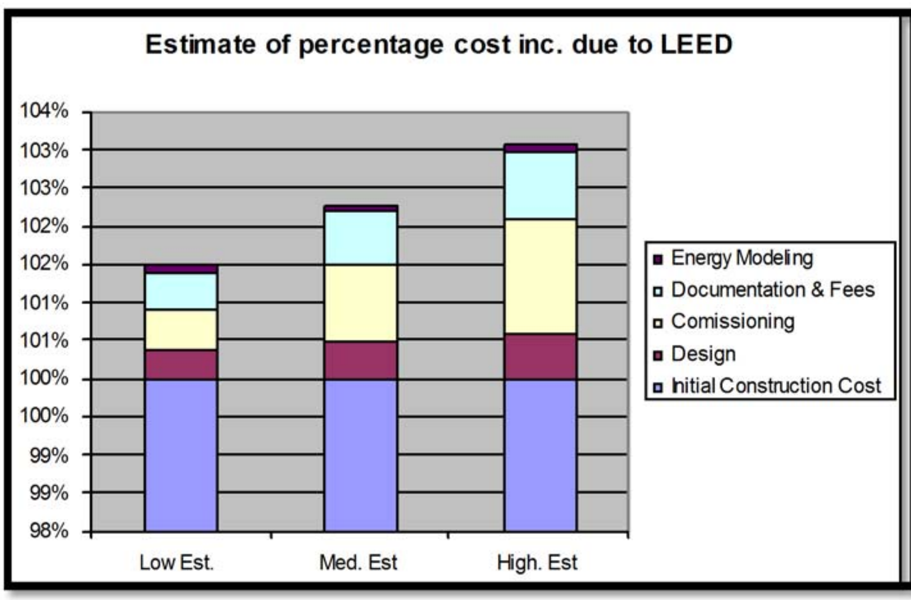

Figure (3-1) Costs of LEED

Source: Northbridge Environmental Management Consultants. "Analysing the Cost of LEED" http://www.cleanair-oolplanet.org/for_communities/LEED_links/AnalyzingtheCostofLEED.pdf

With these increases in costs, it is ambiguous whether, in terms of a cost-benefit analyses, LEED is profitable to commission. As will be discussed in more detail later, this is partially due to LEED's one item one point structure; items that make more of an environmental and/or economic impact are generally weighted the same as those who do not.

As a result, the benefit for the building is rather difficult to measure and the lack of a clear figure and the wide range of equally scored items of different impact tend to cause prospective commissioners to shy away from attempting to attain LEED certification. In addition, there is always the issue of discount rates; some of LEED's benefits, such as reduced energy bills, accrue in the future.

If consumers place too high of a discount rate on the future, then LEED will not be profitable. Nevertheless, the existing premium for LEED buildings suggests that either this is not the case, or the reputational benefits are enough to override the discount (Northbridge Environmental Management Consultants).

3.2.5 Need for Life Cycle Focus

The above sections discussed near-term costs and benefits of LEED. However, to truly understand the costs and benefits of LEED, it is necessary to understand its impact over an entire building life-cycle. This type of analyses is known as the life-cycle approach (LCA) and looks at the benefits and costs of a LEED building over its entire lifetime, discounted to reveal its true present value. Using LCA, it is possible take into account the item's production, maintenance and other costs. Discounting it over its lifetime, meanwhile, will allow for better comparison of the item with other alternative opportunities.

3.2.6 Other barriers to LEED expansion/adoption

In addition to the above mentioned cost issues, there are also other barriers that are not measured in direct financial costs For example, obtaining LEED certification requires a great deal of time investment. One study concluded that, on average, it takes 300 days for a project to become fully certified. Another found that it took over 225 hours to complete the documentation process. Furthermore, administrative obstacles depend highly on the level of expertise and can cost up to $70,000 per project. This is quite a high opportunity cost as it causes the commissioner to forego possibly more productive activities (Northbridge Environmental Management Consultants).

Another significant barrier is expertise. Unfortunately, given that LEED is only a 10 year old concept, a lack of knowledge regarding its codes and practices exists among the community of architects, engineers and other contractors for buildings. While this community often has a reasonable base of knowledge in specific LEED components, there is a lack of cross-functional expertise and coordination (Pise, 2006, Johnson, 2005) .Indeed, often a one size fits-all approach is taken, which does not take into account locational, financial and dimensional difference between different buildings. In some ways, this problem will be difficult to rectify without more and better training for professionals involved in the construction sector. Nevertheless, in terms of LEED implementation, changes can be made to the current regulations in order to streamline the process. In particular, as mentioned before, the one-item one-point system is not an effective measure of a building's environmental and energy efficiency and does not create the most efficient incentives for obtaining certification. Furthermore,

it bogs down the administrative process. Instead of focusing on high-impact easy to certify components, the one point system shifts the focus toward more tedious, less consistent items.

These inconsistencies compound the coordination issues and lower the incentives for learning and adopting the necessary expertise.

3.2.7 Point Reallocation

LEED encourages a whole-building approach to sustainability by awarding points in five key areas of human and environmental health (Energy Star). One of the central performance areas of LEED is energy efficiency, which is recognized in the Energy and Atmosphere (EA) section of the LEED scorecard. However, there have been critiques of the current LEED EA section that recommend LEED points need to be allocated based on an overall environmental and economic impact instead of just an energy savings.

The objective of this section is to articulate critiques of the LEED point system and suggest improvements that will include both economic and environmental impacts. (Tolley and Sabina, 2009)

EA: Credit 1 Allocation

According to the USGBC, LEED Rating Systems are developed through an open, consensus-based process led by a group of qualified committees (Energy Star). The current rating system for the EAc1 section for LEED-NC sets a minimum performance requirement, based on the ASHRAE 90.1-2004 standard. This baseline is then compared to the percent savings that is calculated using the ASHRAE 90.1-2004 appendix G. This quantification system of point allocation based energy savings does provide an overall metric for reducing energy consumption. However, one of the biggest critiques of the LEED scorecard is that most items are worth one point (Scheuer, and Keoleian, 2002). even though some items have a greater environmental/economic impact (Solomon, Green Sources Magizine, 2008). To illustrate this issue, the following section will compare two energy savings strategies that incur the same energy efficiencies, but have very different economic impact.

3.2.8 Life Cycle Cost Analyses

One potential modification of LEED would be to take into account the economic impact of a given technology over its entire lifecycle. This type of analyses is called Life Cycle Cost analyses, or LCC. For example, according to Energy Star data, both an Energy Star programmable thermostat and an oil furnace are predicted to be approximately 18 % more efficient than conventional appliances (Energy Star Savings Calculator) as described in **Tables (3-3a) and (3-3b)**. However, these two technologies should not be assumed to be equal; when their Life Cycle Costs (LCC) are compared side by side, there is a significant difference between their economic impacts.

For example, the Energy Star graphs above calculate the Life Cycle Cost of an efficient furnace by first, taking the cost difference between an Energy Star furnace and a conventional furnace. Then, this difference of $320 is discounted by the rate of 4% over a 17-year life span.

The final calculation for the Energy Star furnace is a 330%, dollar savings over the life of the furnace compared to the retail price. On the other hand, with the thermostat, Energy Star assumed a cost difference of $19 between a conventional thermostat and an Energy Star thermostat, discounted by the rate of 4% over a 17-year life span.

Table (3-3a) Summary of benefits for an oil furnace (Energy Star Savings Calculator)

Summary of Benefits for a Oil furnace	
Initial cost difference	320$
Life cycle savings	3,955$
Net life cycle savings (life cycle savings – additional cost)	3,635$
Simple pay back of additional cost (years)	1
Life cycle energy saved (MMBtu)	319
Life cycle air pollution reduction (lbs of Co_2)	51,400
Air pollution equivalence (number of cars removed from the road for a year)	4
Air pollution equivalence (acres of forest)	6
Savings as a percent of retail price	330%

Table (3-3b) summary of benefits for 1 programmable thermostat(s), (Energy Star Savings Calculator)

Summary of Benefits for 1 Programmable Thermostat(s)	
Initial cost difference	19$
Life cycle savings	2,519$
Net life cycle savings (life cycle savings – additional cost)	2,500$
Life cycle energy saved (MMBtu)-includes both Heating and Cooling	236
Simple pay back of additional cost (years)	0.1
Life cycle air pollution reduction (lbs of Co_2)	30,297
Air pollution equivalence (number of cars removed from the road for a year)	3
Air pollution equivalence (acres of forest)	4
Savings as a percent of retail price	2718%

Ultimately, the Energy Star thermostat, with the same 18% energy savings s the furnace, results in a 2718% dollar savings in relation to the retail price. Clearly, these technologies should be provided with different point allocations. However, LEED does not address economic impacts, only energy savings.

For LEED to take a more holistic approach the USGBC committees need to weight technologies according to the economic impact they produce.

Additionally, a more holistic point structure would not only include the economic impacts but also incorporate energy costs consumed during the life of a technology.

3.2.9 Benefits of Point allocation based on Life Cycle Analyses

A second critique of the LEED EA point system is that the cost savings formula does not account for the real energy costs of a given technology; it fails to incorporate the energy costs of production, transportation, and other steps in the supply chain. The quantification method for this is called Life Cycle Analyses (LCA). According to Boustead Consulting, the concept of LCA originated in the 1960's when architects realized the importance of examining the performance of industrial systems through their entire life cycle, not just during operation.

The analyses of a building's energy life cycle begins with calculating the energy needed to extract raw materials from the earth, energy needed to transport the materials, energy needed for operation, and finally the energy needed to dispose of the materials. This has also been referred to as "cradle to grave" analyses (Nebel, 2006). LCA is becoming nationally and internationally more recognized as a best practice model for understanding the total environmental impact of building construction.

The Environmental Protection Agency (EPA), along with other international leaders in energy reduction, has recently placed heavy emphasis on refining and requiring a decision-making tool based on LCA (Stone, 2007). The reason for this emphasis is that an implemented building technology, with the intention to reduce energy consumption, could potentially consume more energy through its entire life cycle then it will reduce during its operational life. If an analyst is well trained and using up to date software, LCA is a very reliable method for architects and builders to identify and manage the total environmental impact of implementing energy technologies, and is thus a good way to assign LEED points in the EAc1 section.

LCA aligns well with sustainability because it addresses one of the main goals of LEED; reduce a building's total environmental impact. It also would serve a key role in increasing awareness of the true impacts of different technologies. If the LEED EA point system was made more equitable by using output from interpretation of LCA data, the point system will encourage engineers to gain knowledge about what designs are worth replicating in the long run based how much economic and environmental life cycle impact they will have during their life, not just while they are in operation. Since engineers' recommendations are incorporated into all phases of a building's lifecycle, not just the design, this knowledge would have significant impact (Horst1, Scot and Wayne Trusty, MA2).

Another benefit of LCA is it isolates the technologies that will have the highest Energy Return on Energy Invested (EROEI).

EROEI is the ratio of the amount of usable energy gained from a technology compared to the amount of energy expended to obtain that technology. To increase its impact and continue its leadership in the green community,

LEED should weight points based on LCA analyses, incorporating the life cycle energy consumption of new technologies into their point structure.

3.2.10 Methods of Calculating LCA

There are many high quality Life Cycle Analyses software applications. However, 'GABI 4' is one of the most used and recognized applications (Ivanovich, 2007). Other tools include: Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), developed by EPA (Shyam, Lippiatt, and Helgeson, 2008) and Building for Economic and Environmental Sustainability (BEES) developed by the U.S. federal government (Lippiatt, Barbara. NIST 2007). All of these computer applications are able to calculate many different environmental and economic outcomes from the entire life cycle of the materials used in green buildings .

The software's data base includes most common building technologies, however if the data you need is not in the data base it can be entered in the form of an excel spread sheet.

Currently the biggest drawback of LCA is a lack of databases for the most cutting edge technologies, in addition to the required training necessary for professionals to interpret the findings and apply them appropriately. Proponents of LEED should work to advocate for investment in the development of these databases; greater amounts of knowledge incorporated into LCA analyses will eventually translate into greater environmental gains from LEED certification.

