Comparative Study of Building Environmental Assessment Systems:

Pearl Rating System, LEED and BREEAM

A Case Study Building in Abu Dhabi, United Arab Emirates

مقارنة بين نظم التقييم البيئي للمباني: نظام درجات اللؤلؤ ونظامي

(LEED) و (BREEAM)

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الخلاصة:

إن النمو المتواصل للمدن والتطور السريع لأنماط الحياة ،التأثيرات السلبية على البيئة الطبيعية ورفاهية المجتمعات ، والإشارات المتزايدة لتغيرات المناخ ونفاد الموارد الطبيعية . كل ذلك أعطى ضرورة حيوية لتطوير أنظمة للتقييم البيئي التي تهدف إلى التخفيف من الآثار السلبية للبيئة العمرانية على البيئة الطبيعية دون المساس بجودة أنماط الحياة لدى المجتمعات المحلية.

وتعتبر أنظمة التقييم البيئي واحدة من أهم الحوافز الرئيسية لتطوير صناعة المباني الخضراء، وكلها أظهرت دورا هاما في توجيه صناعة البناء والتشييد, ظهر العديد من هذه التقييمات في العقدين الماضيين ، يعتبر بعضها دوليا مثل (LEED) أو (BREEAM) وبعضها محلي مثل نظام التقييم بدرجات اللؤلؤ (PRS) والمعمول به في إمارة أبوظبي . وعلى الرغم من أن جميع طرق التقييم مشتركة في الاهداف التي يمكن أن تؤدي إلى تصاميم أبنية خضراء ، إلا أنه لا يزال لكل أسلوب قواعده ومعاييره وإجراءاته التنفيذية . وقد أدت هذه الاختلافات إلى ظهور بعض محولات لتقييم هذه الاساليب و بحث مدى نجاحها في تحقيق الصورة متوقعة للمباني الخضراء.

نطاق هذه الدراسة هو عقد مقارنة بين أكثر المخططات الدولية استخداما (LEED) و (BREEAM) وبين نظام التقييم بدرجات اللؤلؤ, و منهجيات البحث المستخدمة هى استعراض للمؤلفات ودراسة حالة ومحاكاة بالكمبيوتر ، هذه المنهجيات ساعدت الباحث على أن يلقي نظرة شاملة على خطط تقييم محددة ويسمح بإجراء المقارنات المطلوبة.

وفي الختام ، وجد أن نظام تقييم اللؤلؤ هو نظام فريد مستقل يجمع بين معظم متطلبات (LEED) و (BREEAM) ، حيث أنه يحتوي على نفس الاستراتيجيات ، و وجد أن نظامي (LEED) واللؤلؤ يعتبر الاكثر تشابها من حيث طرق التطبيق الطلب و الاعتماد ، بينما (BREEAM) أقل في المقارنة ويمثل المخطط الأصعب بين الثلاثة . كما وجد أن الاهتمام بالاستثمار في الطاقة متساويا في المخططات الثلاثة بينما التوفير في المياه يتضح فقط في مخطط اللؤلؤ. إن دراسة الحالة ومراجعة المؤلفات أظهرت أن النظم الثلاثة و حتى في اختلافاتها جميعها أظهرت أثر إيجابي على كل من تصماميم و اداء الانظمة بالمباني ، و اثر ايجابى ايضا على شاغلي المباني و البيئة الطبيعية.

Abstract

The continuous growth of cities, the fast developing lifestyles, the negative impacts on the natural environment and wellbeing of communities ,the increasing signs of climate changing and running out of natural resources. All that gave vital necessity for developing environmental assessment schemes that aims to mitigate the negative impacts of our built environment on the natural environment without compromising the quality of the lifestyles of the communities.

Environmental Assessment Schemes are considered to be one of the main catalysts for the generation and development of the industry green buildings. Varies Schemes had appeared in the last two decades, part of them considered to be international such as LEED or BREEAM and some local such Esitdama Pearl Rating systems (PRS) of the Emirate of Abu Dhabi, all had shown an important role in guiding the construction industry.

Although almost all of the assessment methods share goals that can lead to; green building design and construction or improving the performance of existing conventional buildings, still every method has its own structure, certification process and weighting criteria. These differences led to the generation of multiple questions such as which assessment schemes succeeded more in the anticipated image of a green building.

The scope of this study is to compare two of the most representative international schemes which are LEED and BREEAM against the PRS. The aim is to benchmark the performance of buildings developed under the PRS against international level schemes.

The used methodology for the research is literature review, case study and computer simulation, these methodologies helped the researcher to have a comprehensive look on a selected assessment schemes and allowed to make the required comparisons.

In conclusion, it was found that PRS is standalone system that combines most of LEED and BREEAM schemes, and that they have big overall laps in terms of sustainability strategies but from an application and certification levels side, LEED and PRS are more comparable especially in the higher certification levels while BREEAM is less comparable and presents the hardest scheme of the three to score under.

It was also found that investment in energy related credits has the mose significant impact in all the three schemes while water credit only impacts PRS.

The study of the literature review and the case study had showed that the three environmental assessment schemes even with its differences; all showed in overall a definite positive impact on the building design, performance, a positive impact on the occupants of the rated buildings and positive impact on the environment.

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Introduction

1.1 INTRODUCTION

For decades, green movements and environmental scientists have been working on showing the world the necessity of giving proper attention to the environment and the natural fortune. They explained the expected problems which may happen in the near future if we continued to survive with our current life styles. These environmental problems became famous to the general public as a synonyms to a phenomenon known as "climate change", it was defined by the United Nations Framework Convention on Climate Change (UNFCCC, 1992) as " a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.".

Due to climate change, scientists have warned of severe consequences on earth such as an expected high frequency appearances of natural disasters such as Earth quakes, Tsunamis and Floods which all took place. When these events started to take place as anticipated, it showed the world the nature and scale of what may happen in future and the importance of reconsidering their actions and life styles. In spite of these appearances of natural disasters, still majority of world leaders did not guide their countries towards solving the problem until another factor came in the equation which is the energy then the economical crisis. The record breaking prices of energy where a barrel of brent oil has reached more than 140 dollars (BBC News,11 July 2008), after it was less than 20 dollars in the 90s (OPEC, 2011), this had made a clear statement to the world that our current rate of energy consumption is not going to be sustainable not only for the saving the planet but also for saving the economies world and that gave a big momentum to the green movements.

In another look to the last decade, it didn't only bring the energy market into focus but also brought some other markets such as Water and Food. The three markets had an established importance throughout history, but lately the importance has growing to alarming levels where severe clashes between demand and supply had started to take place. The pace of development of the world economy especially that of the developed countries has encouraged them to excessively consume these markets in an unsustainable manner, that led the prices of the products to increase. This increase in the food prices on the other hand had maximized problems for the poor side of the world countries whom already are finding difficulties in having any growth in their economies as they are trying just respond to the local needs of their communities with its limited recourses and low income. And with high levels of corruption in these countries, their poor communities were most negatively impacted due to this economical crisis. Some argues that economical crisis will help to eased down the record breaking prices of oil and food supplies, then pressures on begin more sustainable for the world leaders will be less, this may be true, but as the wheel of economy starts to move again, problems will start to show up again, simply because what's happing is not sustainable. Clashes of demand and supply for the markets of (energy, water and food) have global consequences, where a high consumption of resources can occur in one part of the world but the negative effects may appear in other areas and mainly in the poor countries.

In 2011, multiple incidents took place around the world that can potentially be related in a direct and indirect way to our current un-sustainable lifestyles from all the sides "economical, social and environmental", where Clashes of markets of Food, Water and energy appeared severely in places such as shortage in water and food supplies in the Horn of Africa which lead the region to starvation, where according to the BBC News channel (2011) was recorded as the "Worst Drought in 60 years". As well as the wave of social revolts that hit most of the Middle East where the people demanded better living conditions. "High resources consuming" life style of the communities of the developed countries are so far blamed as the sources of the majority of the current global problems and tensions.

Misconception

Communities around the globe seem to have a theory that exaggerated use of resources will lead to an increased level of satisfaction. The New Economic Foundation (NEF) had tried to find a correlation on this issue. It had conducted a study Fig. 1.1 that shows the ecological foot print per captia around the world, and conducted another study Fig. 1.2 that shows the life satisfaction, from observing these two figures, it seems that there is a true correlation between increasing the life satisfaction with the ecological footprint, however there is a point where increasing the footprint will not have any more increase in the happiness index. This means that there is a point where resources consumption becomes a habit rather than a tool for increasing happiness for communities.

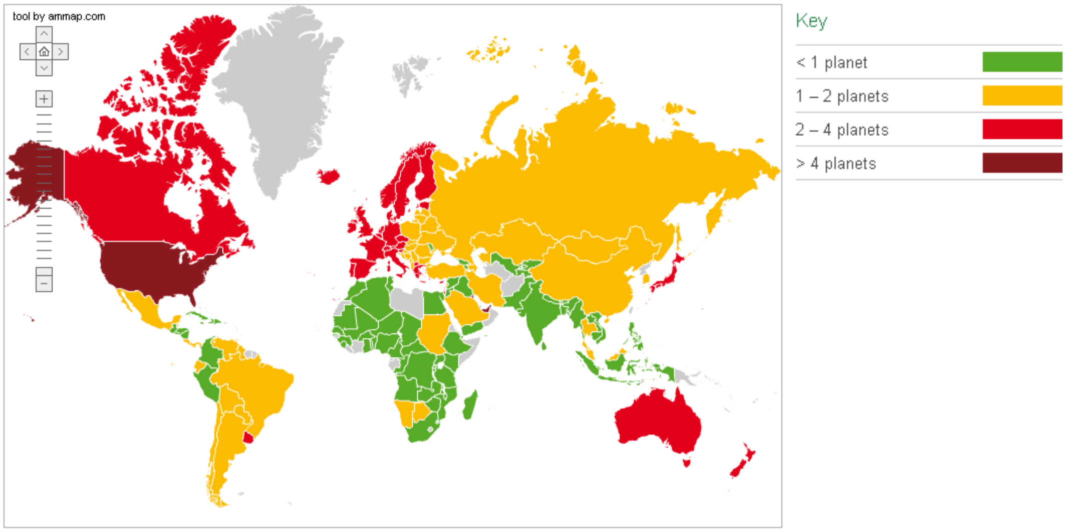

Figure 1.1 the ecological footprint per capita (NEF, 2005)

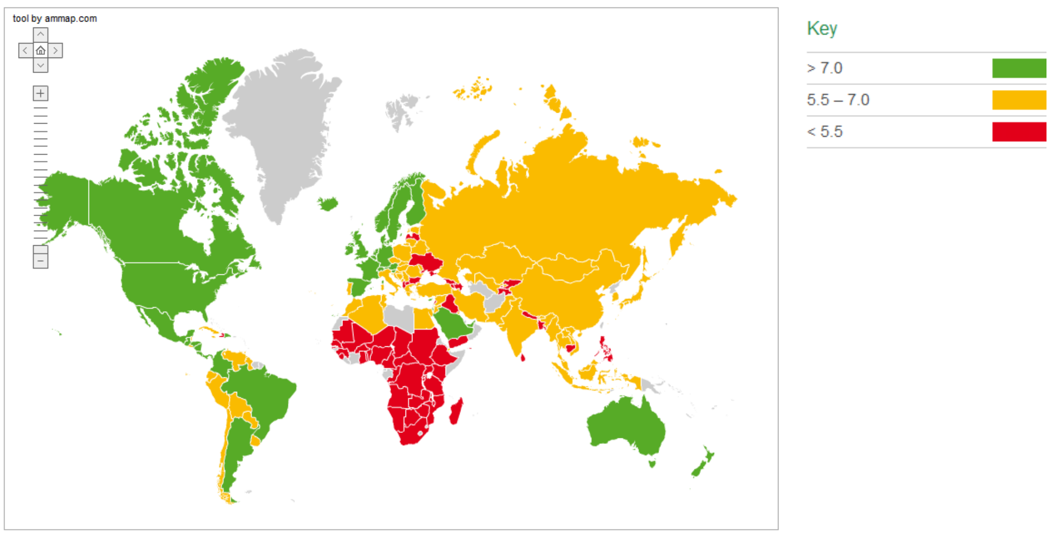

Figure 1.2 Life Satisfaction levels (NEF, 2005)

As the negative impacts of a "High resources consuming" lifestyles will continue to appear in the poor side of the world, new big emerging markets such as India and China are coming in to the picture and will enlarge the scale of the problems by continuing to follow the path of the developed countries in their rate of consumption of resources and refusing to present a different sustainable example.