Case Study: Life Cycle Analyses costs for a Solar Panel

As mentioned in previous section, the current LEED point system only includes the energy savings during the operation of the technology, not during the entire life cycle. According to a resident case study, a Photovoltaic (PV) Solar Panel of 2.5 Kw is estimated to yield a 10% annual energy savings for a house of approximately 2500 square feet (Energy Efficiency Contractor). However, this energy savings does not take into account potential energy used or saved during manufacturing and transportation, as compared to alternative sources of energy as shown in **Figure 3-2**.

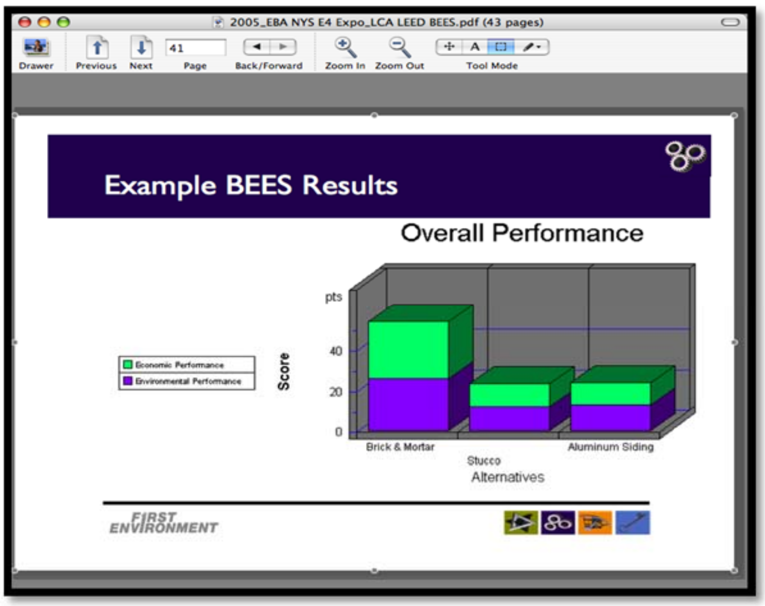

Figure (3-2) example BEES results

Costs of implementing a more sophisticated point system

Although LCA would contribute significantly to the efficiency of the LEED point allocation, it comes with its onset of costs. One of these costs is complexity. A more sophisticated LEED point system yields a more accurate environmental impact, but it may not be easily understood by architects and homeowners. Moreover, there will be costs involved in building the required knowledge base. As mentioned above, the biggest drawback of LCA is a lack of databases for the most cutting-edge technologies. In addition, it will be necessary to invest in training to enable professionals to interpret the findings and apply them appropriately.

However, if USGBC committees are able to conduct a complete Economic and Environmental impact analyses and equate the LEED point system to these quantifications, USGBC will move much closer to a fully sustainable green building approach. Ultimately, the benefits of this approach should extend far beyond the initial cost.

3.2.11 Incorporating Appropriate Standards for Lab Buildings:

Currently, analysts are able to be reasonably accurate in projecting energy performance for most LEED certified buildings. However, for high energy-use buildings (such as labs), the projections do not correlate well with actual performance. Without an accurate understanding of future performance, it is difficult to design appropriate LEED standards for high energy buildings. Thus, we recommend efforts to improve the current knowledge base in relation to Lab buildings. In addition, we propose establishing a separate point-allocation system specific to lab buildings; like LEED for average buildings, this system should allocate points based on actual energy savings.

The current LEED system has achieved a great deal and started us on a path towards environmental sustainability in buildings. However, it is critical that we continue to build on this success and allow LEED to have the greatest impact possible. (LEED Certification for Buildings, 2007)

3.2.12 Energy Performance of LEED Buildings

As discussed throughout this paper, a central goal of the LEED system is to achieve energy savings. However, optimal energy savings are not achieved by merely installing an energy-efficient technology. In the life-cycle energy consumption of a building, the operation of the building occupies a dominant portion. As a result, the success of LEED ultimately relies on the energy performance of the building after LEED certification. While LEED certification is based on a point scheme, the effectiveness of LEED as a system should not be judged by the amount of points achieved, but by the actual energy performance of LEED buildings in comparison to average buildings of the same type. Indeed, at first glance, LEED performs quite well. In 2008, the first comprehensive post-occupancy assessment of LEED-certified buildings was published (Turner and Frankel, 2008); this study, together with an earlier, smaller-scale similar study, has provided the first evidence of LEED building performance (Diamond, 2006). They show that LEED buildings of median energy usage—offices, schools, libraries, etc.—are 25% more energy efficient than non-LEED buildings of the same types.

These studies also show that, on average, the actual energy performances of LEED buildings are highly correlated with their design projections. The energy usage intensities of LEED buildings from Diamond et al (2006) and Tuner and Frankel (2008) are shown; for median energy usage buildings, good correlations are shown between design projections and actual measurements.

Nevertheless, despite the success of LEED with median energy usage buildings, these studies also reveal significant discrepancies between design and actual performances in high energy usage buildings, predominantly scientific laboratories. The actual energy consumptions of these buildings generally exceed design projections.

Furthermore, their performances show significant inconsistency. The energy performance data of laboratory buildings from Diamond et al (2006) and Tuner and Frankel (2008) are also shown. Ultimately, it's clear that the understanding in this area is lacking.

Current Knowledge in Laboratory Building Energy Performance

The causes of the 'poor' performances in laboratory buildings are presently not fully understood. In presenting their data, Tuner and Frankel (2008) observe that "the characteristics [of laboratory buildings] are not well understood by the design community," and this understanding "has significant implications on [building] life-cycle cost analyses." They conclude rightly that "there is a need for significant additional research into the performance characteristics of [laboratory] buildings"

This need is made even more significant when the high quantities of energy consumption of laboratories are considered. An extensive study of laboratory energy consumptions, covering 4 million sq. ft. of laboratory spaces on five campuses of the University of California system, indicates that laboratories on average use 5 times more electricity and 5 times more fuel than non-laboratory spaces (Mills, 1996).

The majority of recent literature concurs with this estimation; in particular, the design guide by National Institute of Building Sciences estimates that laboratory buildings consume 4 to 8 times more energy than non-laboratory buildings.

This need to increase understanding of lab building performance is also made urgent by the present boom in green laboratory constructions. Driven by increased consciousness to energy conservation and legislative mandates, and coinciding with intensified investments in research facilities by research universities, the number of new construction (NC) LEED laboratories has significantly increased in the last few years.

3.2.13 LEED's Relative Strengths (Inbuilt Ltd, 2010)

- **Transparency**

LEED's approach is more consensus-based and transparent compared to BREEAM's. For example the technical criteria proposed by the various LEED committees are publicly reviewed for approval by USGBC's c. 15,000 member companies and organizations.
However the USGBC has in the past been criticized for being unduly influenced by the manufacturers, contractors and developers in its membership rather than by scientific research (Gifford, 2008).

- **Resources**

LEED provides more extensive publicly accessible resources, research and case studies than BREEAM. This includes, for example, the Green Building Information Gateway, a "map-centric" portal providing LEED certification data and analyses at national, state, city and project level.
BREEAM does not publish data on numbers of buildings certified by type and rating achieved.

- **Post-Occupancy Evaluation**

Post-occupancy evaluation (POE) provides the scheme operators with valuable feedback on the effectiveness of particular credits in terms of their take-up and actual environmental impact, which it can use to disseminate best practice and inform future development of the assessment method.

LEED is more rigorous in this regard. Under the compulsory Minimum Program Requirements, all certified projects must commit to sharing with USGBC/GBCI all available actual energy and water usage data for the whole project for a period of at least five years from occupancy. This commitment continues if there is a change of ownership or occupation. In addition LEED offers a credit to develop and implement an energy consumption measurement and verification plan as well as a corrective action process for a minimum of one year post-occupancy.

Under BREEAM an optional exemplary level credit is available for committing to the following for three years post-occupancy:
(a) collecting occupier satisfaction, energy and water consumption data, (b) utilizing the data to maintain expected performance, (c) setting reduction targets and monitoring water and energy consumption and (d) providing annual consumption and satisfaction data to the design team/developer and BRE.

- **Heat Island Effect**

LEED has credits for reducing the heat island effect (for example through shading by trees and specifying high solar reflectance materials). BREEAM does not address this, and although it offers credits for green roofs, it is for the purposes of mitigating ecological impact and reducing surface water run-off.

- **Thermal Comfort**

Although both methods address thermal comfort through design, only LEED offers an additional credit for verification – by way of a survey of occupiers between 6 to 18 months of occupancy, and a corrective action plan in the event that more than 20% are dissatisfied with thermal comfort.

- **Indoor Air Quality**

LEED's indoor air quality credit requirements are more sophisticated than BREEAM's, driven by the USA's climate and greater reliance on mechanically ventilated and air conditioned buildings.

Furthermore, LEED addresses indoor air quality (IAQ) and mould prevention post-construction but prior to occupancy by offering a credit which requires either a full air flush-out in accordance with specific air volume, temperature and relative humidity parameters, or IAQ testing consistent with EPA or ISO methods. BREEAM has no such requirements.

- **Irrigation**

LEED's water efficient irrigation credit offers a higher number of points with stricter requirements and a specified threshold – ie a minimum 50% reduction in potable water use for irrigation. BREEAM's water efficient equipment credit requires specified water efficient strategies/systems but does not quantify a required reduction in water use.

3.2.14 Conclusion

Overall, the LEED system has been shown to have several important benefits and has expanded accordingly. However, the one item-one point system does not efficiently allocate points. Moreover, direct costs and administrative barriers could be reduced to facilitate even greater uptake of LEED certification.

USGBC is continually working toward improving their point system to reflect relevant environmental impacts. However, the LEED points in the EA section lack net energy reductions and fail to incorporate economic impacts that accrue over the technology life cycle. The next step is for USGBC to create benchmarks based on LCC and LCA that can be applied as a new point LEED structure.

The LEED standard has accomplished a great deal; despite the oft-heard criticisms the pioneers of LEED should be commended for their efforts to develop a standardized evaluation mechanism for green buildings. Undoubtedly, these efforts have led to dramatic reduction in energy usage and emissions within certified buildings. Nevertheless, as LEED evolves from a general benchmark into a more widespread mandate, two critical changes should be made:

1) The point system should take into account relative energy savings across the entire life cycle of a given technology and
2) A modified LEED evaluation system should be developed for energy-intensive/lab buildings; this system should be developed using savings weighted point allocations that award points for variable savings measures.

One issue not directly addressed in our paper, but that still needs a great deal of consideration, is quantifying and weighting LEED points based on greenhouse gas emission from both building materials and new technologies.

Ultimately, if these recommendations are adopted, LEED certification will allow commissioners around the world to more efficiently build toward a better future.

3.3 BREEAM (www.breeam.org)

BREEAM is the world's foremost environmental assessment method and rating system for buildings, with 200,000 buildings with certified BREEAM assessment ratings and over a million registered for assessment since it was first launched in 1990.

BREEAM sets the standard for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognized measures of a building's environmental performance.

A BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. A certificated BREEAM assessment is delivered by a licensed organization, using assessors trained under UKAS accredited competent person scheme, at various stages in a building's life cycle. BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other parties. BREEAM:

– Uses a straightforward scoring system that is transparent, flexible, and easy to understand and supported by evidence-based science and research

– Has a positive influence on the design, construction and management of buildings

– Defines and maintains a robust technical standard with rigorous quality assurance and certification

Clients, planners, development agencies, funders and developers use BREEAM to specify the sustainability performance of their buildings in a way that is quick, comprehensive, and highly visible in the marketplace and provides a level playing field.

Property agents use it to promote the environmental credentials and benefits of a building to potential purchasers and tenants.

Design Teams use it as a method to improve the performance of their buildings and their own experience and knowledge of environmental aspects of sustainability.

Managers use it to reduce running costs, measure and improve the performance of buildings, empower staff, develop action plans and monitor and report performance at both the single and portfolio level.