It's now expected worldwide that in the near future there will be shortage in multiple materials, water and energy, in addition to the impacts climate change. In this context issue and before the end of 2011, World Summit on Climate Change was held in Durban, South Africa, and highlight that there is an issue of how the world is reacting to the global climate challenges and highlighted that still there is no solid agreement on how to combat it and urged the necessity of finalizing this long awaited agreement on cutting down emissions.

Historically these world summits on climate change were not much successful. On one hand developing countries always highlights that they are not responsible for the current global problems especially the environmental ones and demands more commitment from the developed world in absorbing their carbon footprints which they are responsible for. On the other hand developed countries such as USA and China, agrees with this concept but refuses to commit under any agreement. To tackle this disagreement and to increase cooperation, UNFCC had developed multiple mechanisms under Kyoto protocol that will help developed countries meet their target carbon emission either through direct national reduction or by help a developing country to develop in a sustainable way, these mechanisms is named Clean Development Mechanisms (CDM), the main aim of these mechanism are:

- Stimulate sustainable development through technology transfer and investment
- Help countries with Kyoto commitments to meet their targets by reducing emissions or removing carbon from the atmosphere in other countries in a cost-effective way
- Encourage the private sector and developing countries to contribute to emission reduction efforts

Late in 2011, a BBC report on the world summit on climate change had shown that still the developing countries are increasingly not appreciating the role of the developed countries in cutting their carbon emissions and showed a concern that a worldwide agreement seems to be very hard at this point, and as declared by the Alliance of Small Island States (AOSIS) when describing what’s happening right now between the world countries that its "reckless and irresponsible" from the world.

1.2 Sustainability

Initiatives have been taken around the world in order to guide the communities to have more sustainable life styles to protect their future. Sustainability in it self has different definitions which changes with its context, but in general it can be defined as "a system or process is sustainable if it can be continued indefinitely, without depleting any of the material or energy resources required to keep it running" (Wright, 2011). Different official declaration had been made worldwide to define the components of sustainability; at the 2005 World Summit it stated that the three pillars of Sustainability are "Economy, society and Environment". In Abu Dhabi, UAE the country of the case study, the authorities' define sustainability with four pillars by adding "culture" to the other three mentioned in the World Summit. This direction and care from Abu Dhabi government about its not cultural heritage was clear in the Abu Dhabi 2030 development plan, where Abu Dhabi Gov. had stated in the report that it believes that cultural identity is something that could not be compromised to achieve the other three pillars of "Economy, Society and Environment", and that if there is no careful equal attention had been given to all the pillars, there is a great possibility that whatever happening won't be sustainable.

Sustainable Development

To celebrate our present and prepare for the future, world leaders and their communities have aimed to achieve a development which is Sustainable, the term "Sustainable Development" appeared to be the keyword of the current era. This term was first used by the World Commission on Environment and Development (WCED) which is a group formed by the United Nations (UN), it has defined sustainable development as what "meets the needs of the present without compromising the ability of future generations to meet their own needs".

Natural Environment

In order to have a Sustainable future, Countries around the world agreed on the importance of continuing developing their communities while protecting the real fortune of the planet earth "the Natural Environment" which is defined as " all the natural surroundings that grow naturally without the involvement of human begins; it is created as balanced and sustainable System for the humans so they can benefit from." (Wright 2011). Ignoring the effect of our activities on the environment may result with severe impacts such as Air Pollution, Water pollution, Climate change, depletion of resources.

Built Environment

The ways we plan our cities, neighborhoods and build our building contributes to our daily lifestyles and affect things like how we work and how we use our recourses. The shaping of our life styles happens due to multiple factors such as "Economical, Political, Social, Cultural and Environmental" and it's only in the hands of people the will to change life styles to be more sustainable. The built environment is one of the major contributors to the quality of life of people and at the same time it has a major impact on the natural environment if not planned properly.

1.3 Efforts around the world to be more sustainable

In the 1992 Earth Summit, Rio de Janeiro, countries of the world met for the first time to discuss the international cooperation on development and environmental issues, they met with an understanding of the global nature of these issues and "Recognizing that no nation could resolve global problems on their own, those attending the Summit signed agreements on international cooperation for tackling development and environment concerns" (Fien and Tilbury, 2002), the agreement aimed to find ways to fight problems such as “the perpetuation of disparity between and within nations, a worsening of poverty, hunger, ill health and illiteracy and a continuing deterioration of the ecosystem on which we depend for our wellbeing, and agenda 21 “a global partnership for sustainable development” (UNESCO, 1992).

Although world countries had agreed on some guidelines, still every country had to formulate its own plan based on its local conditions, therefore Countries had responded to its environmental, social and economical problems differently; however there seem to be two approaches in guiding the communities into a sustainable future. The two approaches are educating the community and the other is controlling their actions.

1.3.1 Educating the community

Education is one of the main tools that are used to guide people into sustainability .In The 1980 World Conservation Strategy had stated the important role of education and argued that:

> *A new ethic, embracing plants and animals as well as people is required for human societies to live in harmony with the natural world on which they depend for survival and well-being. The long-term task of environmental education is to foster or reinforce attitudes and behaviors compatible with this new ethic.*

(IUCN, UNEP & WWF 1980, sect. 13)

In Rio world Summit in 1992, among the signed agreements was (Agenda 21) "through which countries committed themselves to promoting sustainability through a great variety of means, including education." (Fien & Tilbury 2002).

Due to that clear importance of education, the United Nations (UN) in 2002 declared a decade for education of sustainable development from 2005 to 2014 where the United Nations Educational, Scientist and Cultural Organization (UNESCO) will take the lead in it.

And in their book, Tilbury et al. (2002) had showed that Several Countries around the globe "Developed and Developing Countries" had already developed educational initiatives with specific and general nature such as:

1. Australia: *The Australian Government action plan for education for sustainability*.

This is considered to be a general initiative aimed at all people, where it prepared a plan for education of sustainability that included 4 strategies:

- Strategy 1: Demonstrating Australian Government leadership
- Strategy 2: Reorienting educational systems to sustainability
- Strategy 3: Fostering sustainability in business and industry
- Strategy 4: Harnessing community spirit to act

The Australian government tried to diversify the sources of education in order to be able to reach most of its communities through schools, legislations, business and community lectures.

2. India: *The education for sustainability for the central Himalayas*.

In this initiative, the Indian government found specific problems such as (loss of biodiversity, soil erosion, water sacristy and excessive use of timber from forests then turning it in to reserved areas preventing the people from entering it) and with the population growth, the demand increased on wood, food and water. It was felt that an educational intervention is required to change the people attitude towards their village; the intervention was through local Non governmental Organization and formal schools. The project team concluded that the most important success was the emerge of "several groups and individuals who are active in environmental issues and who therefore can act as agents of change in the villages and schools" (Pande, 2002)

1.3.2 Improving the built Environment

The second approach is reshaping and upgrading the built environment to be more environmentally responsive, hoping that this reshaping will inspire people to have a more sustainable life “We shape our buildings, then our buildings shape us” (Churchill, 1943).

1.3.2.1 Negative Effects of buildings on the environment:

We need buildings in our daily life; not only as a shelter but also as the controlled environments we create to suite our different activities. Buildings allow us to things that are not related to existing natural conditions, we can go skiing in the middle of the desert, we can plant tropical vegetables in the North Pole, and whatever human beings can imagine doing can be done through buildings. It’s considered as a mirror for the life styles and degree of development of communities. The argument now is the negative impacts of buildings construction in an irresponsible way on the environment such as:

Energy Consumption

In the US, buildings are responsible for consuming 30% of the total energy and 60% of the electricity annually (LEED, 2009) and as per Environmental Protection Agency (EPA) (2011) “36 percent of total energy use and 65 percent of electricity consumption, and are responsible of 40% of the energy consumption in Europe (European Commission, 2011). Energy use is divided where the construction process consumes around 20 % and the operation 80% of the total energy (UNEP, 2007).

Green House Gases GHG Emissions

Buildings participate by a big share in the greenhouse gases emissions whereas per EPA (2011) Buildings contribute to 30 percent of greenhouse gas emissions to the atmosphere where as per LEED (2009) “About ¼ of the increase in carbon dioxide is due to the building sector” and as “The EPA estimates, the use of energy efficient lighting alone would be the equivalent of getting 15 million cars off the road in terms of carbon dioxide reduction.” (LEED, 2009).

Water Consumption

Buildings and built environment consumes 12 percent of potable water consumption EPA (2011), this excessive water consumption is due to the use of items such as inefficient fixtures. Whereas per LEED (2009) “Buildings consume 5 billion gallons of potable water per day to flush toilets” and leaks with the system plumbing building may lead to loss of a big amount of pure water.

1.3.2.2 The benefits of green and sustainable buildings

As per EPA (2011) Green Buildings (GB) are “the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition “. As per LEED (2009) GB proved to have multiple benefits such as;

Environmental benefits

It can reduce or eliminate environmental effects such as (waste generation, air and water pollution, heat islands, Enhance and protect biodiversity and ecosystems, reduce storm water runoff , conserve green land and reduce noise generation) through high performance & market leading designs. GBs also reduces the energy and water consumption where electricity and water can be reduced by 60 % (Estidama PRS, 2011)

Economic benefits

GB can mainly reduce operational costs, increase the lifetime of the building systems through proper maintenance and training of facility management teams, also increasing marketability of buildings as it will have less operational costs and will be recognized in the market through certification by its high efficient and ecofriendly performance, improve employees’ productivity and Optimize life-cycle economic performance. (EPA, 2011)

Social benefits

GBs in general seems to present a better working and living space for its occupants than conventional buildings, where as per Abbaszadeh et al. (2006) occupants in green buildings are more satisfied with thermal comfort and air quality in their workspace, he highlight some features that helps the occupant satisfaction in green buildings such as "improving ventilation, removing indoor pollutants, using green materials, giving occupants personal control over operable windows, task air-conditioning, or under floor air distribution systems, employing daylight, and reducing ambient light levels by using task lighting".