The adoption of BREEAM provides:

- Market recognition for low environmental impact buildings
- Confidence that tried and tested environmental practice is incorporated in the building
- Inspiration to find innovative solutions that minimize the environmental impact
- A benchmark that is higher than regulation
- A system to help reduce running costs, improve working and living environments
- A standard that demonstrates progress towards corporate and organizational environmental objectives
-

3.3.1 The Scope of BREEAM

BREEAM covers all building types, schools, healthcare buildings, offices, industrial units and more. For the housing sector, there are a number of variants:

- The UK Government's Code for Sustainable Homes (CSH) replaced Eco Homes for the assessment of new housing in England, Wales and Northern Ireland
- BREEAM Eco Homes for new homes in Scotland
- BREEAM Multi-Residential covering buildings housing many individuals and offering shared facilities

3.3.2 BREEAM work mechanism

BREEAM rewards performance above regulation which delivers environmental, comfort or health benefits. BREEAM awards points or 'Credits' and groups the environmental impacts as follows:

- Energy: operational energy and carbon dioxide (CO_2)
- Management: management policy, commissioning, site management and procurement
- Health and Wellbeing: indoor and external issues (noise, light, air, quality etc.)
- Transport: transport-related CO_2 and location related factors
- Water consumption and efficiency
- Materials: embodied impacts of building materials, including lifecycle impacts like embodied carbon dioxide
- Waste: construction resource efficiency and operational waste management and minimization
- Pollution: external air and water pollution
- Land Use: type of site and building footprint
- Ecology: ecological value, conservation and enhancement of the site
- The total number of points or credits gained in each section is multiplied by an environmental weighting factor which takes into account the relative importance of each section.
- Section scores are then added together to produce a single overall score.
- Once the overall score for the building is known this is translated into a rating on a scale of:
- Pass
- Good
- Very Good
- Excellent
- Outstanding

A star rating from 1 to 5 stars is also provided

3.3.3 BREEAM AP

The BREEAM Accredited Professional qualification recognizes specialist skills in sustainability and environmental design combined with a high level of competence in the BREEAM assessment process. It is aimed at architects, engineers and others with design skills and responsibilities. BREEAM Excellent-rated Cardiff Library.

Clients use BREEAM to specify the sustainability performance of their buildings in a way that is quick, comprehensive, and highly visible in the marketplace and provides a level playing field.

To improve the sustainability of our built environment, there is now a strong focus on communities, especially on communities which provide integrated working, living and recreational facilities.

BREEAM Communities is a certification scheme to independently certify development proposals at the planning stage. Search for BREEAM certified buildings on Green Book Live You can search for BREEAM certified buildings at www.greenbooklive.com/breeambuildings.

This provides information on the location, rating and type of building for all projects certified under BREEAM 2008 schemes onwards.

3.3.4 BREEAM In-Use

A significant opportunity to address the environmental impact of buildings lies in better management and improvement of the existing building stock. BREEAM In-Use is a scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings.

It consists of a standard, an easy-to-use assessment methodology and a 3rd party certification process that provides a clear and credible route map to improving sustainability. BREEAM In-Use can assist users to:

- Reduce operational costs
- Enhance the value and marketability of property assets
- Give a transparent platform for negotiating building improvements with landlords and owners
- Provide a route to compliance with environmental legislation and standards,
- Give greater engagement with staff in implementing sustainable business practices
- Provide opportunities to improve staff satisfaction with the working environment with the potential for significant improvements in productivity

3.3.5 Country-specific BREEAM schemes

As part of our sustainability commitment for the built environment, promoting and influencing sustainability practices across the globe, we engage directly with selected organizations, assisting them in developing their own national sustainability assessment method. National schemes are adapted to local social, cultural and climatic conditions, translated in the local language with local assessors and aligned with the country's building regulations.

Such schemes can act as a mass market driver to influence the local construction industry to go above and beyond building regulations.

Once we have approved a new scheme for a specific country, we sign a Framework Agreement with a National Scheme Operator, which may be a government body, a national Green Building Council or other relevant organization.

3.3.6 National Scheme Operators (NSOs)

Country-specific local schemes that are BREEAM affiliated are owned and developed by a Scheme Operator, for example BRE Global is the Scheme Operator for the UK (BREEAM UK), the Dutch Green Building Council is the National Scheme Operator for the Netherlands (BREEAM NL) and the Instituto Tecnológico de Galicia is the National Scheme Operator for Spain (BREEAM ES).

The Schemes developed by National Scheme Operators can take any format as long as they comply with the requirements established by the Code for a Sustainable Built Environment.

The local Scheme can be developed from new:

- By adapting BREEAM UK, European or International Schemes to the local context
- By interpreting the BREEAM Core Technical Standard for the local context

3.3.7 About BRE Global

BRE Global Limited (incorporating BREEAM & LPCB) is an independent third party approvals body offering certification of fire, security and sustainability products and services to an international market. BRE Global's product testing and approvals are carried out by internationally recognized experts in renowned testing laboratories. BRE Global Limited is a custodian of a number of world leading brands including:

- BREEAM is the leading environmental method for buildings, sets the standard for best practice in sustainable design and has become the de-facto measure of a building's environmental performance
- LPCB for the approval of fire and security products and services, listed in the Red Books BRE Global is part of the BRE Group, the trading subsidiary of the BRE Trust, a registered research and education charity.

3.3.8 BREEAM's Relative Strengths (Inbuilt Ltd, 2010)

- **Minimum Standards**

BREEAM's minimum standards, pertaining to specific credits or specific criteria for credits, are tiered based on the target rating, ranging from four to 26 credits or criteria as set out in Table 1 above.

This enables the scheme to progressively achieve key priorities and greater impact on a building's sustainability at the highest ratings, whereas LEED has a fixed number of eight prerequisites applicable across all rating classifications (plus one of the seven Minimum Program Requirements pertaining to sharing energy and water usage data considered to be comparable).

- **Energy Consumption / CO_2 Reduction**

BREEAM encourages reduction in CO_2 to zero net emissions in relation to Building Regulations Part L 2010 to achieve maximum points worth 10.56% of the total score. LEED targets energy cost reduction, instead of CO_2, based on improvement over an ASHRAE 90.1-2007 baseline, and offers maximum points worth 17% of the total score for an energy cost reduction of only 48%. This reaffirms the above mentioned findings of Lee and Burnett (2007) in relation to earlier versions of both methods.

- **Energy Sub-Metering**

BREEAM has a compulsory minimum standard of sub-metering substantial energy uses for Very Good, Excellent and Outstanding ratings. LEED has no energy sub-metering prerequisite.

- **Life-Cycle Cost Analyses**

There are no LEED credits for life-cycle costing, therefore it may not encourage the most environmentally efficient allocation of capital.

- **Materials**

In relation to sustainable materials and life-cycle impacts, BRE has produced the Green Book Live and the Green Guide to Specification which provide useful information for designers and make it more likely to achieve these credits (and the environmental benefit), whereas under LEED.

Designers seeking to achieve corresponding credits must rely on a multiplicity of manufacturers' and/or third parties' product evaluations/certifications (Reed et al., 2010, p.147) or relatively simplified checklists (Saunders, 2008, p.25).

- **Transport**

BREEAM's travel plan credit is more rigorous in relation to actual accessibility of public transport compared to LEED which does not take account of the routes, hours of service and frequency of service. Furthermore this BREEAM credit includes a requirement to actively encourage alternative options to car or other high environmental impact forms of transport.

3.3.9 Conclusion

There is evidently a need for sharing building performance data and more work in the field of ensuring building design performance follows through to building operation.

A key area for BREEAM is reviewing guidance to consider new areas for incorporation and setting minimum standards as well as clearly outlining BREEAM"s future strategies and direction so that industry is prepared for future changes.

It is clear that several areas require improvement in the operational context of BREEAM, in particular, customer service and moving to online systems. This is important if BREEAM is to continue to respond to market needs.

Through improved investment in systems, services and research it is felt BREEAM can continue to be an effective assessment methodology in the market place and can continue to mainstream sustainable buildings and drive transformational change.

3.4 The Green Pyramid Rating System (GPRS)

3.4.1 Introduction

Climate change is possibly the greatest challenge facing humanity, and research appears to show that the phenomenon is a result of the increased levels of greenhouse gas emissions resulting from human activity. In spite of Egypt's relatively low levels of greenhouse gas emissions, the Nation is considered to be one of the countries of the world most 'at risk' from climate change, making this a key issue for national policy.

Given that around half of total carbon-related emissions come from buildings and their use, sustainable building development and green building, should be recognized to be of crucial importance. The government of the Arab Republic of Egypt, represented in the Ministry of Housing, Utilities and Urban Development has an interest in promoting green building as part of the Ministry's overall sustainable development policies. Green building should reduce pollution and enhance the efficiency of energy and water use.

Furthermore, green buildings are designed and constructed in such a way that the activities of their occupiers and users do not endanger the environment or human health and well-being. Green building, with its use of renewable energy, recycling and reduction of pollution and waste involves more responsible, rational and sustainable use of land, raw materials, energy and water. This in turn should lead to a healthier more comfortable environment and a stronger economy.

The concept of green building observes important criteria which secure the attainment of the required quality and efficiency of buildings. It covers guidance, location preparation and careful study, consideration of optimal methods for water consumption including recycling of used water for other industrial and agricultural purposes, studies on lighting, air conditioning, natural ventilation and the renewable energy sources such as the solar and wind energy systems. These technologies now exist, but it is crucial that they are promoted.

In harmony with the policies of The Ministry of Housing, Utilities and Urban development The Housing and Building National Research Center took the initiative to establish The Egyptian Green Building Council (GBC-Egypt) at the beginning of 2009.

The aims of the Green Pyramid Rating System are:

- to provide a benchmark for good practice that enables buildings in Egypt to be assessed for their green credentials through a credible, challenging and transparent environmental rating system;
- to enable building designers, constructors and developers to make reasoned choices based upon the environmental impact of their decisions;
- to stimulate awareness of, and demand for sustainable green buildings;
- to allow informed dialogue with interested parties and contribute to wider debate on Green Building in Egypt over the coming years;
- to encourage the design and construction of sustainable green buildings, and contribute significantly to a better, more sustainable building stock for the Nation.
- In order to achieve these aims, the following objectives have been set:
- to produce rating criteria that reinforce and enhance National standard regulations;
- to promote a rating system that is understandable and achievable yet challenging;
- to raise awareness of resource scarcity and ways to mitigate demand for these resources;
- to raise awareness of best environmental practice in the design, construction and use of buildings;
- to minimize the environmental impact of buildings whilst maintaining their function and the comfort, health and well-being of their occupants and of the community;
- to encourage innovative solutions that minimize environmental impact;
- to raise the awareness of the benefits of buildings with reduced impact on the environment.

The rationale, application and detailed ratings of the Green Pyramid Rating System are given in the following sections of this document. Philosophy of the Logo Design: The logo was designed around the symbolic meaning of the green pyramid which is the oldest green structure in the world. It is the historical Egyptian pyramid with the lotus flower which represents its connection with the local environment.

The external circular green frame symbolizes the focus of the Egyptian Council on preserving environmental equilibrium and sustainability. The philosophy of green building expresses the fact that once a building is completed, it becomes an indivisible part of the environment around it.

3.4.2 General Overview of the Green Pyramid Rating System

The Green Pyramid Rating System is a national environmental rating system for buildings. It provides definitive criteria by which the environmental credentials of buildings can be evaluated, and the buildings themselves can be rated. Additionally, the System should assist building designers, constructors and developers to make reasoned choices based upon the environmental impact of their decisions.

Scope of the Green Pyramid Rating System and eligibility for assessment: The Green Pyramid Rating System is designed for use in new building works.

The Rating can be used to assess individual new buildings at either or both of the following stages:

- At Design Stage
- At Post-Construction Stage

It will be mandatory for applicants wishing for a Green Pyramid assessment at Post-Construction stage to have first undergone a Green Pyramid assessment at Design Stage.

For assessment of Refurbishment-only projects (i.e. where building work will take place on an existing building) certain of the credits that apply to new buildings will not be applicable. This will require modification of the current system and The Green Pyramid Rating System for Refurbishment-only Projects will be produced at a later date.

The system for assessment of New Buildings at Post-Occupancy Stage1 and for Existing Buildings (i.e. where no intended building work will take place) will also require further modification of the current system. Two further documents – The Green Pyramid Rating System for New Buildings at Post-Occupancy Stage and The Green Pyramid Rating System for Existing Buildings will be produced at a later date.

To be eligible for assessment, a building should meet all of the minimum national statutory provisions and Egyptian National Codes for the design and construction of buildings.

A more detailed explanation of the Rules and Procedures for Green Pyramid Application and Approval are given in Sections 8 and 9 of this document.

3.4.3 Components of the Green Pyramid Rating System

The system comprises seven rating Categories (1-7) which in turn contain sub-categories (numbered 1.1, 1.1.1, etc.).

Credit points will be awarded based upon criteria given in this document, and in certain cases a Category will have one or more Mandatory Minimum Requirements without which no further points will be obtainable.

There are also occasional conditions stipulated, which take the form (for example) 'Credit points for this Sub-category will not be awarded if …' Failure to observe these conditions will nullify the award of other credit points in the Category or Sub-category.

3.4.4 Category Weightings

Green Pyramid Category Weightings are illustrated in **Table 3-4**:

Table (3-4) Green Pyramid Category Weightings

Green Pyramid Category	Category Weighting
1: Sustainable Site, Accessibility, Ecology	15%
2: Energy Efficiency	25%
3: Water Efficiency	30%
4: Materials and Resources	10%
5: Indoor Environmental Quality	10%
6: Management	10%
7: Innovation and Added Value	Bonus

3.4.5 Certification and Levels of Rating

To earn Green Pyramid certification a project must satisfy all the stated Mandatory Minimum Requirements and may obtain Credit Points by meeting certain criteria. Projects will be rated, based on Credit Points accumulated, according to the following rating system:

GPRS Certified: 40–49 credits
Silver Pyramid: 50–59 credits
Gold Pyramid: 60–79 credits
Green Pyramid: 80 credits and above
Projects with less than 40 credits will be classified as 'Uncertified'

3.4.6 Category 1: Sustainable Site, Accessibility and Ecology Objectives

The objectives of this Category include:

1. **Site Selection**: to encourage development in desert areas, redevelopment in informal areas and avoid projects which negatively affect archaeological, historical and protected areas.
2. **Accessibility:** to minimize pollution and traffic congestion from car use and to conserve non-renewable energy by encouraging public and alternative transport.
3. **Ecological balance:** to minimize the environmental impact of the project on the site and its surroundings; to protect existing natural systems, such as fauna and flora (including wildlife corridors and seasonal uses), soil, hydrology and groundwater from damage and to promote biodiversity.

The summary of credit points in this category are presented in **Table 3-5 and 3-6**.

Table (3-5) Category 1 credit point summary

1.M Mandatory Minimum Requirement2	
1.M.1 Presentation of a Project Design and Implementation Plan	
1.1 Site Selection	
1.1.1 Desert area development	1 point
1.1.2 Informal area redevelopment	1 point
1.1.3 Brownfield site redevelopment	1 point
1.1.4 Compatibility with National development Plan	1 point
1.2 Accessibility	
1.2.1 Transport infrastructure connection	1 point
1.2.2 Catering for remote sites	1 point
1.2.3 Alternative methods of transport	1 point
1.3 Ecological balance	
1.3.1 Protection of habitat	1 point
1.3.2 Respect for sites of historic or cultural interest	1 point
1.3.3 Minimizing Pollution during construction	1 point
TOTAL 10 credit points	

Table (3-6) Details of credit points in category 1: sustainable site, accessibility and ecology

Category 1: Sustainable Site Mandatory Minimum Requirement3		
1M.1	**Presentation of the Project Design and Implementation Plan**	M
1.1 **Credit Points for Site Selection**4		
1.1.1	**Site selection in desert areas to encourage development in the desert outside the Nile Valley:** A credit point is obtainable with documentary evidence that the project is in a desert area.	1
1.1.2	**Redeveloping informal areas:** A credit point is obtainable for projects that redevelop and re-plan informal areas to achieve maximum benefit from land use, provide services, and distribute population density in these areas.	1
1.1.3	**Redeveloping Brownfield sites:** A credit point is obtainable for projects that redevelop a brown field site in order to achieve maximum benefit from such areas and to rationalize land use. Where remediation of the site has been necessary, documentary evidence should be provided that the site was properly remediated (including an Environmental Site Assessment).	1
1.1.4	**Compatibility with the National Development Plan:** A credit point is obtainable for compatibility with the National Development Plan in order to achieve maximum benefit from the existing infrastructure, protect green land and spaces, preserve natural resources, provide green areas and services and distribute population density.	1

Table (3-6) Details of credit points in category 1: sustainable site, accessibility and ecology continue:

1.2 Accessibility		
1.2.1	**Transport infrastructure connection:** A credit point is obtainable for demonstrating a suitable connection with existing public transport systems.	1
1.2.2	**Catering for remote sites:** Where the site is currently remote a credit point is obtainable for presenting a suitable method for connecting it with the nearest urban area (including establishing the required infrastructure).	1
1.2.2	**Alternative methods of transport:** A credit point is obtainable for demonstrating strategies to reduce reliance on private automobile use and encourage the use of greener methods of transport.	1.2.2
1.3 Ecological balance		
1.3.1	**Protection of habitat:** A credit point is obtainable for demonstrating a suitable strategy for conserving or restoring natural areas to provide habitat and promote biodiversity, including the preserving / replanting of trees found on site.	1
1.3.2	**Respect for sites of historic or cultural interest:** A credit point is obtainable for demonstrating a suitable strategy for conserving and protecting remains of historic or cultural interest that are part of or nearby the site.	1
1.3.3	**Minimizing pollution during construction:** A credit point is obtainable for demonstrating a strategy to minimize pollution from construction operations (including generation of dust and pollutants).	1
Total available credit points in category 1: sustainable site		10

These points are obtainable based upon documentary evidence of the optimal site selection for the project. For example, efforts should be made to avoid building a project which:

- Negatively affects agricultural or natural protected areas.
- Negatively affects monuments, archaeological and historical areas.
- Is located in landmine or quick sand areas.
- Is located in flash flood spillways.

3.4.7 Category 2: Energy Efficiency Objectives

The objectives of this Category are:

a) To reduce energy consumption and carbon emissions by incorporating passive design strategies;

b) To optimize the choice of electrical and mechanical equipment, to and to evaluate the inventory of energy and carbon for each developed MEP system, and to minimize their impact on the environment;

c) To reduce energy demand to cater for loads at peak use times through efficient building and services design and site based, where possible, on renewable energy generation.

d) To encourage the provision of metering facilities that allow the energy performance of the building to be recorded and monitored to allow future improvement and prove validity;
e) To minimize the energy consumed by the commonly used building appliances.

A summary of credit points in this category are illustrated in **Tables 3-7 and 3-8.**

Table (3-7) category 2 credit point summary

2.M Mandatory Minimum Requirements5	
2.M.1 Minimum Energy Performance Level	
2.M.2 Energy Monitoring & Reporting	
2.M.3 Ozone Depletion avoidance	
2.1 Energy Efficiency Improvement:	10 points
2.2 Passive External Heat Gain Reduction:	7 points
2.3 Energy Efficient Appliances:	3 points
2.4 Vertical Transportation Systems:	3 points
2.5 Peak Load Reduction:	6 points
2.6 Renewable Energy Sources:	12 points
2.7 Environmental Impact	4 points
2.8 Operation and Maintenance:	1 points
2.9 Optimized balance of Energy and Performance:	4 points
2.10 Energy and Carbon Inventories:	2 points
Total 50 credit points	

Table (3-8) Details of Credit Points in Category 2: Energy Efficiency

Category 2: energy efficiency mandatory Minimum Requirements6		
2M.1	**Minimum Energy Performance Level:** Demonstrate a Minimum Energy Performance Level 10% above an appropriate simulated base case model. The base case model is to be produced in accordance with the Egyptian Energy Efficiency Code and using the methods outlined in Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 (or equal approved standard).	M
2M.2	**Energy Monitoring and Reporting:** Demonstrate provision of accessible energy sub-meters, clearly labelled and with instructions, for all occupied areas. Sub-meters should enable monitoring and recording of a minimum of 90% of the estimated annual consumption of each fuel type, with separate meters for equipment that exceeds 10 kW.	M
2M.3	**Ozone Depletion avoidance:** Demonstrate that all refrigerants and gaseous fire suppression agents within the Project have an Ozone Depletion Potential (ODP) near zero.	M

Table (3-8) Details of Credit Points in Category 2: Energy Efficiency continue:

2	**Credit Points for Energy Efficiency**		
2.1	**Energy Efficiency Improvement**: A maximum 10 credit points are obtainable for demonstrating (using the methodology outlined in 2M.1, above) further reductions in energy consumption from the base case determined in item 2M.1 (above). Points awarded are accumulative, and are shown opposite:	Reduction 5-10% 11-15% 16-20% 21-25% 26-27% 28-30% 31-35% 36-40% 41-45% 46-50%	 1 1 1 1 1 1 1 1 1 1
2.2	**Passive External Heat Gain\loss Reduction:** A maximum 7 credit points are obtainable for demonstrating reductions in annual external heat gain\loss (from the base case determined in item EF-01) through use of passive design measures in the building. Points awarded accumulative, and are shown opposite:	Reduction 5-10% 11-20% 21-30% 31-35% 36-40% 41-45% 46-50%	 1 1 1 1 1 1 1
2.3	**Energy Efficient Appliances:** Credit points are obtainable for demonstrating that the building occupier will be provided with formal documentary guidelines on the purchase and use of Energy Efficient Appliances for the building, with reference to rating schemes such as Energy Star (USA) or the Energy Efficiency Labelling Scheme (EU).		3
2.4	**Vertical Transportation Systems:** Credit points are obtainable for demonstrating that: • stairs are visible from the main entrance or from the main building lifts; have a minimum lighting level of 150 lux measured at the walking surfaces; any artificial lighting used within the stairs must be supplied with colour corrected lamps with minimum Colour Rendering Index CRI=80. • all lifts within the building are energy efficient – i.e. operate in stand-by mode during off-peak periods; include a regenerative drive system for buildings over 3 stories; and use LED lighting and LCD display features.		1 1

Table (3-8) Details of Credit Points in Category 2: Energy Efficiency continue:

	• all escalators and travelators are energy efficient – i.e. have an automated stop/start function linked to occupancy sensors to enable standby mode when there is no passenger demand; and use LED strip lighting.	1
2.5	**Peak Load Reduction:** Credit points are obtainable for demonstrating that a peak electrical load has been achieved that is not more than 80% greater than the project design annual average electrical load. Further credit points are obtainable for demonstrating that a peak electrical load has been achieved that is not more than 60% greater than the project design annual average electrical load. Evidence should include results of dynamic energy simulations giving annual average, and peak electrical loads for the building and explanation of peak load reduction methodology, including drawings, equipment data sheets/specifications as necessary.	3 3
2.6	**Renewable Energy Sources:** Credit points are obtainable for demonstrating that: • an on-site and/or off-site renewable energy feasibility study has been undertaken; • a minimum of 5% of the project's non-renewable energy use will be provided by on-site generated renewable energy. • A maximum 8 credit points are obtainable for demonstrating that a percentage of total energy demand is supplied through renewable energy, utilizing on-site or off-site sources. Points awarded are accumulative, and are shown opposite: **% Total** 1-4% 5-8% 9-12% 13-15% 16-20% 21-25% 26-29% over30%	1 1 1 1 1 1 1 1 1 1
2.7	**Environmental Impact:** The weighted average of all refrigerants and fire suppression systems media has an equivalent Global Warming Potential (GWP) that meets or is less than the requirements of Egyptian Environmental Law. Credit points are obtainable for demonstrating that: • **Points awarded as follows:** • The weighted average of all refrigerants shall have a GWP of 12 or less;	1