1.4 Approaches of improving the built environment

In order to upgrade the built environment, initiatives had been taken to guide the new and existing buildings stock towards more responsible practices. Three approaches had been adopted by the world (Legislations, voluntary and Incentives and mixed).

1.4.1 Improving the Built Environment through law enforcement

This approach aims to control the built environment through legislations. Municipalities enforce set of rules to be followed as minimum requirements in order to issue a building permit.

Dubai has implemented this approach since 2007 when it issued a resolution that "all owners of residential and commercial buildings and properties in the emirate of Dubai must comply with the internationally recognized environment friendly specifications to turn Dubai into a healthy city that meets the demands of best practices and benchmarks of pollution-free sustainable development. " The Emirates News Agency (2007). This approach was somehow appropriate for Dubai as most of the professionals there already have the capabilities and knowhow of creating more sustainable buildings and was only missing the will. The construction industry in Dubai is market driven, owners and investors in some cases were caring only about the initial costs and were willing to do cost cuts in the budgets even by avoiding sustainable or green features which may have a high initial cost but lower operational cost. In Dubai case the market was ready for being greener but just needed the spark and the will, that's what the resolution of green buildings has made. It had leaded the construction market of Dubai to transform its operations and produce more green products in a relatively short period of time.

In some other parts of the world this approach has been also adopted, in the US several federal initiatives had been implemented mandating having LEED certified buildings. On the states level, States such as Arizona, California and District of Columbia, all had mandated that new or renovated state owned buildings to be built on minimum LEED certified and in some cases minimum LEED Silver (USGBC Website, 2012)

1.4.2 Improving the Built Environment through voluntary and incentives schemes

The second approach is a total voluntary with incentives scheme, in this approach the municipalities depend only on the will of the community on going green and award their behavior with incentives. This approach seemed to be successful in highly environmental aware communities rather than others.

Germany is one of the countries which used this approach through initiatives such as "The German Renewable Energy Sources Act" (EEG) which came into effect in 2000, in this initiative "Both private and institutional investors in photovoltaic systems receive a guaranteed remuneration (feed-in tariff) for solar electricity fed into the public grid. " Singapore also had adopted the same approach whereas per the green business times (2011) “several funding and incentive schemes related to energy efficiency, clean energy, green buildings, water and environmental technologies, green transport, waste minimization, environmental management system, environmental initiatives, clean development mechanism, and green IT”. Also the Australian Government had developed multiple initiatives for the use of solar and renewable energies which has incentives schemes through grants and funds included inside these initiatives (Australian Government, department of climate change and energy efficiency, 2012), similar to that in other countries such as UK, Spain and the US.

1.4.3 Improving the Built Environment by a mixed approaches

The third approach is the mixed approach, where municipalities make a mandatory minimum level then a voluntary higher scheme. Abu Dhabi is one of those who used this kind of approach to direct its construction industry. USA is another example for that system but on the state level and not on a federal level (USGBC Website, 2012)

The three schemes are acceptable but which one is more successful is still not clear as it depends on the readiness, specifics of each community and how they will react to the new sets of environmental codes.

1.5 The Rise of Environmental Assessment Schemes

In order to meet the demands of going green, and since green building definition is very wide and can accept multiple interpretations, a need of assessment schemes that demonstrates a commitment to sustainability and measured by a third parties had immerged. As per Poveda (2011) the main role of assessment schemes is to “make a progress towards a purpose”, as shown in Fig. 1.3 environmental assessment schemes are meant to be an upgrade and higher standard compared to the local regulations. These schemes started to appear early in the 90s as a tool for a systematic upgrading for the built environment.

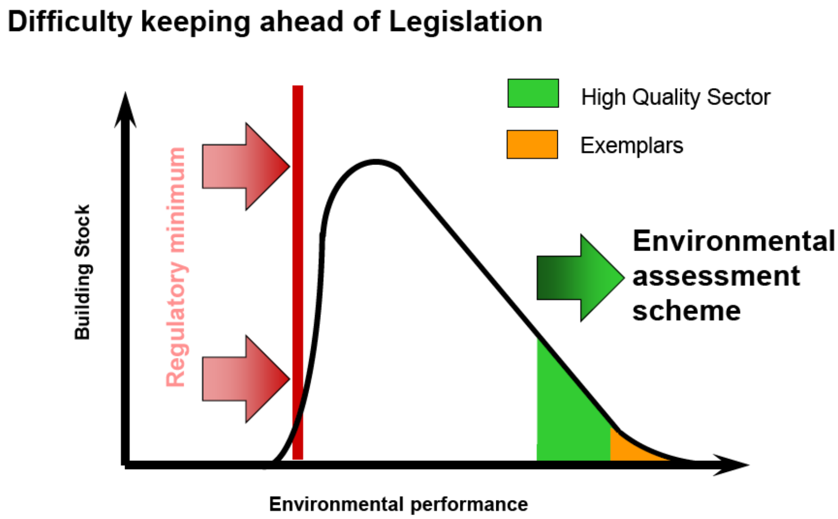

Figure 1.3 a graph showing how would be a relation between an Environmental Assessment Scheme and the regulatory minimum (BRE 2011)

The first Environmental assessment scheme of buildings was developed by the British Research Establishment (BRE) in 1990 which was BREEAM. (Lee, 2012)

And as per Inbuilt report comparing LEED and BREEAM (2010):" In order for any scheme to retain value, it should be hard to achieve", so as shown in Fig. (1.3), most of the schemes are designed as a step further than local legislations.

Types of Environmental Assessment Schemes.

In his research paper, Pavoda (2011) classified environmental assessment schemes in to the following categories:

1. Environmental, Social and Economic Impact Analysis

Environmental Impact Analysis main aim is to assess the physical and social issues related to the projects and to inform the stakeholders the environmental, social and economical implications before proceedings with their decisions.

2. Strategic Environmental Assessments (SEA)

This is similar to Environmental Impact Assessments (EIA), the only difference is that EIA is on project level, while SEA is on a higher level of assessment for policies, plans, and programmes (PPP).

3. Cost-Benefit Analysis (CBA)

As it's stated in its name, this assessment is concerned with the cost and benefits of a specific project and is meant to be applied in the early stages to determine the viability of specific project.

4. Travel Cost Theory

Which as per Pavoda (2011) this theory "estimates economic use values related to sites or ecosystems used for recreation" and "measures people's willingness to pay to visit the site, based on the number of trips that they make at different travel costs."

5. Community Impact Evaluation

It presents an adaptation of cost-benefit analysis (CBA) for urban and regional planning, in addition to providing the total costs and benefits of projects.

6. Contingent Valuation Method (CVM)

This assessment method considers "For environmental improvements, CVM considers willingness to pay. For reduction in environmental quality, it assesses willingness to accept." (Pavoda, 2011)

7. Hedonic Pricing Method

This method is used to estimate the economical value of ecosystems and environmental services; it was developed by Rosen (1974) and was based on Lancaster's consumer theory (1966).

8. Multi-Criteria Analysis (MCA)

Similar to CBA method but weights impacts in non monetary terms.

9. Material Intensity Per Service Unit (MIPS)

It relates the amount of materials moved or extracted to specific provided service.

10. Analytic Network Process (ANP)

It's a multi criteria analysis that consists of "clusters, elements, interrelationships between clusters, and interrelationships between elements" that helps in decision making processes. (Pavoda, 2011)

11. Life Cycle Assessment (LCA)

This assessment examines a "product or service throughout its life cycle to assess its environmental impacts". (Pavoda, 2011)

12. Sustainability/Environmental Rating Systems

This type of assessment is focus of this study, these systems was designed to assess different aspect of building construction industry from a social, economical and environmental point of view through an integrative approach between all the design teams, contractor and stakeholders related to a specific project.

Benefits of Environmental Rating systems

Assessment schemes are like building codes but performance based and depends on the voluntary choices of the design teams with minor mandatory requirements, it gives only the needed guidance to the industry professionals on how to make buildings green with different standards and benchmarks such as (Energy and Water conservation, Indoor Environmental quality and eco-friendly materials selection), it also gives the end users the assurance by a third party qualified professionals review and certification.

Disadvantages of Environmental Rating Systems

Mainly it was about time and cost of applying these schemes. Some arguments had been made about the necessity of following Environmental assessment schemes such as the famous Architect Frank Gehry who raised a concern when commenting on one of his public speeches on 2010 about "LEED" which is one of the famous assessment schemes by saying that "its just waste of time and money", but in a later commentary on the same topic he clarified that he respects LEED but he just did not want it to turn into an obsession. Increase in the initial cost of buildings is somehow true due to the extra consultant fees plus fixation of high performance fixtures and equipments and to achieve a high performance rated building the initial cost of the building is expected to increase 12 to 14% (Abu Dhabi Urban Planning Council AD UPC, 2010).

1.6 User appreciation and market awareness.

The construction market readiness for accepting environmental assessment schemes as an extra set of green specifications and the end user appreciation for its importance are key issues in deciding which approach from the three above mentioned approaches to follow. A voluntary with incentives assessment schemes can suit a good educated community with high educated industry professional while a less educated community would fit more in a scheme with mandatory minimum simple sets of instructions.

Having a green sustainable built environment may have some extra initial cost, that is the main perception for the end users and market professional about green buildings and that is the main reason why having a green building is not so popular without an incentive or a mandatory scheme. The awareness of the Users and market stakeholders must be raised to a level of knowledge where the benefits of a green sustainable built environment are more clear, and that its green buildings benefits are beyond the initial cost and that its real value comes in the operational and lifetime expenses.

Sustainability is not about the saving the environment only, the communities appreciate the real value of it and to understand that having a sustainable green building will not only have a positive environmental impact but also economical, social and cultural impacts on their lives.

1.7 Significance of the study

This study will present a literature review for some of the current available environmental schemes around the globe, it will provide the professionals related to the construction industry and other who are interested in green buildings development necessary information such as: a glance on the creation of environmental schemes, how they got developed and how they are currently performing in the market worldwide and especially in Abu Dhabi.

The main focus of the study is the local assessment scheme of Abu Dhabi which is Pearl Rating system and will aim to benchmark it by an overall comparative analysis against two of the most well established schemes worldwide which are LEED of US and BREEAM of UK. By comparing and relating the Pearls system to these schemes, the study will help relating the Pearl Rating Scheme and its buildings with a wider scale of opportunities of being certified and recognized world wide as a high efficient green building and not only in Abu Dhabi.

1.8 Dissertation outline

The dissertation is divided into 6 Chapters plus conclusion.

The first chapter is an introduction about the reasons behind the appearance of environmental assessment schemes and how it got developed. The second chapter focuses on providing literature review on the scientific work on assessment schemes in general, how it performs and relates to each other. Then the third chapter reviews and evaluates the methodologies used in comparing assessment schemes and then justifies the methods to be used in this study. These first three chapters provides a basis and the background knowledge required to perform the comparative analysis of three assessment scheme using a case study building in Abu Dhabi which will be explained in the following three chapters.

Chapter 4 introduces the case study building by providing necessary information such as its location, design, parameters, modeling software, etc. The first actual assessment is conducted in Chapter 5 and then is followed chapter 6 which includes the suggested upgrades to achieve highest performance levels in the rating scheme.