Table (3-8) Details of Credit Points in Category 2: Energy Efficiency continue:

	• The Project has installed a permanent refrigerant leak detection system; • The Project has installed an automatic refrigerant pump-down system to a dedicated storage tank with isolation valves; • All gaseous fire suppression systems have a GWP of 2 or less.	1 1 1
2.8	**Operation and Maintenance:** Credit points are obtainable for providing for a simple and easily-followed Operations Manual for all Mechanical, Electrical and Plumbing (MEP) apparatus, equipment, device, and sub-system.	1
2.9	**Optimized balance of Energy and Performance:** Credit points are obtainable for demonstrating design optimization studies and implementation of the following: • Natural Vs. Artificial Lighting; • Optimization between Minimum Thermal Cooling loads and Maximum Day Lighting, using Window-Wall Ratio (WWR) and Skylight-Roof Ratio (SRR); • Acceptable Indoor air quality at all operation profiles; • Optimization between building Passive systems and the anticipated Minimum Thermal Cooling	1 1 1 1
2.10	**Energy and Carbon Inventories:** Credit points are obtainable for providing an inventory of energy and carbon for each Mechanical, Electrical and Plumbing (MEP) system, including transportation to Site, installation, testing and commissioning and operation	2
Total available credit points in category 2: energy efficiency		50

3.4.8 Category 3: Water Efficiency Objectives

The objectives of this category are:

- Helping professionals across the country to improve the quality of our buildings and their impact on the environment
- Develop and implement a comprehensive water strategy
- Minimize indoor and outdoor water demands
- Reduce potable water use.
- to reduce potable water use by promoting the use of reused grey water or avoiding the use of potable clean water, where possible;
- Water efficient landscaping
- Minimize potable use for irrigation
- Reduce generation of wastewater

A summary of credit points in this category are illustrated in **Tables 3-9 and 3-10.**

Table (3-9) Category 3 credit point summary

3.M Mandatory Minimum Requirement7	
3.M.1 Minimum Water Efficiency	
3.M.2 Water Use Monitoring	
3.1 Indoor Water Efficiency Improvement	8 points
3.2 Outdoor Water Efficiency Improvement	9 points
3.3 Efficiency of Water-based Cooling:	4 points
3.4 Water Feature Efficiency	4 points
3.5 Water Leakage Detection	6 points
3.6 Efficient water use during construction	3 points
3.7 Waste water management	12 points
3.8 Sanitary Used Pip	4 points
Total 50 credit points	

Table (3-10) Details of credit points in category 3: water efficiency

Category 3: Water Efficiency Mandatory Minimum Requirements8			
3M.1	**Minimum Water Efficiency:** Demonstrate, by means of a parametric analyses report, that the building's predicted potable water consumption will be no greater than that of a simulated base case model. The base case model and subsequent analyses referred to in the following sections to be produced using a suitable Building Water Calculator.		M
3.M.2	**Water Use Monitoring:** Demonstrate that efficient, regularly calibrated, easily accessible and clearly labeled water meters are provided and capable of monitoring the water consumption.		M
3	**Credit Points for Water Efficiency**		
3.1	**Indoor Water Efficiency Improvement:** A maximum 8 credit points are obtainable for demonstrating that the proposed building has achieved a sensible reduction in indoor potable wate consumption (not including irrigation) than the Water use baseline calculated for the building compared to the base-case in 3M.1(above) Calculations are based on using efficient, accessible, and clearly labelled water metering devices, and estimated occupant usage, and the use of conserving (saving) water and sanitary devices (fixtures) rather than the conventional ones (lavatory faucets, showers , kitchen sinks, water closets, and urinals). Points awarded are accumulative, and are shown opposite.	Reduction <10% 10-20% 21-30% 31-40% 41-50%	 2 1.5 1.5 1.5 1.5

Table (3-10) Details of credit points in category 3: water efficiency continue:

3.2	**Outdoor Water Efficiency Improvement recommend to be replaced by (Water Efficient Landscaping):** A maximum 9 credit points credit points are obtainable for demonstrating that:	
	• An Irrigation Operation and Maintenance plan has been developed;	2
	• A water-efficient irrigation system is incorporated into landscape design;	1
	• Landscape irrigation demand is less than 5 liters/m2/day average;	1
	• Landscape irrigation demand is less than 3 liters/m2/day average;	1
	• 100% exterior irrigation demand is met using Exterior Water Allowance;	1
	• Reused grey water is maximized OR a recycled water mainline loop has been installed in anticipation for the availability of reused grey water;	1
	• Color coding of pipes is used to distinguish recycled water from potable.	1
	• Use of water treated and raw water resources by a public agency specifically for non-potable uses.	1
3.3	**Efficiency of Water-based Cooling systems:** A maximum 4 credit points are obtainable for demonstrating that the Water-based Cooling system for the proposed building shows a saving in consumption compared to the base-case model in 3M.1 (above). Points awarded are accumulative, and are shown opposite **Saving** 25-50% 51-75% 76-100%	2 1 1
3.4	**Water Feature Efficiency:** Credit points are obtainable for demonstrating that	
	a) EITHER that the Project has no exterior water features or swimming pools;	4
	b) OR that all external water features or swimming pools are provided with adequate retractable shading covers or pool blankets.	2
3.5	**Water Leakage Detection:** A maximum 6 credit points are obtainable for demonstrating the provision of:	
	• Easily accessible and clearly labeled water meters that are capable of monitoring the water consumption of major uses of water;	3
	• A leak detection system that covers all main water distribution pipes within the project.	3

Table (3-10) Details of credit points in category 3: water efficiency continue:

3.6	**Efficient water use during construction:** Credit points are obtainable for demonstrating the use materials such as pre-mixed concrete for preventing loss during mixing.	3
3.7	**Waste water management:** A maximum 16 credit points are obtainable for demonstrating that: - No un-treated water will enter the local environment (for example, into surfaces, deep wells, rivers, and enclosed lakes) or affect neighboring developments; all in accordance with National Environmental Laws. (**Obligatory Issue**), supporting documentation should include: drawings showing the proposed systems and relevant calculations, specifications and data sheets - Ensuring that the reused treated waste water generation quality must compiling the standards as prescribed in the Egyptian Environmental Laws (In case the water quality cannot be ensured, provide necessary treatment of raw water for achieving the desired concentration for various applications). (**Obligatory Issue**) - Reduce potable water use for building sewage conveyance by use of non-potable water (captured rainwater, or recycled grey water).	6 4 2
3.8	**Sanitary Used Pipes:** Ensure the type of sanitry pipes material are obtainable for demonstrating that: - Optimal choice for certified sanitary pipes material which secures water quality, cleanliness and sustainability for human use. - Tested sanitary systems which ensure the high level of installation.	2 2
Total Available Credit Points in Category 3: Water Efficiency		50

3.4.9 Category 4: Materials and Resources Objectives

The objectives of this Category are:

Selection of materials:

to encourage selection of materials with a low environmental impact and cost over the full life cycle of the building, particularly:

- Regional and local materials (to reduce the environmental impacts resulting from transportation)
- Renewable materials
- Recycled materials
- Highly efficient materials (to reduce the need for maintenance, construction energy or skill or can be easily dismantled for reuse).

Materials re-use:

To promote the re-use of previously used materials and avoid wastage.

Note: The determination of the environmental impact and the life cycle cost of particular materials may be based on published international guidelines until a National or Regional material selection guideline is produced.

A summary of credit points in this category are illustrated in **Tables 3-11 and 3-12.**

Table (3-11) category 4 credit point summary

4.M Mandatory Minimum Requirements11	
4.M.1 Presentation of a Schedule of Principal Project Materials	
4.M.2 Elimination of exposure to hazardous and toxic materials	
4.1 Regionally procured materials:	3 points
4.2 Materials fabricated on site:	1 point
4.3 Use of readily renewable materials:	3 points
4.4 Use of salvaged materials:	3 points
4.5 Use of recycled materials:	4 points
4.6 Use of lightweight materials:	1 point
4.7 Use of higher durability materials:	1 point
4.8 Use of prefabricated elements:	3 points
TOTAL 20 credit points	

Table (3-12) Details of Credit Points in Category 4: Materials and Resources

Category 4: Materials and Resources Mandatory Minimum Requirements12		
4M.1	Presentation of a Schedule of Principal Project Materials which lists all significant13 building materials to be used on the Project. Information to be provided on the quantity, cost, and origin of the materials and transportation to site.	M
4M.2	Elimination of exposure of building occupants to asbestos and to any other hazardous and toxic materials.	M
Credit Points for Materials and Resources		
4.1	**Regionally procured materials (to reduce the environmental impact of transportation):** Credit points are obtainable for demonstrating that building materials are extracted and manufactured in Egypt. Points awarded as follows: • Value of regional materials is not less than 25% of total materials value;	1

Table (3-12) Details of Credit Points in Category 4: Materials and Resources continue:

	• Value of regional materials is not less than 50% of total materials value; • Value of regional materials is not less than 75% of total materials value.	2 3
4.2	**Materials fabricated on site:** A credit points is obtainable for demonstrating the use of building materials (such as bricks) that are fabricated on site.	1
4.3	**Use of readily renewable materials:** Credit points are obtainable for demonstrating that building materials are readily renewable. Such materials include earth materials, natural stone, palm tree products, bamboo, wool, cotton for insulation, agrifiber, linoleum and products made from crop fibers, such as rice and barley straw. Points awarded as follows: • Value of regional materials is not less than 5% of total materials value; • Value of regional materials is not less than 10% of total materials value; • Value of regional materials is not less than 20% of total materials value.	 1 2 3
4.4	**Use of salvaged materials:** Credit points are obtainable are obtainable for demonstrating that salvaged or re-used building materials have been used, as follows: • Value of salvaged materials is not less than 25% of total materials value; • Value of regional materials is not less than 50% of total materials value; • Value of regional materials is not less than 75% of total materials value.	 1 2 3
4.5	**Use of recycled materials:** Credit points are obtainable (with evidence) for the use of recycled materials, as follows: a) Steel: at least 50% of all structural steel (by weight) has a minimum of 25% post-consumer recycled content or is reused (for structural steel buildings) OR at least 75% of all reinforcing or stressing steel (by weight) has a minimum of 90% post-consumer recycled content (for concrete-framed buildings).	 1

Table (3-12) Details of Credit Points in Category 4: Materials and Resources continue:

	b) Concrete: demonstrate that the overall amount of Portland cement used has been reduced by the use of supplementary cementitious materials such as fly ash, ground granulated blast furnace slag; c) Aggregates; demonstrate that at least 20% of all aggregates used on site (by volume), in structural and non-structural applications are recycled. d) Other Materials: demonstrate that materials of at least 10% of the total material costs are constituted of at least: 30% post-consumer recycled content, 80% post-industrial content, and 50% agricultural waste by-products.	1 1 1
4.6	**Use of lightweight materials:** A credit point is obtainable where it can be demonstrated that at least 25% (by value) of total materials are lightweight (e.g. hollow or compound) materials or elements (e.g. frames) in comparison with similar conventional materials.	1
4.7	**Use of higher durability materials:** A credit point is obtainable where it can be demonstrated that at least 25% (by value) of total materials have higher abrasion resistance and minimal maintenance costs in comparison with similar conventional materials.	1
4.8	**Use of prefabricated elements:** Credit points are obtainable for using totally or partly prefabricated elements (e.g. walls, cladding, frame, slabs) which reduce the need for construction skills and simplify dismantling for reuse. Points are available as follows: • Value of prefabricated elements not less than 10% of total project value; • Value of prefabricated elements is not less than 30% of total project value; • Value of prefabricated elements is not less than 50% of total project value.	1 2 3
4.9	**Life Cycle Cost (LCC) analyses of materials in the project:** A credit point is obtainable for presenting a Life Cycle Cost (LCC) analyses of all significant14 building materials to be used on the Project.	1
Total Available Credit Points in Category 4: Materials and Resources		20

3.4.10 Category 5: Indoor Environmental Quality Objectives

The objectives of this Category are:

a) to provide a building and its systems that support the wellbeing and comfort of occupants by providing sufficient outside air ventilation and indoor air quality;

b) to eliminate exposure of building occupants to the harmful effects of tobacco smoke, the risk of Legionella and other pathogens;

c) to encourage use of low-emission adhesives, sealants, paints, coatings, flooring and ceiling systems and to mitigate the health risks associated with formaldehyde in building products.

d) to promote thermal, visual and acoustic comfort of occupants (including provision of individual comfort controls, where appropriate) to optimize occupant wellbeing, productivity, energy efficiency and future flexibility.