The last chapter is 7 and represents a conclusion for the study and whether or no it succeeded to fulfill its objectives.

Chapter 2

Literature Review

2.1 Literature Review Introduction

The Review is divided in to two parts, the first part is reviewing the three rating schemes which are in focus and the scientific work done around the build up of these systems, the second part is reviewing the scientific work done measuring and evaluating the effectiveness of the these three rating schemes.

A wide research work had been done around the world on Environmental Assessment schemes on sole basis; it was found that the majority of the available papers are mainly focusing on the US LEED rating system and British BREEAM rating system. (LEED) stands for Leadership in Energy and Environmental Design, and (BREEAM) stands for British Research Establishment Environmental Assessment Method. Very limited research work has been found on Estidama PRS probably because it's a relatively new rating system summary for the previous science work for Environmental assessment. It was found the majority of papers who are testing or comparing a local assessment or rating scheme use LEED and BREEAM as a benchmark.

Rich and diverse research work on LEED / BREEAM was reviewed but a very limited research work had been found comparing rating systems towards each others, however the topic of reviewing LEED, BREEAM and Estidama PRS.

2.2 Estidama Pearl Rating System (PRS) vs LEED and BREEAM

LEED and BREEAM schemes where chosen to be compared against Estidama PRS for two reasons, the first reason was as per Roderick (2009) that LEED and BREEAM are "The most representative building environment assessment schemes that are in use today", the second reason that they have been in operation for more than a decade for LEED (LEED Reference Guide, 2009) and 2 decades for BREEAM and already have successful buildings built according to their standards (BREEAM Technical Manual,2011).

These two schemes are widely spread and accepted around the world as international schemes due to their " wide coverage of the environmental issues; the range of building types that are covered; and the significant difference in scope and assessment criteria between schemes" (Lee and Burnett, 2008). In order to be able to compare the three schemes towards one another it was important first to review (definitions and background, aims and objectives, contents, Certification process) as a first step then reviewing the product of these schemes by comparing (energy performance, water saving, Indoor environmental quality) and its impact on cost.

2.3 Background

<u>LEED</u>

(LEED) is an environmental assessment scheme that had been developed by United States Green Building Council (USGBC) and established on 2000, LEED provides" building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions"(USGBC, 2011). As per the Green Building Certification Institute (GBCI), LEED has grown to cover more than 8,000 buildings on the US alone and more than 650 buildings outside the US (GBCI, 2011) due to its easiness and the good marketing approach by USGBC. LEED had been used also as a reference for other newer local or regional ratings schemes such as "LEED India, or Estidama of Abu Dhabi".

LEED has several rating systems as per the development scale and use, it consists so far of; New Construction (NC), Existing Buildings: Operations & Maintenance (EB: O&M), Commercial Interiors (CI), Core & Shell (CS), Schools (SCH), Retail, Healthcare (HC), Homes, Neighborhood Development (ND). This Research will be studying in detail the LEED for New Construction and will be referred to as LEED NC.

<u>BREEAM</u>

The other competing assessment scheme is BREEAM; which was developed the British Research Establishment (BRE), this scheme is based in UK, operated by BREEAM UK and was established before LEED in 1990. It's defined as the assessment method which “sets the standard for best practice in sustainable building design, construction and operation" (BREEAM, 2011). In 21 years BREEAM had grown to cover " 200,000 buildings with certified BREEAM assessment ratings and over a million registered for assessment since it was first launched in 1990" (BREEAM, 2011).

BREEAM has different rating systems based on the location and building type including; BREEAM New Construction, BREEAM Communities, BREEAM In-Use and BREEAM EcoHomes. in this paper will be reviewing BREEAM New Construction 2011.

PRS

In the growth plan of Abu Dhabi 2030 for the Emirate of Abu Dhabi, the government had established a vision that sustainability must be the foundation of any development in the emirate of Abu Dhabi and therefore they established "Estidama" which is the Arabic word for "sustainability". One of the Estidama key initiatives is Pearl Rating System (PRS) which was designed in such a way that combined components of LEED and BREEAM and transformed it into a more localized code that can be implemented in Abu Dhabi. As per PRS reference book (2010), the PRS system is a "design guidance and detailed requirements for rating a project’s potential performance in relation to the four pillars of Estidama.",

This Rating system has three versions to cover three types of developments (Villas, Buildings and Community) with more rating systems to be released in future such as the system which covers the Operation and maintenance (Estidama, 2011), the Pearl Building Rating System (PBRS) will be the system in focus in this study.

2.4 The Creation of PRS, LEED and BREEAM

The aim of LEED as stated by the USGBC was creating a system that can "define and measure “green buildings.” (LEED, 2009), and a system that can provide a "healthful, durable, affordable, and environmentally sound practices in building design and construction".

LEED Objectives are:

- To define green building by establishing standards of measurement.
- Promoting integrated design practices.
- Recognizing environmental leadership in building industry.
- To increase the awareness among customers by specifying the benefits of green building.

BREEAM also has been very clear in stating its aims as: "To mitigate the life cycle impacts of buildings on the environment, to enable buildings to be recognized according to their environmental benefits, to provide a credible environmental label for buildings, to stimulate demand for sustainable buildings", and the objectives are:

- To provide market recognition of buildings with a low environmental impact.

- To ensure best environmental practice is incorporated in building planning, design, construction and operation.
- To define a robust, cost-effective performance standard surpassing that required by regulations.
- To challenge the market to provide innovative, cost effective solutions that minimizes the environmental impact of building.
- To raise the awareness amongst owners, occupants, designers and operators of the benefits of buildings with a reduced life cycle impact on the environment.
- To allow organizations to demonstrate progress towards corporate environmental objectives. (BREEAM NC, 2011).

The aim of PRS is "to address the sustainability of a given development throughout its lifecycle from design through construction to operation.", and its objectives are:

- Mitigating the negative impacts of buildings on the environment.
- Providing healthy high performance buildings.
- Increasing the awareness of the end users and construction market in Abu Dhabi.
- Providing credible "local" environmental label for buildings.

2.5 Certification Process

Elgendy (2010) describes Pearls systems as a “hybrid between BREEAM and LEED”. In BREEAM, it depends on using assessors trained under a United Kingdom Accreditation Service (UKAS) in an accredited competent person scheme (BREEAM, 2011). LEED doesn’t have an intermediate assessor and depends on a web based online system where “project teams can manage project details, complete documentation requirements for LEED credits and prerequisites, upload supporting files, submit applications for review, receive reviewer feedback, and ultimately earn LEED certification” (USGBC, 2011), this online system of LEED as per Elgendy (2010) may “reduces interaction and dialogue between building professionals and the USGBC to a minimum” which may be a downside. LEED had planned to overcome this by encouraging the involvement of a LEED Accredited Professional (AP) within the design team where projects will be awarded one point if there is a LEED AP onboard, this AP will guide the team through the certification process. Pearls system aimed to combine the merits of the two systems by having both a dedicated competent assessor who reviews the project and a mandatory Pearl Qualified Professional (PQP) within the design team.

Estidama Pearls Rating System

Different than LEED and BREEAM, pearls system was designed to be an integral part of the local building regulations of Abu Dhabi, therefore as shown in fig. 2.1 the certification will be issued from the government (Abu Dhabi Municipality ADM is responsible for 1 pearls projects, and Urban Planning council for 2-5 pearls).

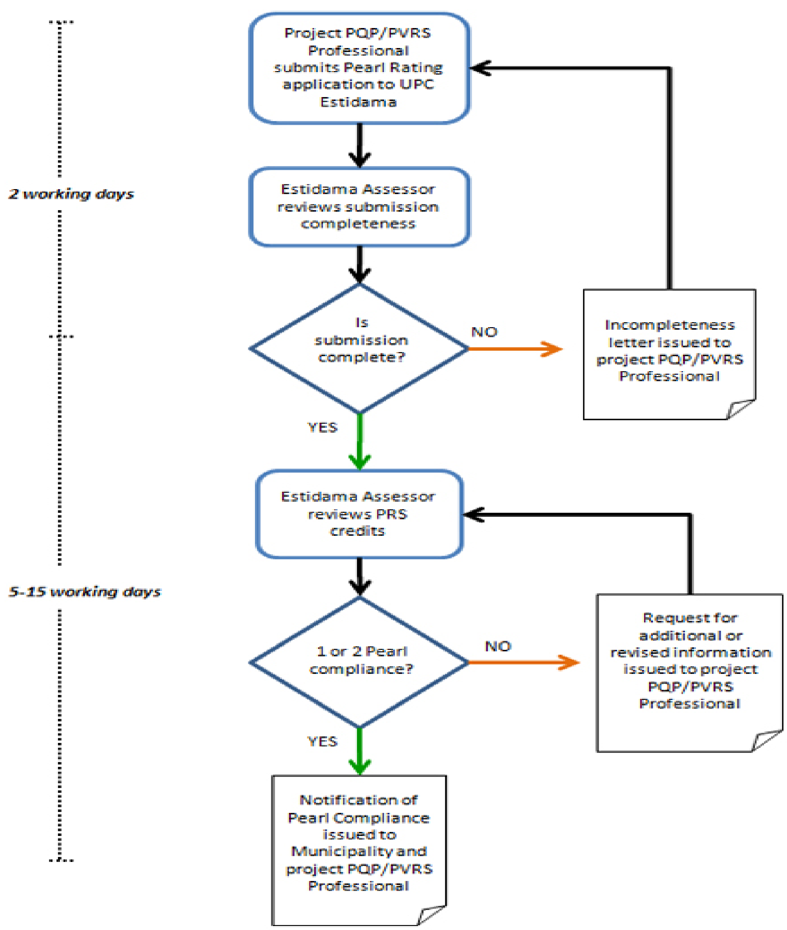

Figure 2.1 Estidama UPC Assessment and Certification Flowchart (Estidama website, 2011).

Fig. 2.1 shows the process as follows:

Appointing a Pearl Qualified Professional (PQP) and Registration: The project team shall appoint a PQP as early as possible to guide the team through Estidama process, register and follow-up the project with the Assessor from UPC or ADM.

Preparing and submitting the application: PQP with the project team will start the process by deciding how many pearls will be targeted, then he will be responsible for collating all the required data and calculations from the team to prove compliance with the targeted certification level, the next step is Submitting the application by the PQP to UPC/ADM for review.

Reviewing the application: one assessor will be appointed on the project and will review the project on two steps, the first step is reviewing the documents for completeness, a process that would take two working days and ends with a notification of completeness or incompleteness of documents to the PQP, when the documents are complete the assessor will start a detailed review for the documents based on the targeted level of certification, this review takes from 5 to 15 days (5 for 1 pearl and 15 days for 2 pearls), review 3 to 5 pearls will require extra 4 weeks as per Estidama website (2011).

Certification: if the project proved to be compiling with pearls, a "Notification of Pearl Compliance (NOPC) will be issued to both the project PQP/PVRS Professional and the respective Municipality" (Estidama, 2011). After construction the project must resubmit a construction application with the same above procedure and the design certificate will be expired.

LEED

GBCI divides the process into five stages: Registration, preparing application, submit application, application review and certification.