A summary of credit points in this category are illustrated in **Tables 3-13 and 3-14.**

Table (3-13) Category 5 credit point summary

5.M Mandatory Minimum Requirements15	
5.M.1 Minimum Ventilation and Indoor Air Quality	
5.M.2 Control of Smoking in and around the Building	
5.M.3 Control of Legionella and other health risks	
5.1 Optimized Ventilation:	5 points
5.2 Controlling emissions from building materials:	5 points
5.3 Thermal Comfort:	2 points
5.4 Visual Comfort:	2 points
5.5 Acoustic Comfort:	1 points
TOTAL 20 credit points	

Table (3-14) Details of credit points in category 5: indoor environmental quality

Category 5: Indoor Environmental Quality Mandatory Minimum Requirements16		
5M.1	**Minimum Ventilation and Indoor Air Quality:** Undertake a verified observational survey of outdoor local air quality according to ANSI / ASHRAE 62. Demonstrate that the building mechanical system meets the following requirements: • Separation distances between outdoor air intakes and any exhausts or discharge points comply with local codes or ASHRAE (whichever is more stringent); • all exhausts are located outside of the defined public realm or as defined by local code, whichever is more stringent; • all occupied areas comply with the minimum thresholds set out in ANSI / ASHRAE 62 using the ventilation rate procedure or local code, (whichever is more stringent).	M

Table (3-14) Details of credit points in category 5: indoor environmental quality continue:

5M.2	**Control of Smoking in and around the Building:** Demonstrate that appropriate measures are incorporated into the building design to reduce exposure to tobacco smoke. Also demonstrate that smoking is prohibited throughout the building including car parks, and 25 m smoke free zones around all entrances, outdoor air intakes and operable windows. Train all security staff for smoking control within and outside buildings. Locate any dedicated external smoking areas away from public or high use pedestrian thoroughfares and install suitable facilities for collecting ash and cigarette ends; and install, in all dedicated external smoking areas, signage that lists the negative health impacts of smoking and details assistance for those aiming to stop.	M
5M.3	**Control of Legionella and other health risks:** Demonstrate that a Legionella Management Plan exists for all relevant water based systems, following the requirements and guidance in Approved Code of Practice and Guidance (L8), 3rd Edition 2000, UK Health and Safety Executive (or other approved) and integrate this plan into the Operations & Maintenance Manual (OMM).	M
Credit Points for Indoor Environmental Quality		
5.1	**Optimized Ventilation:** A credit point is obtainable for demonstrating an increase in the fresh air ventilation rate of 15% over the base case determined in item 5M.1 (above). Credit points are obtainable for the provision of CO_2 sensors installed at all return points with rate of Ventilation exceeds minimum requirements by 15%. Ensure the CO_2 monitoring system has sensors located in the breathing zone and is capable of alerting occupants when additional fresh air is required. At a minimum CO_2 levels must not exceed 1000ppm.	1 4
5.2	**Controlling emissions from building materials:** Credit points are obtainable for demonstrating the use of low emission adhesives, sealants, and paints, coatings, flooring and ceiling systems, and certification that building materials and products containing formaldehyde have not been used.	5
5.3	**Thermal Comfort:** Credit points are obtainable for demonstrating that all spaces within the building have been modelled to determine zonal cooling demand and designed to have separately controllable thermal zones,	2

Table (3-14) Details of credit points in category 5: indoor environmental quality continue:

	Provision for these zones and various types of building should be in accordance with ANSI / ASHRAE 55 adapted for Egyptian Climatic Regions.	
5.4	**Visual Comfort:** Credit points are obtainable for demonstrating that all spaces within the building have been modelled to determine the suitable lighting intensity to meet the required applications as per local codes; In addition the submission shall include the methodologies of controls for optimum energy saving in-conjunction with the analyses for compromising between day-lighting and artificial lighting.	2
5.5	**Acoustic Comfort:** Credit points are obtainable for demonstrating that all spaces within the building have been modelled to determine suitable acoustic conditions and noise control strategies, all in accordance with National and Local Codes.	1
Total Available Credit Points in Category 5: Indoor Environmental Quality		20

3.4.11 CATEGORY 6: MANAGEMENT OBJECTIVES

The objectives of this Category are:

Site Provision:

To encourage development in desert areas, redevelopment in informal areas and avoid projects which negatively affect archaeological, historical and protected areas.

Site Environmental:

To minimize the environmental impacts associated with construction operations.

Building User Guide:

To ensure that the building will be operated responsibly and maintained properly by providing a Building User Guide and Periodic Maintenance schedule.

A summary of credit points in this category are illustrated in **Tables 3-15 and 3-16.**

Table (3-15) category 6 credit point summary

6.M Mandatory Minimum Requirements	
6.M.1 Presentation of a suitable Integrated Plan and Method Statement for site operations.	M
6.M.2 Compliance with all relevant national Health & Safety and Welfare regulations.	M
6.M.1 Where the Project involves demolition work, a Method Statement with clear evidence of the use of suitable methods of demolition.	M

Table (3-15) category 6 credit point summary continue:

6.1 Site Provision	
6.1.1 Containers for site materials waste	2 points
6.1.2 Employing waste recycling workers on site	1 point
6.1.3 Access for lorries, plant and equipment	1 point
6.1.4 Identified and separated storage areas	2 points
6.2 Site Environmental	
6.2.1 Project Waste Management Plan	1 point
6.2.2 Engaging a company specialized in recycling	2 points
6.2.3 Protecting water sources from pollution	2 points
6.2.4 Waste from mixing equipment	2 points
6.2.5 Control of emissions and pollutants	2 points
6.3 Building User Guide	
6.3.1 providing a Building User Guide	3 points
6.3.2 providing a Periodic Maintenance Schedule	2 points
TOTAL 20 credit points	

Table (3-16) Details of Credit Points in Category 6: Management

Category 6: Management Mandatory Minimum Requirements17		
6M.1	Presentation of an Integrated Plan and Method Statement for site operations	M
6M.2	Compliance with all relevant national Health & Safety regulations	M
6M.3	Where the Project involves demolition work, a Method Statement with clear evidence of the use of suitable methods of demolition.	M
6.1 **Credit Points for Site Provision**		
6.1.1	**Containers for site materials waste:** Credit points are obtainable for providing and appropriate number of separate specific and identified containers for different kinds of wastes with clear signs on each.	2
6.1.2	**Employing waste recycling workers on site:** A credit point is obtainable for employing workers for daily recycling of waste materials on site.	1
6.1.3	**Access for lorries, plant and equipment:** A credit point is obtainable for providing proper access roads for lorries to reduce any negative impact on the environment during site operations.	1
6.1.4	**Identified and separated storage areas:** Credit points are obtainable for providing site storage areas, separation of flammable and toxic materials and prevention of soil pollution in these areas.	2

Table (3-16) Details of Credit Points in Category 6: Management continue:

6.2	**Credit Points for Site Environmental**	
6.2.1	**Project Waste Management Plan:** A credit point is obtainable for presenting a project *Waste Management Plan* that includes strategies from reducing, and, where possible, re-using and recycling the waste arising from site operations.	1
6.2.2	**Engaging a company specialized in recycling and disposal:** Credit points are obtainable for engaging a company specialized in building materials recycling and management and in proper disposal of waste.	2
6.2.3	**Protecting water sources from pollution:** Credit points are obtainable for safeguarding water sources from pollution arising from site operations.	2
6.2.4	**Waste from mixing equipment:** Credit points are obtainable for proper disposal of waste (including waste water from the mixing process) from mixing equipment without harm to the environment.	2
6.2.5	**Control of emissions and pollutants:** Credit points are obtainable for mitigating noise and exhaust emissions from machinery and equipment on Site.	2
6.3	**Credit Points for Building User Guide**	
6.3.1	**Providing a Building User Guide:** Credit points are obtainable for providing a building user guide containing the necessary technical and non-technical information for the building users / occupant to enable the efficient and responsible operation of the building.	3
6.3.2	**Providing a Periodic Maintenance Schedule:** Credit points are obtainable for the provision of a Periodic Maintenance Schedule, which should be comprehensive and regularly updated.	2
Total Available Credit Points in Category 6: Management		20

3.4.12 Category 7: Innovation and Added Value Objectives

The objectives of this Category are:

Cultural heritage:

Designs which excel in reflecting national and regional cultural heritage while contributing to the environmental performance of the building.

Exceeding Benchmarks:

Initiatives which demonstrate additional environmental benefit by exceeding the current benchmarks of GPRS.

Innovation:

Design initiatives and construction practice which have a significant measurable environmental benefit and which are not otherwise awarded points by GPRS.

A summary of credit points in this category are illustrated in **Tables 3-17 and 3-18.**

Table (3-17) category 7 credit point summary

7.M There are no Mandatory Minimum Requirements for this Category	
7.1 Cultural Heritage	3 points
7.2 Exceeding Benchmarks	4 points
7.3 Innovation	3 points
TOTAL 10 credit points	

Table (3-18) Details of Credit Points

Category 7: Innovation and Added Value		
1	**Cultural Heritage:** Credit points are obtainable for incorporating architectural, construction and technical solutions which excel in reflecting national and regional cultural heritage while contributing to the environmental performance of the building.	7.1
1	**Exceeding Benchmarks:** Credit points are obtainable for demonstrating that the current benchmarks of GPRS have been exceeded by a significant margin and providing evidence that the improvement has an additional environmental benefit. One Credit Point is available for each Category (up to a maximum of four Credit Points).	7.2
1	**Innovation:** Credit points are obtainable for innovative design or construction practices which have a significant measurable environmental benefit and which are not otherwise awarded points by GPRS.	7.3
Total available credit points in category 7: innovation and added value which will be offered as bonus credits.		**3**

3.4.13 SECTION 8:

1. Procedures for Green Pyramid Approval Application

Applicants who consider that their projects satisfy the requirements and criteria to apply for Green Pyramid Rating may make application as follows:

1.1 Applicants must submit Form 1 (Form To Accompany Green Pyramid Approval Application – see below, Section 9) which will be available on request from the Housing and Building National Research Center (HBRC), 87 Tahrir Street, Dokki, Giza 11511 Egypt.

An online version will also be available. This form is to be completed in full by the Applicant and returned (with associated accompanying documents) to the HBRC at the above address with all accompanying information. Incomplete applications will not be accepted.

1.2 No project rating can be commenced until the form and its associated accompanying documents have been received by HBRC. The Applicant must complete and submit the Green Pyramid Credit Submission Matrix which is part of the form. This highlights which credits the Applicant considers the Project to be eligible for, and confirms that evidence is available for each and that the Mandatory Minimum Requirements for award have been met.

1.3 Applications must be accompanied by the appropriate fee. Fees are determined according to the table in Appendix 1. Fees are not refundable (and this includes projects which fail to achieve certified status). Re-approval may take place on payment of an additional fee. Fees may be changed in certain cases approved by the Council.

1.4 Within 30 days the Applicant will receive a reply either accepting the application for rating or requesting further information. This request may include (but is not limited to):

- Verification of Project conformity with relevant Egyptian codes;
- Verification of the materials and equipment samples presented for approval;
- Verification of supporting documents and reports.

Such further information must be provided by the Applicant within two months of notification.