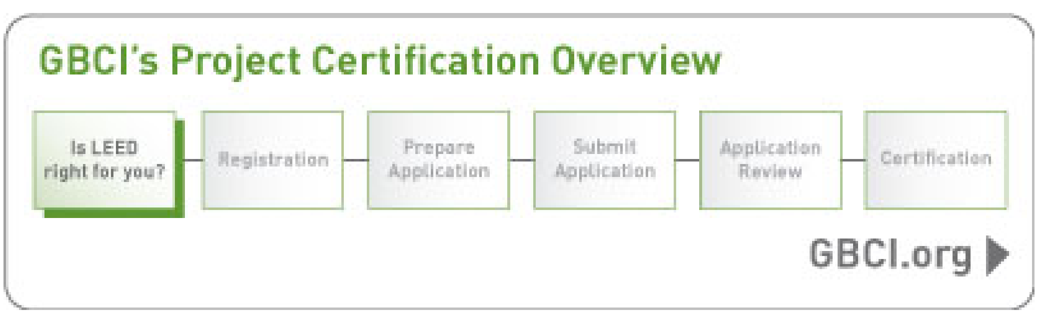

Figure 2.2 GBCI's Project Certification Overview (GBCI, 2011).

Fig. 2.2 shows the process as follows:

Registration: The process starts by registering the project online, the flat fees at the present are 900$ for USGBC Members and 1200$ for Non-Members, the registration gives the team access to a variety of tools and resources that help the projects go through certification, then the project will be listed in the LEED online project directory.

Preparing application: at this stage project team select the credits, then start collecting data and make the calculation required for achieving the prerequisites and optional credits, when the team finishes gathering information it uploads the documents for review.

Submit application and review: LEED project administrator will submit the project documents for review with the relevant fees which varies with the project area and the review stage (Design or construction). There are two types of applications (split and combined applications), split application is dividing it into design and construction phase while combined is only one combined submittal, review process follows the type of submission with the opportunity to appeal with 25 days of the result.

Certification: LEED has one Main construction certification stage and an option design stage review, after the construction submittal review is finished and design team accepts the result, GBCI will award the certified projects with “a formal certificate of recognition”, “information on how to order plaque and certificates, photo submissions, and marketing”, and with the owners discretion included in “online LEED Project Directory of registered and certified projects” and in the US department of energy high performance buildings database.

BREEAM

The process of BREEAM assessment promotes the dialogue between the design team and a qualified independent assessor by mandating appointing the later in assessing the project, BREEAM encourages the early appointment of this assessor in order to ensure a smooth process, Saunders (2008) had outline BREEAM process as shown in Fig 2.3.

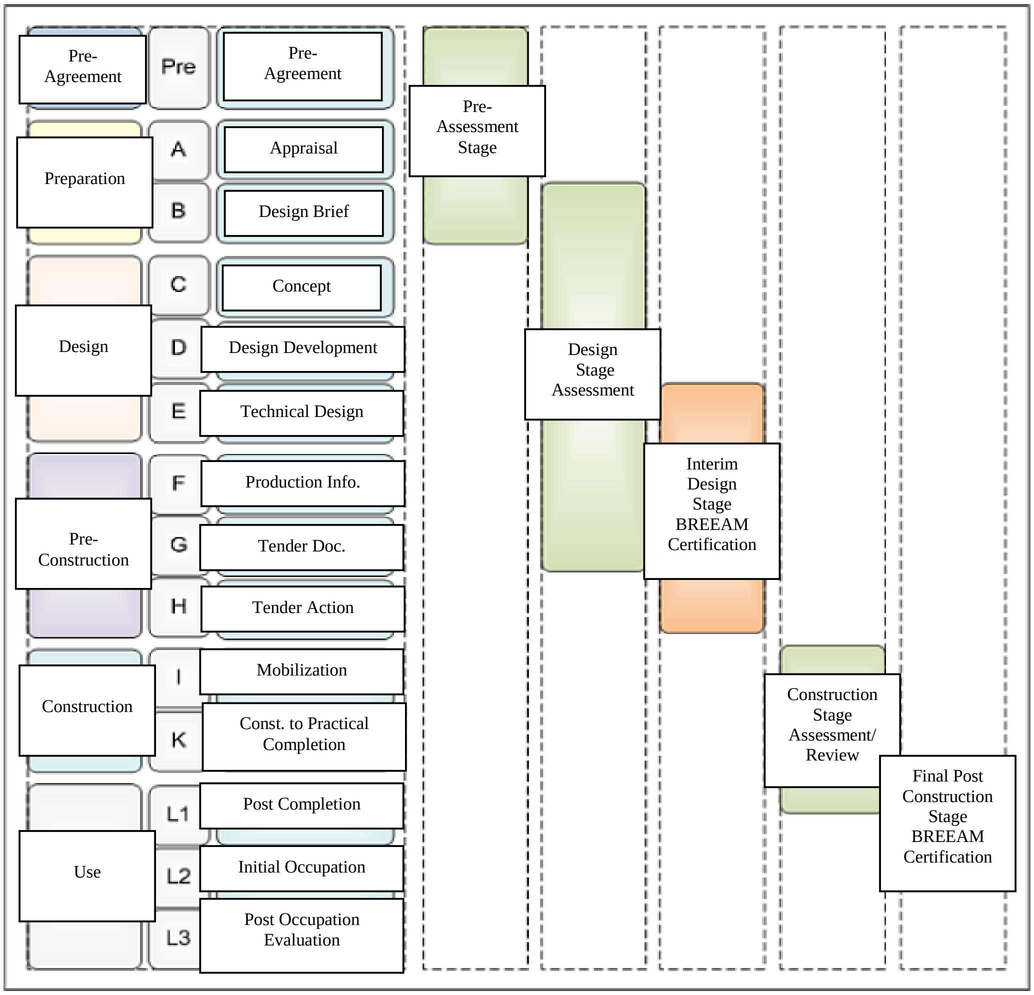

Figure 2.3 BREEAM Assessment and Certification Stages (BREEAM, 2011).

Registration: Registering the development online or by post comes as a first step, and then an "Assessment Reference Number" will be given to the team.

BREEAM Assessor: The Project team appoints an independent assessor who will collates all required data that confirms compliance and conduct the required assessments with the support of BREEAM customer support team.

Assessment Report Submitted: After the report is compiled the assessor submits the report to the BREEAM office for Quality assurance which costs from 740 Euros to a maximum of 1500 Euros for a standard BREEAM office report, this process takes 3 weeks to certification is the report passes from the first time.

Certification: Upon successful Quality Assurance a certification will be issued, after design stage the team can apply for interim design stage BREEAM certification, while the final one comes after construction.

The certification process was summarized for the three schemes by Elgendy (2010) in Fig. (2.4)

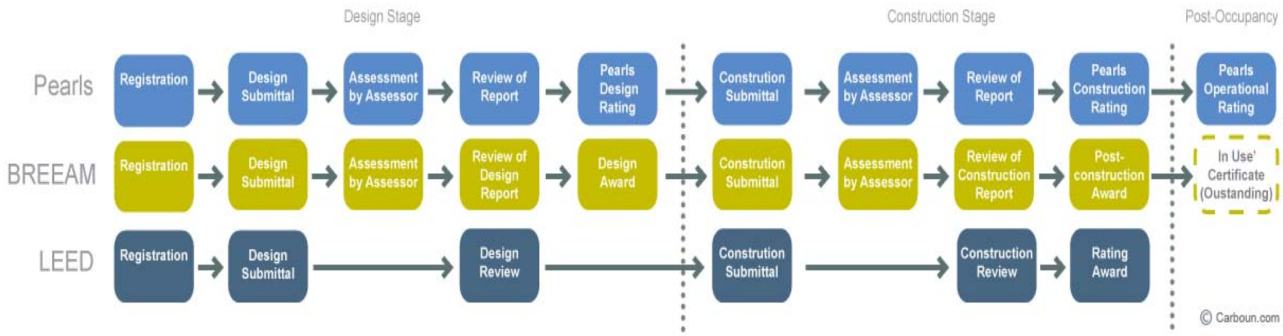

Figure 2.4 BREEAM Assessment and Certification Stages (BREEAM, 2011).

This summary showed in Fig. 2.4 shows the central role that assessor plays in BREEAM and PRS, where there a defined person is assigned to the project and hold meeting with the project team to guide them to achieve certification, while in LEED projects directly submit online for review without workshops or discussions. LEED also has another certification process other that shown one which is called the standard where the project submitted one time only after construction.

2.6 Schemes Structure

The three LEED, BREEAM and PRS are point performance based systems that "awards projects points for different credits that are grouped under a number of general categories"(Elgendy, 2010), these categories are divided into optional and required credits. Points are added together to give an environmental rating which is 4 levels in LEED (Certified, Silver, Gold and Platinum) which compare to the PRS five 5 levels (from One to Five Pearls) BREEAM’s 5 levels (Pass, Good, Very Good, Excellent, and outstanding). (Elgendy, 2010)

2.6.1 Schemes Categories

Every scheme has its own different categories, still the contents of these categories has a lot of overlapping sustainable strategies. Table (2.1) shows that the three schemes have categories that may have the same intent but its still have differences as it will be explained later on the performance or the reference standards.

Table 2.1 Different Categories of PRS, LEED and BREEAM

No.	PRS	LEED	BREEAM
1	Integrated Development Process	Sustainable sites	Management
2	Natural Systems	Water Efficiency	Health & Wellbeing
3	Livable Buildings	Energy and Atmosphere	Energy
4	Precious Water	Materials and Resources	Transport
5	Resourceful Energy	Indoor environmental Quality	Water
6	Stewarding Materials	Innovation in Design	Materials
7	Innovating Practice	Regional Priority	Waste
8			Land Use & Ecology
9			Pollution
10			Innovation

<u>As shown in table (2.1) **PRS** is made of six main and one bonus category :</u>

Integrated Development Process

Encouraging cross-disciplinary Coordination to increase the efficiency and the quality of the project, and to reduce or eliminate problems that may arise in the life time of the project.

Natural Systems

Mitigating the negative impacts of construction activities on the local environment by "conserving, preserving and restoring the region's critical natural environments and habitats".

Livable Buildings

Improving the Indoor Environmental Quality (IEQ) quality, the outdoor comfort and connectivity with the context.

Precious Water

Water is one of the major issues in the Middle East, PRS gave a great emphasis to water saving, this category targets conserving and reducing the use of water by using high efficient fixtures and minimizing the use of potable water.

Resourceful Energy

Energy conservation through "passive design measures, reduced demand, energy efficiency and renewable sources".

Stewarding Materials

"Ensuring consideration of the 'whole-of-life' cycle when selecting and specifying materials".

Innovating Practice

This category was placed as per LEED and BREEAM to give a bonus to innovations in "building design and construction to facilitate market and industry transformation".

As appears in table 2.1 and as PRS, **LEED NC** also consists of seven sections:

Sustainable Sites

In this category LEED deals with the relation of building of study with it's surrounding, such as reducing or eliminating the pollution resulting from construction activity, site selection, community connectivity and development density, transportation to the site, storm water design, reduction of heat islands and light pollution.

Water Efficiency

In this one, it's mainly about reduction of potable water consumption by using high performance water fixtures and using grey and black water where possible.

\

Energy and Atmosphere

This Category aims to reduce energy consumption and gas emissions by conducting systems commissioning and the use of energy modeling to predict how a building may operate in future and correct it early in the design phase, it aimed to achieve this reduction also by introducing energy efficient equipments and the green power and renewable resources.

Materials and Resources

40 % of the generated waste is from Construction activities, this category is all about optimizing materials use to reduce the demand on new virgin materials and therefore reduce pressure on the environment. Strategies such as building reuse and construction waste management were used, also encouraging the use of reused, recycled, rapidly renewable materials and certified wood "the wood which grows in environmentally managed forests".

Indoor environmental Quality

As per LEED 2009, US citizens spend 90% of their time indoors; this shows the importance of this category, it covers the ventilation rates, tobacco smoke control, outdoor air delivery monitoring, increased ventilation, indoor air quality management during and after construction, the use of low emitting materials such as (adhesives, sealants, paints, coatings, flooring systems, composite wood and agrifiber products), it also includes Indoor Chemical and Pollutant Source Control, encourages the Controllability of Systems such as (lighting and thermal comfort), thermal comfort design and verification and daylight and views.

Innovation in Design

This category aims to encourage the innovation by awarding extra bonus credits from exemplary performance and involvement of a LEED accredit professional in the project.

Regional Priority

In order to increase the spread of LEED around the world, this category had been introduced in the LEED 2009; in this one extra incentive was introduced to specific credits that changes according to the region in which the assessment is taking place.

BREEAM, consists of ten sections:

Management

Encouraging coordination between the project team with client, assuring the implementation of best environmental practices in Design, Construction and operation in a cost effective manner.

Health and Well being

Providing a healthy high quality Indoor Environmental Quality (IEQ)

Energy

Emissions reduction by energy and emissions monitoring, and the use of energy efficient equipments.

Transport

Reducing the negative impacts of automobiles on the environment by providing alternative green transportation.

Water

Reducing consumption through monitoring, leak detection and the use of water efficient fixtures.

Materials

Ensuring taking the account of the life cycle of the materials.

Waste

Promoting reduction of waste generated during construction and operation through management, use of recycled materials and the involvement of the end use in the choice of materials.

Land use and Ecology

Reducing/Eliminating the negative impacts of construction on the environment through proper site selection, mitigating impact and enhancing site ecology.

Pollution

Eliminating sources of air, water and noise pollution.

Innovation

Encouraging innovation in implementing best environmental practices.

2.6.2 Mandatory/Prerequisites/required Credits

From reviewing the three rating systems, they have similar structure where it's divided into mandatory and optional credits, most of the credits are optional and tradable but in order to make sure that every development is at least covering the fundamental environmental issues mandatory credits were introduced. Mandatory credits are a group of baseline specifications that must be met; these credits do not award points in LEED and PRS but are mandatory for certification, in BREEAM it both award points and mandatory. On the other hand the optional credits are up to the project team to select based on their project type and targeted level of certification.

Table 2.2 the Mandatory Credits of PRS, LEED and BREEAM

No.	**PRS** has 20 Required Credits	**LEED** has 8 Prerequisites	**BREEAM** has maximum of 14 Mandatory Credits
1	IDP-R1: Integrated Development Strategy	(SS P1) Construction Activity Pollution Prevention	Man 01: Sustainable procurement
2	IDP-R2: Tenant Fit-Out Design & Construction Guide	(WE P1) Water Use Reduction	Man 02: Responsible construction practices
3	IDP-R3: Basic Commissioning	(EA P1) Fundamental Commissioning of Building Energy Systems	Man 04: Stakeholder participation
4	NS-R1: Natural Systems Assessment	(EA P2) Minimum Energy Performance	Hea 01: Visual comfort
5	NS-R2: Natural Systems Protection	(EA P3) Fundamental Refrigerant Management	Hea 04: Water quality
6	NS-R3: Natural Systems Design & Management Strategy	(MR P1) Storage and Collection of Recyclables	Ene 01: Reduction of CO2 emissions
7	LBo-R1 Plan 2030	(IEQ P1) Minimum Indoor Air Quality Performance Required	Ene 02: Energy monitoring
8	LBo-R2 Urban Systems Assessment	(IEQ P2) Environmental Tobacco Smoke (ETS) Control	Ene 04: Low or zero carbon technologies
9	LBo-R3 Outdoor Thermal Comfort Strategy		Wat 01: Water consumption
10	LBi-R1: Healthy Ventilation Delivery		Wat 02: Water monitoring
11	LBi-R2: Smoking Control		Mat 03: Responsible Sourcing

12	LBi-R3: Legionella Prevention		Wst 01: Construction waste management
13	PW-R1: Minimum Water Use Reduction		Wst 03: Operational waste
14	PW-R2: Exterior Water Monitoring		LE 03: Mitigating ecological impact
15	RE-R1: Minimum Energy Performance		
16	RE-R2: Energy Monitoring & Reporting		
17	RE-R3: Ozone Impacts of Refrigerants & Fire Suppression Systems		
18	SM-R1: Hazardous Materials Elimination		
19	SM-R2: Basic Construction Waste Management		
20	SM-R3: Basic Operational Waste Management		

As shown in Table 2.2, PRS has the highest number of mandatory credits (20 credits) and includes almost all LEED Prerequisites except the construction activity pollution prevention. Abu Dhabi Municipality had mandated all the new projects in the emirate to achieve minimum this 20 required credits, and there is no new building permit can be issued before a confirmation of compliance from the reviewing authority of PRS which is AD UPC.

The "Required credits" of PRS and the Prerequisites of LEED are constant in all the certification levels, the only difference is that in PRS a project can gain the lowest certificate of compliance by only following only these required credits, while in LEED any certification level is a combination between a mandatory and required credits.

LEED and BREEAM are different than PRS and their lowest certification level mandates a combination between mandatory and optional credits.

In BREEAM, Mandatory credits here are different as it increases with the certification level as shown in the Table 2.3 from BREEAM.

Table 2.3 Minimum BREEAM standards by rating level (BREEAM, 2011)

BREEAM issue	Minimum standards by BREEAM rating level				
	PASS	GOOD	VERY GOOD	EXCELLENT	OUTSTANDING
Man 01: Sustainable procurement	One credit	One credit	One credit	One credit	Two credits
Man 02: Responsible construction practices	None	None	None	One credit	Two credits
Man 04: Stakeholder participation	None	None	None	One credit (Building user information)	One credit (Building user information)
Hea 01: Visual comfort	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Hea 04: Water quality	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Ene 01: Reduction of CO_2 emissions	None	None	None	Six credits	Ten credits
Ene 02: Energy monitoring	None	None	One credit (First sub-metering credit)	One credit (First sub-metering credit)	One credit (First sub-metering credit)
Ene 04: Low or zero carbon technologies	None	None	None	One credit	One credit
Wat 01: Water consumption	None	One credit	One credit	One credit	Two credits
Wat 02: Water monitoring	None	Criterion 1 only	Criterion 1 only	Criterion 1 only	Criterion 1 only
Mat 03: Responsible Sourcing	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only	Criterion 3 only
Wst 01: Construction waste management	None	None	None	None	One credit
Wst 03: Operational waste	None	None	None	One credit	One credit
LE 03: Mitigating ecological impact	None	None	One credit	One credit	One credit

From the reviewing the mandatory credits, LEED and Pearls have in common mandating energy and water use reduction, reducing or eliminating refrigerants, building commissioning and operational waste management. Pearls and BREEAM share mandating the integrated design management process of the project in order to ensure the production of a sustainable project.

Pearls is the system with the most mandatory requirements, reasons probably because the mandatory credits are a building code mandated, while for LEED and BREEAM, they are a full voluntary system and not related to building codes, therefore achieving the mandatory is not enough for gaining a certificate and the project must apply also for optional credits.

LEED and Pearls share two things in common about the mandatory credits which that they are both fixed with all the levels of certifications and that they don't award points, while for BREEAM as shown in figure 5 above, mandatory credits change with the desired certification level.

2.6.3 Categories weightings

As per a white paper produced by a UK Environmental assessment specialized consultant "Inbuilt" which was published in (2010), there are big overlaps between the categories of LEED and BREEAM that was illustrated in their report as shown in Fig 2.4. From looking in to the list of credits of PRS, most of its credits are shared with BREEAM and LEED, however still the sections weighting of the three systems are different, that reflects the difference in the local perception of how a green building shall be.

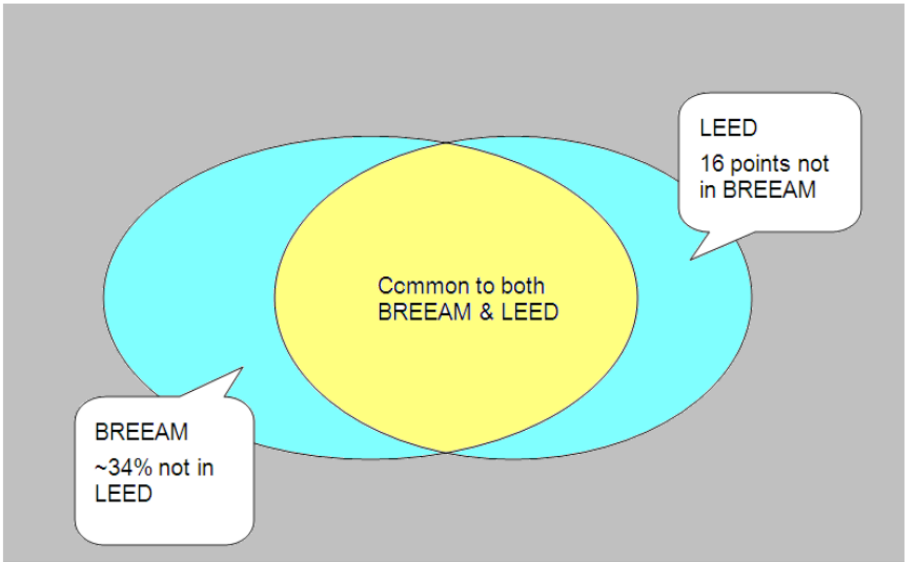

Figure 2.5 Overlaps between the credits of LEED and BREEAM (Inbuilt, 2010)

Elgendy (2010) in his research paper comparing the three systems had highlighted that there is a "considerable" overlap between the systems in spite of having their own particularities. In order to be able to form a comparison, Elgendy had to make some changes in the names of the sections in order to highlight overlaps and differences.

Table 2.4 Comparison between the major categories in LEED, BREEAM and PRS (Elgendy, 2010).

PEARLS		BREEAM		LEED	
Site selection and Natural systems	16%	Site Selection and ecology	20.5%	Site Selection	24.5%
Water	25%	Water	2.5%	Water	5.5%
Energy	25%	Energy	33%	Energy	33%
Materials	16%	Materials	13.5%	Materials	13.5%
Indoor Environmental Quality	20%	Indoor Environmental Quality	13%	Indoor Environmental Quality	14%
Innovation	2%	Innovation	6.5%	Innovation	6.5%
Integrated Design Process	7%	Facility management	12%	Regional Priority	4%

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In comparison table 2.4, Elgendy highlights the particularities of every system which are Integrated Design Process IDP for Pearls, Management for BREEAM and Regional Priority for LEED, he also highlights that in spite of the over laps between the systems' categories, still the weightings of the sections are different.