1.5 Laboratory tests shall take place in laboratories satisfying ISO 17025. Documents from non-licensed laboratories will not be accepted except in cases requiring laboratories not available in the Arab Republic of Egypt. Such situations shall be referred to the HBRC for directing the Applicant to laboratories acceptable to the GBC-Egypt.

1.6 In the case of any applicant not providing the further information referred-to in 8.1.4 within two months of notification, or in the case of non-payment of fees, the application will be cancelled. The Applicant may apply again for re-approval after 2 months from the date of the cancellation.

1.7 All intellectual property rights and data ownership will be retained by their original owners, and all information provided by the Applicant will remain confidential unless they are disclosed resulting from written approval of the Applicant or a Court Order.

2. ASSESSMENT AND RATING

2.1 Head Committee for Green Pyramid Assessment

The assessment, approval and certification process shall be directed by the GPRS Head Committee. This Committee will be established and directed by the Chairman of the Board of Directors, Housing and Building National Research Center. The GPRS Head Committee will pass on all applications received to one of the standing multi-disciplinary GPRS Assessment Groups which shall be formed for this purpose.

2.2 Standing Green Pyramid Assessment Groups

Each Assessment Group will comprise a small number of experts, drawn from within the Housing and Building National Research Center and outside, who can adequately represent the technical know-how that is necessary to assess GPRS Applications.

2.3 Licensed Assessors

In due course, after the Green Pyramid Rating System has accumulated sufficient expertise, training and licensing of Assessors will take place, with a view to assessments being carried out by these individuals.

2.4 Reporting and Responsibility

GPRS Certification is a matter for the EGPRS Head Committee. Neither GPRS Assessment Groups, nor (ultimately) GPRS Licensed Assessors shall themselves issue certification under the System. They will instead report back to the GPRS Head Committee with a recommendation, and the GPRS Head Committee will then issue the appropriate Green Pyramid certification.

2.5 Application, assessment and rating process

The application, assessment and rating process is outlined in the following figure:

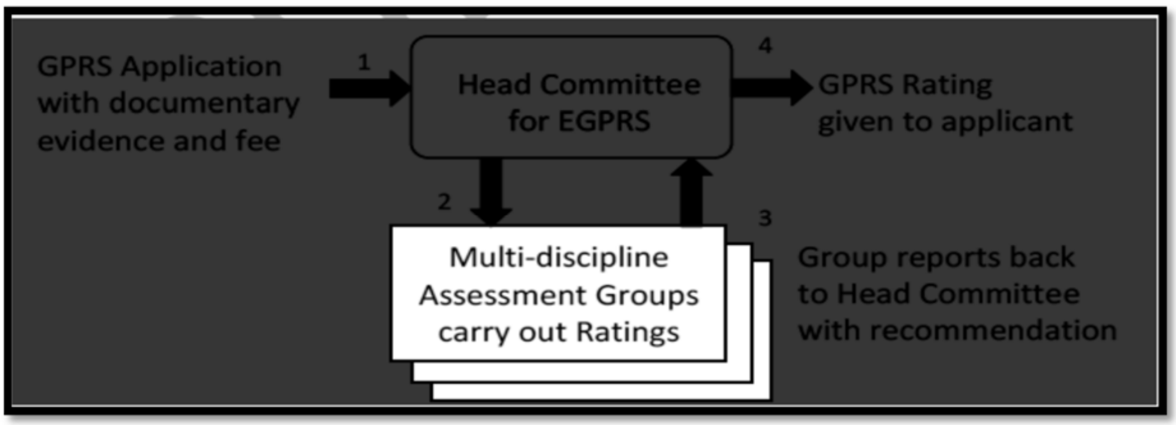

Figure (3-3) GPRS assessment and rating process

2.6 Process of Assessment

The Assessment Group or Licensed Assessor will use the Green Pyramid Rating Spreadsheet. The process of assessment will be as follows:

1. For each Category the number of credits awarded will be determined by a Green Pyramid Assessment Group or Licensed Assessor in accordance with the Green Pyramid requirements (detailed in the Category sections of this document).
2. The credits achieved for each Green Pyramid Category are calculated.
3. The percentage of credits achieved is then multiplied by the corresponding Category Weighting. This gives the section score.
4. The scores for each Category scores are then added to give the overall Green Pyramid Rating.

An example of green pyramid rating calculation is shown in table 3-19:

Table (3-19): Green Pyramid Rating calculation

	A	B	C = B/Ax 100%	D	E = C x D
Green Pyramid Category	**Credits Available**	**Credits Achieved**	**% Credits Achieved**	**Category Weight**	**Category Score**
1:Sustainable Site, Accessibility, Ecology	10	5	50%	15%	7.5
2:Energy Efficiency	50	40	80%	25%	20
3:Water Efficiency	70	35	50%	30%	15
4: Materials and Resources	20	10	75%	10%	5
5:Indoor Environmental Quality	20	10	50%	10%	5
6: Management	20	10	50%	10%	5
TOTAL	57.5				
Green pyramid rating	SILVER				

3.4.14 Results of Assessment and Certification

The result of an assessment will be a Green Pyramid Rating in accordance with the following rating system:

GPRS Certified: 40–49 credits
Silver Pyramid: 50–59 credits
Gold Pyramid: 60–79 credits
Green Pyramid: 80 credits and above
Projects with less than 40 credits will be classed as 'Uncertified'.
The relevant certificate, if attained, will be issued to applicants by HBRC on behalf of the EGBC. Such certificates will be valid for 5 years, after which time a new application for rating may be made under the Green Pyramid Rating System for Existing Buildings. This version of the System is currently in preparation.

3.4.15 Conclusion

Obviously, to deriving a local system, it should be taken in consideration the privacy of the place and the big difference between economics of countries which have the global classification systems and Egypt as a country of the third world, therefore the difference between the technology and the awareness degree of people, and make way for the privacy of the Egyptian experience, and its richness by several natural treatments which reduce the energy consumption and resources and therefore to limit the negative effects of the building on the environment, and in this context the Egyptian pyramid system is considered as the first step to achieve the green architecture concepts in Egypt, and it can be used as a start

3.5 LEED, BREEAM and GPRS comparison

3.5.1 Introduction

With the increasing awareness of sustainable development in the construction industry, implementation of an energy rating procedure to assess buildings is becoming more important. The most representative building environment assessment schemes that are in use today are Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) and Green Pyramid Rating System (GPRS)

The introduction of a system for green building assessment and rating is considered to be one of the cornerstones of promoting sustainable green building development. For example, in 1990 the Building Research Establishment in the UK introduced the (BREEAM) and several years later, the United States Green Building Council launched its LEED system. Many other countries have followed suit. There is increasing evidence from these countries that owners, investors and the public are starting to place a premium on certified green buildings. In response to the need for an Egyptian green building assessment system, and with the benefit of the experiences of early-adopters in other countries, the Housing and Building National Research Center has produced The (GPRS).

A comparison of LEED, BREEAM, and GPRS is summarized in Table (3-20) as follows:

Table (3-20): Comparison Summary between LEED, BREEAM, and GPRS

	BREEAM 2011	**LEED 2009**	**GPRS 2009**
Proprietor	BRE Global Ltd	US Green Building Council	The Egyptian GB Council
BREEAM Schemes / LEED Rating / GPRS Systems	New Construction* Refurbishment Code for Sustainable Homes Communities In-Use (*New Construction assesses the following building types: offices, industrial, retail, data centres, education, healthcare, prisons, law courts, multi-residential institutions, non-residential institutions, assembly & leisure and other).	New Construction and Major Renovations Existing Buildings: Operations & Maintenance Commercial Interiors Core & Shell Schools Retail Healthcare Homes Neighborhood Development	Building in design stage Post-construction stage: Residential buildings Commercial buildings Education Healthcare Neighborhood Communities assembly leisure and other
Rating Classifications	Pass, Good, Very Good, Excellent and Outstanding	Certified, Silver, Gold and Platinum	Certified, silver, gold and green pyramid
Number of Credits	Up to c. 150 credits depending on building type	49 credits	180 credits

Table (3-20): Comparison Summary between LEED, BREEAM, and GPRS continue:

	BREEAM 2011	LEED 2009	GPRS 2009
Minimum Standards	Minimum standards are tiered based on the target rating, eg pertaining to 4 specific credits or criteria for a Pass rating, 6 for Good, 8 for Very Good, 18 for Excellent and 26 for Outstanding	8 prerequisites in addition to the above credits, plus 7 primary Minimum Program Requirements for eligibility which apply across all rating systems (except those adopted pre-2009)	6 mandatory minimum requirements (40 points) the building must satisfy and may obtain credit points by meeting certain criteria.
Credit Weighting	Based on relative environmental impact, reviewed periodically	Based on relative environmental impact and human benefit, reviewed periodically	Based on relative environmental impact and human benefit, reviewed periodically.
Evidence Collation	BREEAM Assessor, design, construction & management teams and Accredited Professional (AP).	Design, construction & management teams and Accredited Professional (AP)	Design, construction & management teams and Accredited Professional (AP)
Assessment / Review	Design Stage & Post-Construction Assessment by trained and licensed BREEAM Assessors	Design & Construction Review by Green Building Certification Institute (GBCI) through network of third party certification bodies	Experts and licensed assessor
Certification	BRE	GBCI	GP certification
QA	BRE & UKAS	USGBC	GBC-Egypt
Availability of information	Pre-Assessment tool and Scheme Manual available free of charge. Technical guidance only available by attending BREEAM Assessor and/or AP training courses run by the BRE.	Tools and public guide can be downloaded free of charge. Reference Guides cost $195 (hardcopy) or $180 (e-book) for each rating system. Further technical guidance available through LEED Green Associate and AP training courses.	Pre-Assessment tool and Scheme Manual available free of charge.

3.5.2 Environmental Assessment Areas

A comparison of the BREEAM Environmental Sections, LEED Environmental Categories, and GPRS categories and their respective weightings is set out in Table (3-21) as follows:

Table (3-21) Comparison of BREEAM, LEED and GPRS Assessment Areas

BREEAM 2011		LEED 2009			GPRS 2009		
Environmental Section	**Max. Weighted % Points**	**Environmental Category**	**Weighting**	**Max. Points**	**Environmental category**	**Max. Weighted % Points**	**Max. points**
Land Use & Ecology	10%	Sustainable Sites	23.6%	26	Sustainable site	15%	10
Water	6%	Water Efficiency	9.1%	10	Water efficiency	30%	50
Energy	19%	Energy & Atmosphere	31.9%	35	Energy efficiency	25%	50
Materials	12.5%	Materials & Resources	12.7%	14	Materials &resources	10%	20
Health & Wellbeing	15%	Indoor Environmental Quality	13.6%	15	Indoor environment	10%	20
Transport	8%	Innovation in Design	5.5%	6	management	10%	20
Waste	7.5%	Regional Priority	3.6%	4	Innovation & added value	Bonus	10
Pollution	10%						
Management	12%						
Innovation (additional)	10%	**Total**	**100%**	**110**			
Total	**110%**				Total	100%	180

3.5.3 Rating Benchmarks and Classification

All methods have a tiered classification structure **as shown in Table (3-22) and table (3-23)** as follows:

Table (3-22): Rating Benchmarks

BREEAM 2011	**% Points**	**LEED 2009**	**Points**	**GPRS 2009**	**Points**
Outstanding	:: 85%	Platinum	:: 80	Green pyramid	::80
Excellent	:: 70%	Gold	60-79	Gold pyramid	60-79
Very Good	:: 55%	Silver	50-59	silver	50-59
Good	:: 45%	Classified	40-49	Certified	40-49
Pass	:: 30%	Unclassified	< 40	Uncertified	< 40
Unclassified	< 30%				

Table (3-23) Approximate Rating Comparisons for a Building Constructed in the UK

BREEAM	LEED	GPRS
Excellent	Platinum	Green pyramid
Very good	Gold	Gold pyramid
Good	Silver	Silver pyramid
Pass	Certified	Certified

Source: Saunders, 2008, Table 3, p.41

3.5.4 Conclusions

Although there is a considerable degree of commonality between BREEAM, GPRS and LEED in terms of their aims, approach and structure, there are significant differences in terms of scope of environmental issues addressed, metrics and performance standards. The LEED certification process is more expensive primarily because its business model is based on a monopoly of supply of assessment.