But in another look to the three rating schemes as shown in Table 2.5, it was a found some slight differences than Elgendy schemes summary.

Table 2.5 Comparison between the major categories in LEED, BREEAM and PRS

Pearl Rating System			**LEED**			**BREEAM**		
Credit Points Category	Pts. Avail.	Weight	Credit Points Category	Pts. Avail.	Weight	Credit Points Category	Pts. Avail.	Weight
IDP-Integrated Development Process	13	7.3%	EA-Commissioning*	2		Man-Management		12.0%
			EA-Measurement and Verification*	3				
			IDP LEED Related credits Total	5	5.0%			
NS-Natural Systems	12	6.7%	SS-Site Selection*	0	0.0%	LE-Land use and Ecology		10.0%
			SS-Site Development*	2	2.0%			
Lbo-Livable Buildings-Outdoors	14	7.9%	SS-Sustainable Sites	24	24.0%	Tra-Transport		8.0%
Lbi-Livable Buildings-Indoors	23	12.9%	IEQ-Indoor Environmental Quality	15	15.0%	Hea-Health and wellbeing		15.0%
PW-Precious Water	43	**24.2%**	WE-Water Efficiency	10	10.0%	Wat-Water		6.0%
RE-Resourceful Energy	44	**24.7%**	EA-Energy and Atmosphere	30	**30.0%**	Ene-Energy		**19.0%**
SM-Stewarding Materials	29	16.3%	MR-Materials and Resources	14	14.0%	Mat-Materials		12.5%
						Wst-Waste		7.5%
						Pol-Pollution**		10.0%
IP-Innovating Practice	6		ID-Innovation in Design	6		Inn-Innovation		10
			RP-Regional Priority	4				
Total Points / Excludes Bonus credits of innovation	178	100.0%	Total Points / Excludes Bonus credits of innovation	100	100.0%	Total Points / Excludes Bonus credits of innovation		100.0%

* Credits taken out from its main category as they representing another category in PRS

** Pollution Category of BREEAM is included in PRS in the categories of Lbo, LBi and SM

The differences were mainly the way the credit were organized and the percentage or the overall weight of every credit as follows:

Sustainable sites (SS) and Natural systems (NS)

In Elgendy (2010) comparison, sustainable sites category is mentioned as site selection which is only one credit in LEED, the comparison shows that LEED and BREEAM puts more emphases on site selection than in Pearls, however it seems more appropriate to related the sustainable systems category of LEED to the Livable outdoor category of PRS as it has similar topics.

Water

There are big differences between the three systems regarding "Water" credits, as per Elgendy (2010) represents 25% in Pearls, represents only 2.5 % in BREEAM and 5.5% in LEED. This was found true when this was recalculated in this research but the percentages was as follows: 25% in Pearls,6 % in BREEAM and 10% in LEED. This high importance of water credits in PRS seems convenient especially when looking to that fact that "the Emirates ranks third in the world in terms of the volume of sea water desalinated daily, at 4.7million cubic meters every day", and since water is not as major issue in UK and US as in the middle east, they put it with lower weight, also it seems like Pearls cover more issues especially in the exterior water use by adding credits for water use reduction for heat rejection and another credit for water use reduction for in water features and swimming pools, plus awarding what BREEAM and LEED awards also such as water use reduction, waste water recycling and landscaping water use reduction .

Energy

As per Elgendy (2010) in table 2.4, energy represents the highest category in the Pearls system (25%) but still lower than those of LEED and BREEAM (33%), this was a direct category comparison, but when similar related credits of these schemes are been compared together as shown in table 2.5, the percentages changes where LEED leads the scene with the energy credits worth 30% then PRS comes second with 25% then BREEAM with 19%, these percentages is a direct translation of how important saving energy is for the three assessment schemes.

Energy performance credits of LEED and BREEAM are nearly same (14.5%) and (14.7%) but less in Pearls systems around (8.4%), as shown in Fig. 2.5 and Fig 2.6 the maximum percentage reduction energy use in PRS is (60%) and (48%) while BREEAM aims for the zero

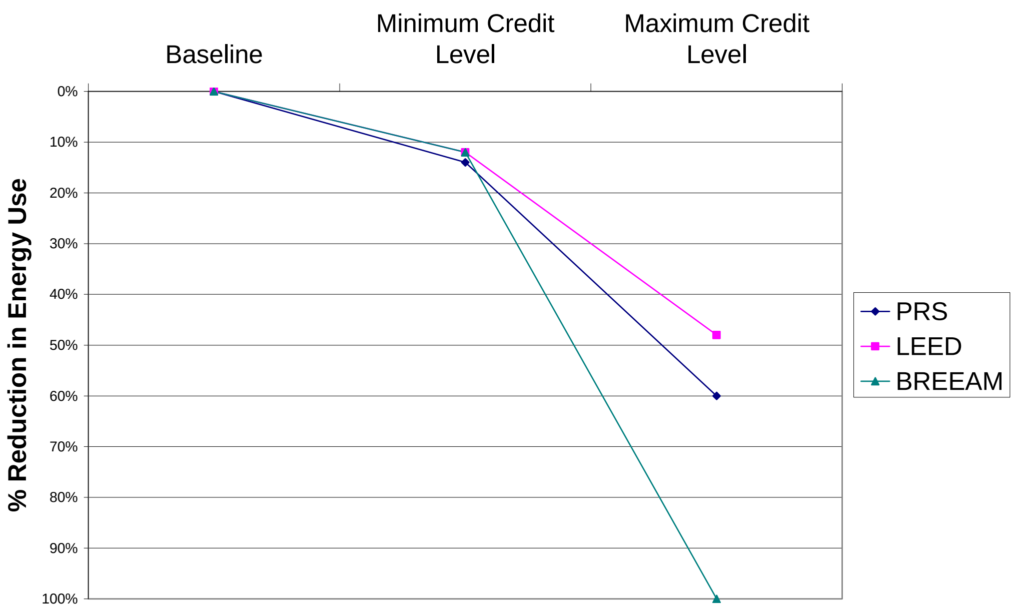

Figure 2.6 Performance criteria of the schemes

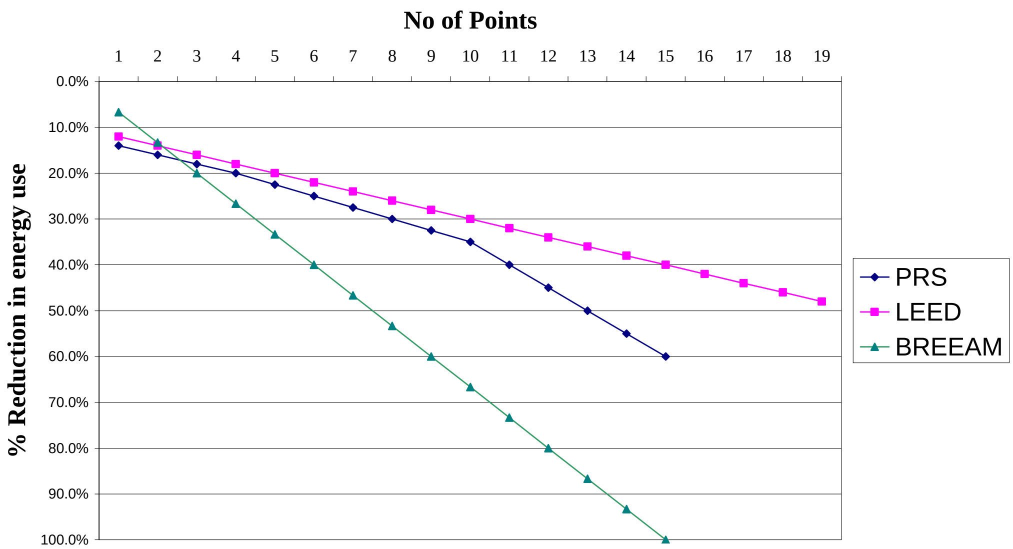

Figure 2.7 Credit scales of PRS, LEED and BREEAM

Materials

Elgendy (2010) highlights that BREEAM and LEED dedicate the same percentage of its points (13.5%) for materials which is less than the (16%) of the Pearls, but when the Waste category for BREEAM is added to Materials as in LEED and BREEAM, the percentage jumps up to be (20%) which is the highest in the three schemes, therefore BREEAM leads the scene here.

Indoor Environmental Quality (IEQ)

Pearls system leads in this category as per Elgendy (2010) by dedicating 20% of the total points to IEQ, while BREEAM and LEED dedicates almost the same 13% and 14% respectively, but when recalculated it was found that PRS fall behind with only (13%) as shown in Fig 2.5.

Innovation

This category is introduced in the three rating schemes; it has a great importance as it encourages environmental innovation and exceeding the limits, this category also is essential in awarding ideas that can promote sustainability which is not mentioned already in the schemes. BREEAM and LEED are leading in this category as they are dedicating 6.5% of its credits for innovation while the Pearls put only 2%.

From the detailed credit review it seems as the Inbuilt report (2010) and Elgendy (2010) had stated, there seems to be big overlaps between the three schemes, but still some differences can be highlighted.

The first difference is the credit contents, where some topics are not mentioned directly in one system but can still be included in an indirect way such as the natural systems (NS) credits which is mentioned directly in PRS and indirect way in site selection credit in LEED , this was clear also in credits such as Stewarding Materials (SM) SM-2 to SM-6 in the Pearls systems which encourages adopting techniques such as (design for materials reduction, flexibility and durability, disassembly, having modular flooring systems), these are not mentioned directly in LEED or BREEAM but its considered as good engineering practice and can help in Management category of BREEAM Materials and Resources credit 4 “Materials Reuse”.

Another difference is the areas that are not covered in some schemes just because they are covered in their local codes such as “tobacco smoke control” which is a credit in LEED and Pearls and not in BREEAM as its already covered in the UK legislations.(Elgendy, 2010). Pearls seem to give more importance to cultural issues than BREEAM and LEED by providing a direct bonus credit with a maximum of three points that award "Innovative Cultural & Regional Practices". Integrated development process (IDP) is the process with encourages effective multidisciplinary coordination efforts between the project team members throughout the life time of the project, this process is very important to produce a sustainable green and performance efficient building as tends to tackle most of the obstacle as early as possible. One of the things that differs Pearls from LEED and BREEAM is that it requests IDP clearly and even mandates preparing and implementing an Integrated Development Strategy.

From the overall look at the credits selection and its weightings, its seems that every rating scheme was designed as a response and under the influence of the local problems/challenges in its country of origin, where for LEED, it is" geared towards climates which use mechanical ventilation and air conditioning and where existing infrastructure promotes the use of cars as is the case in much of the United States" (Elgendy, 2010), while for BREEAM it " responds to a built environment where natural ventilation is more prevalent and where a strong public transportation infrastructure exists " (Elgendy, 2010), for Pearls it has also its special local influences where it dedicates half of its points structure for saving water and energy the two main challenges in the middle east region.

2.7 The effectiveness of PRS, LEED and BREEAM

Measuring the effectiveness of a rating scheme and whether or not it has succeeded to achieve its aims and objectives has been the topic of some research papers especially on LEED and BREEAM. PRS is a new born systems with no buildings constructed yet, therefore wasn't not possible to measure its effectiveness but its still possible to at least predict or have some ideas from what happened with the two elder schemes LEED and BREEAM.