Although studies indicate that BREEAM's scope is wider and its standards are on the whole more difficult to achieve than LEED's and GPRS's, BREEAM, GPRS and LEED continue to compete and develop against a background of continually improving regulatory standards and dissemination of best practice worldwide.

CHAPTER FOUR

CASE STUDY

CHAPTER FOUR
CASE STUDY

4.1 Introduction

This section include the case study strategy, the different data collection methods, and the green building related items to be analyze in the AASTMT buildings. Also, defining the building information modeling (BIM) process and the purpose of using it, to get a better understanding of the case study problem.

Both quantitative and qualitative methods were applied in this research to collect data from buildings A, B, and GS. Includes field survey, literature review, interviews, workshops, observations, and the use of Building Information Modeling (BIM) for analyses. The buildings were created using Autodesk Revit software for BIM application to utilizes a parametric 3D model for generation plans, sections, elevations, perspectives, details, and schedules.

4.2 Case Study Strategy

This study focused on evaluation of AASTMT building to be oriented towards a green building. A field analyses had been made for the post-occupancy performance and the cost and benefits for the AASTMT building related to the following items:

4.2.1 Energy consumption

-Indoor lighting

Survey of different indoor lighting technologies for artificial lighting options such as fluorescent lamps, fluorescent bulb, spot lights and outdoor lighting, and natural lighting options such windows and, daylight harvesting. Usage feasibility assessment, Cost benefit analyses, and Environmental impacts will also be done.

- Air-conditioning

ASHRAE standard 90.1- 2010 was consulted for regulations and recommendations regarding HVAC. The general aim will be to contrast a baseline economic model of the building, incorporating no or modest green designs, with subsequent additions of green designs according to ASHRAE standards. Recommendations were then made accordingly.

4.2.2Greenhouse gas emissions

Studying the amount of Co_2 gas emissions due to the electricity consumption in the buildings and determining the effect of the application of sustainability practices on it.

4.2.3-Operating cost

Studying cost reduction mechanism according to LEED standards.

4.3 The Case of AASTMT

4.3.1 General project information

AASTMT is considered as an educational organization specialized in science, technology and maritime transport and a subsidiary of the Arab league and it is aiming to education, training, and scientific research. The AASTMT had serviced 20,000 student in 2014.

AASTMT buildings (A, B, and GS) are located in Heliopolis to the North-East of Cairo near Cairo international airport as shown in **Figure 4-1**.

Building (A) consist of five floors with total area 11176 m^2 divided between administrational offices1980 m^2, lecture rooms 4294 m^2, laboratories1412 m^2, cafeterias 650m^2, library 300m^2, bank 120m^2 and corridors 2430 m^2. Building (B) consist of five floors and basement with total area 3894 m^2 divided into administrational offices584 m^2, lecture rooms1947 m^2, laboratories390 m^2, cafeterias97 m^2, and corridors876 m^2 and it is relatively smaller than building (A).Building (GS) is a medium size building includes the graduate school of business, the head office of AASTMT, and the Regional Centre for Disaster Risk Reduction for Training and Research. It consists of five floors and basement with total area 6242 m^2 divided into administrational offices1561 m^2, lecture rooms3121 m^2, cafeteria 312 m^2, and corridors 1248 m^2.

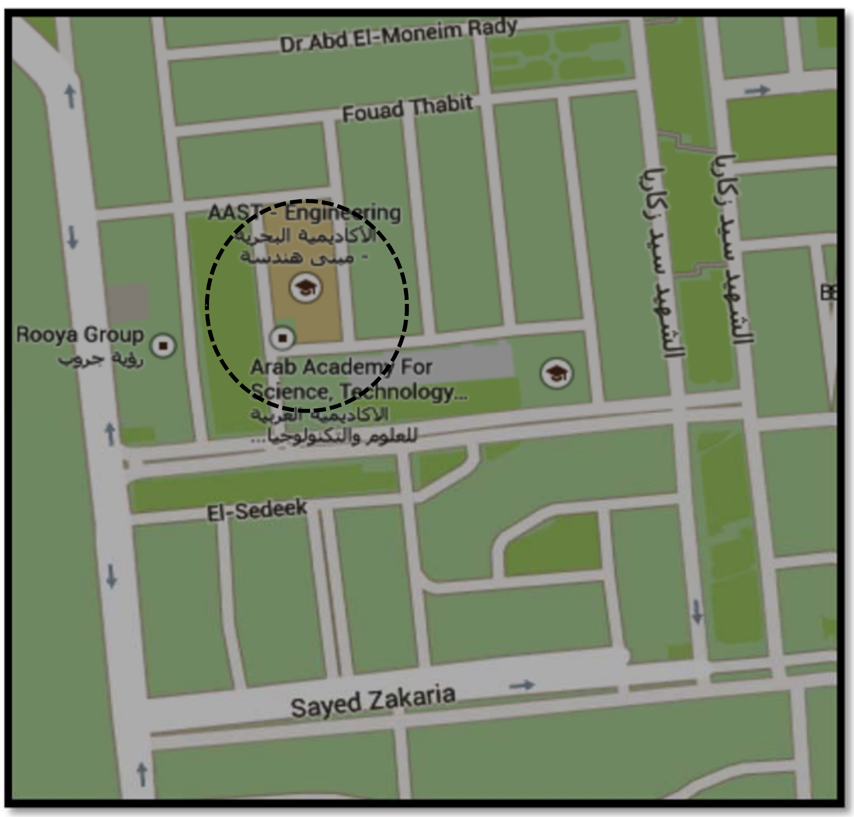

Figure (4-1) satellite photo for AASTMT location

During the Site Visit to the buildings a field survey had been made to collect the data related to the buildings orientation towards green buildings including the electrical component, lighting fixtures, and natural lighting.

The researcher also met with various members of the administration, staff, and student at the buildings to gather information. The following paragraphs describe the information gathered from the Site Visit.

The buildings are at a good state, and there is over use of energy. Insulation is sparse, and energy systems applies some of energy efficiency strategies. Furthermore, the buildings size is suitable as respect to the faculty needs and the number of students. \The indoor environment quality and natural lightening is very good in general. The water quality and the water distribution network inside the buildings is at very good condition.

4.3.2 Case Study Objectives

The objectives of Evaluation of the Arab Academy for Science, Technology &Maritime Transport (AASTMT) Building to be oriented towards a Green Building were:

(1) To identify and research green and sustainable design building features.

(2) To evaluate the applicability of green features in buildings (A, B, and GS).

(3) To conduct a lifecycle cost analyses associated with the implementation of each green feature.

(4)Evaluate how do current policies make use of the key stakeholders in the green building system to encourage the development?

(5) To make preliminary recommendations to the stakeholders regarding the implementation and effectiveness of each green building feature at AASTMT.

4.3.3 Building Information Modeling (BIM)

Building Information Modeling BIM is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. (National BIM Standard - United States) **as shown in Figure 4-2.**

Autodesk Revit software is a BIM application that utilizes a parametric 3D model to generate plans, sections, elevations, perspectives, details, and schedules—all of the necessary instruments to document the design of a building.

Drawings created using Revit are not a collection of 2D lines and shapes that are interpreted to represent a building; they are live views extracted from what is essentially a virtual building model. This model consists of a compilation of intelligent components that contain not only physical attributes but also functional behavior familiar in architectural design, engineering, and construction.

As the Revit program has many helpful advantages, it was decided to utilize them in building a 3-D model for the AASTMT buildings (A, B, and GS) which will result in greater understanding of the case study buildings in pure engineering way. In addition a detailed shoots will help to clarify every part of the building in scientific way.

The program was utilized in survey process throw scheduling features of the Rivet and to calculate the energy consumption also to calculate the natural lighting percentage inside the building.

The usage of BIM is considered a great addition to the study as the case study buildings were described in scientific way rather than photographically which give it a great value from an engineering point of view.**(as shown in Figures 4-3 to 4-8)**

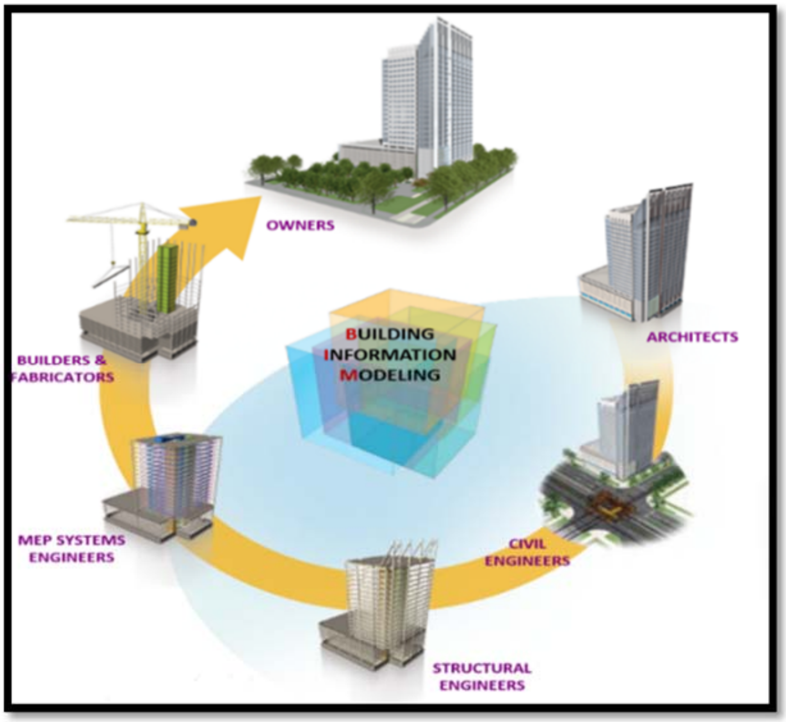

Figure (4-2) BIM process

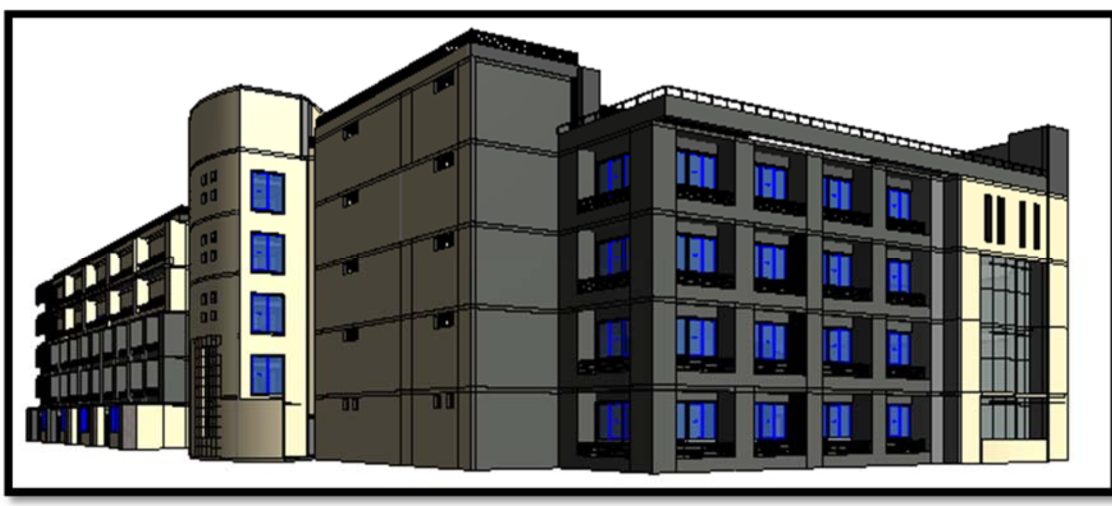

Figure (4-3) building (A) North Side