There seem to be two main approaches in analyzing and comparing assessment schemes, one is on the design phase and the other one is after completion as post occupancy evaluation for an assessed building, both have their benefits. Comparing schemes on the design phase can help on direct horizontal evaluation between the assessment schemes, while on the other hand post occupancy can help creating a vertical evaluation of the product against design intentions.

Most of the Reviewed research papers that chose to perform horizontal comparisons between assessment schemes preferred to have wide comparison with no area of focus while deep comparison chose to focus mainly in Energy consumption and Indoor Environmental Quality.

2.7.1 Energy Consumption

Most of the research papers which are comparing environmental assessment schemes are using energy performance as a basis for comparison, this seems understandable as LEED and BREEAM puts the high percentage of the schemes points on Energy related strategies.

In a comparison between LEED, BREEAM and the Australian scheme Green Star, Roderick (2008) had aimed to compare how buildings energy performance is assessed and awarded in the 3 schemes. He highlighted that the energy performance credits weights are nearly the same in the compared schemes (between 14.1% to 14.7%), he also stated that the unit of measuring the energy consumption is different were BREEAM calculations are based on CO2, Green Star on green house gas emission and dollars for LEED. The study had concluded that measuring the performance of a building depends strongly on the used assessment scheme where "The case study office building received a high energy rating score in the Green Star scheme, but a low energy rating in BREEAM and it even failed to be certified in the LEED scheme". This result raises the concern that different assessment schemes are not related and that a certified building under a specific scheme may not be good enough when assessed by other standard, and therefore two of the main of objectives of environmental assessment schemes which is defining green buildings and recognizing it, had been compromised.

Table 2.6 General Comparison for Energy Performance assessment criteria between LEED, BREEAM and HK-BEAM (Lee and Burnett, 2008).

Item	HKBEAM	LEED	BREEAM
Assessment method	Mixture of performance-based and feature-specific criteria	Options of feature-specific criteria and energy cost budget method	Mixture of performance-based and feature-specific criteria
Simulation tool	HTB2 + BECON or approved equivalent	DOE-2 or BLAST or approved equivalent	No specific requirements. Actual consumption figures may be used where available
Scope of assessment	• Annual energy use • Maximum electricity demand • Energy efficient design • Envelope performance	• Energy-efficient design • Annual energy cost	• Annual CO_2 emissions • Energy-efficient design
Max. credit level performance based criteria	Reduction of 57% in annual energy use over the baseline case	Reduction of 60% in annual energy cost over the budget	Zero emissions
Min. credit level performance based criteria	120 kWh/m^2/yr	Reduction of 15% in annual energy cost over the budget	160 kg CO_2/m^2/yr
Baseline case/zero credit level	Compliance with the minimum requirements laid down by relevant laws or codes of practice	Compliance with ASHRAE/ IESNA 90.1-1999 [38]	Compliance with DETR (1998) good practice guides
Energy-related credits/points (%)	23	25	20

Lee and Burnett (2008), had another opinion when they compared BREEAM, LEED and HK-BEAM (the local assessment scheme of Hong Kong), and although they highlighted that the schemes are different in “scope and assessment criteria” as shown in Table 2.6, they concluded that “The difference in energy use assessment methods, baseline buildings, simulation tools and performance criteria do not affect the assessment results” but they highlighted that its harder to score under BREEAM.

Another group of researchers aimed to evaluate a specific environmental assessment scheme by comparing it with its product building after operations data, this approach was adopted by Sabapathy et al. (2010) when they tried to benchmark the performance of LEED rated buildings for "Information Technology facilities in Bangalore, India", in the paper they concluded that on average "LEED rated buildings outperform the other buildings" in terms of energy efficiency.

2.7.2 Water

There is very few research work done regarding water saving for green buildings and the energy saving related to the reduction in water use, most of the work which was done was just a direct comparison of the required water reduction percentages between different assessment schemes. Elgendy (2010) has tackled the water issue slightly in his comparison paper and highlighted that Pearls dedicates a large percentage of its credits to water credits to overcome its high consumption problem and there is also the Inbuilt report (2010), which highlight the differences between the water credits in LEED and BREEAM.

2.7.3 Indoor Environmental Quality (IEQ)

IEQ consists of different components such as:

- Indoor Air Quality (IAQ)
- Thermal Comfort
- Daylight
- Views
- Acoustical Comfort

All of these components are related to the occupants' satisfaction and in order to evaluate if assessment schemes had succeeded to achieve these components or no, post occupancy evaluation must be conducted.

There have been an extensive research work around this topic, and it was done either as direct brief credit by credit comparisons such as the Inbuilt report (2010) and Elgendy (2010) research papers, or as post occupancy evaluations for the IEQ performance in general of a specific building, where the researcher test the building post occupancy against its design intent.

The majority of the research work on IEQ was conducted as post occupancy evaluations such as the work of Clara et al. (2010) about the" Evaluation of Indoor Environment Quality with a Web-based Occupant Satisfaction Survey" and Lee and Kim (2008) who used a secondary data " the online database of the Occupant Indoor Environmental Quality (IEQ) Survey from the Center for the Built Environment (CBE) at the UC, Berkeley" to evaluate the IEQ in the LEED-certified buildings in the US, these papers in addition to Heerwagen and Zagress (2005) research work have all found evidence that there are actual real improvement in the LEED buildings in terms of IEQ and that the only negative was acoustics. Acoustics are not covered in LEED while it's covered in BREEAM/PRS systems.

On the other hand, there was another opinion which was less spread, that says that green buildings are not better than conventional buildings in terms of IEQ and especially in thermal comfort (Paul and Taylor, 2008) and Acoustics (Heerwagen and Zagress, 2005).As per Heerwagen and Zagress (2005) it's widely believed that green buildings has more comfortable environment than conventional but there is little empirical evidence supporting that. Paul and Taylor (2008) also had investigated the concept of green buildings by comparing it with a conventional building, the aim of the study was to test the statement which says that “green buildings perform better and have better IAQ than conventional”, and they concluded that there is no evidence to believe that statement.

Between these two opinions the debate of whether green building provide more comfortable indoor environment remains unresolved.

There were also another group of researches who focused on only a specific aspect and not the general look of IEQ of green buildings. Huizenga et al. (2006) had studied the air quality and thermal comfort only through post occupancy online survey for 215 buildings in US, Canada and Finland; they found that most of the buildings fail in the thermal comfort and IAQ scores higher. Also there is Mardaljevi (2009) research work, where he tried to relate the quality of day lighting in spaces with energy savings, where he stressed on that " energy considerations should ideally make account of the impact that daylight has on heating/cooling load as well as on electric lighting usage" and that computer modeling for day lighting is an essential step in predicting the day light levels but must be followed on a later stage after occupancy to "both validate and calibrate the predictions obtained from daylight simulations, and provide information that allows corrections for observed user behavior and system performance."

It seems from the reviewed paper on the evaluation of IEQ that most of it depends on post occupancy surveys to check whether or no the green buildings are performing as per the design intent.

2.7.4 The Impact of Environmental Assessment Schemes on Cost

Since creation of environmental assessment schemes the question of how much does it cost had always been raised, this created a debate because the actual savings in green buildings are in the operational cost, but in a market driven building industry, reduction in operational costs is not enough and that the initial cost has just the same importance for the market.

The Increase on Demand of Green Buildings

Buildings are huge investment in time and cost, the demand of having a green building is increasing with time whereas per McGraw Hill Construction in Green outlook (2009), the overall value of green building market is estimated to be between 36 billion to $49 billion with an expected increase to reach of $96 billion to $140 billion by 2013.

Main obstacle

And although the interest in having green building is significantly increasing, still there are some obstacles facing this increase. The main obstacle is that it all comes down to the cost of having a green building and for some clients it all comes down to only the "Initial cost", and since most of the green technologies especially on the side of energy generation are still on research and development (R&D) process it do impact the cost and requires an extra incentive. That is considered to be the major obstacle of having outstanding buildings interims of green buildings standards.

Main opportunity

In Green buildings the main investment lies in the operational costs and the market value whereas per Royal Institute of charted surveyors (RICS) report “there is an observable link between the values achieved in the market place for commercial properties and their sustainability credentials” and that the increase is around 6%.

Two opinions

Langdon (2004) had conducted a study on the cost of impact of LEED on Buildings under the name "Costing Green: A Comprehensive Cost Database and Budget Methodology", the study concluded the following:

1. Many projects are achieving LEED within their budgets and in the same cost range as non-LEED projects.

2. Construction costs have risen dramatically, but projects are still achieving LEED.

3. The idea that green is an added feature continues to be a problem.

Davis Langdon had revisited the same topic three years later (2007) and had the same conclusion that "...there is no significant difference in average cost for green buildings as compared to non-green buildings".

On the other hand there are a lot research work claims that green buildings do actually cost more than conventional building. Rawlinson (2007) of Davis Langdon had made a case study on an office building designed to meet a BREEAM Excellent rating, he concluded that there is a "6% premium is due to sustainable design features for the building", Langdon (2007) also had conducted another study on the Australian scheme "Green Stars", and as shown in the Fig 2.5 it actually shows a rise in the construction costs for more green buildings which lead to direct increase in the initial cost of buildings.

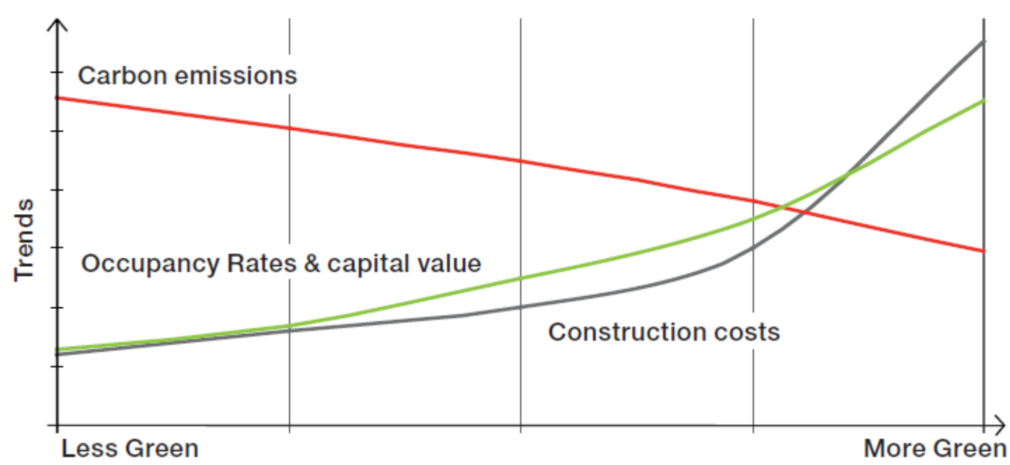

Figure 2.8 the Cost of Green Buildings (Langdon, 2007)

Langdon (2010) had conducted a study in conjunction with Abu Dhabi Urban Planning Council (UPC) the creator of Estidama PRS, to measure the expected impacts of the pearls on the costs of the buildings, as shown in the Fig 2.6, there seem to be a linear increase in the initial cost with the increase in the targeted level with minimum from 1 to 2% increase for 1 pearls to 6 to 14% when aiming for the 5 pearls.

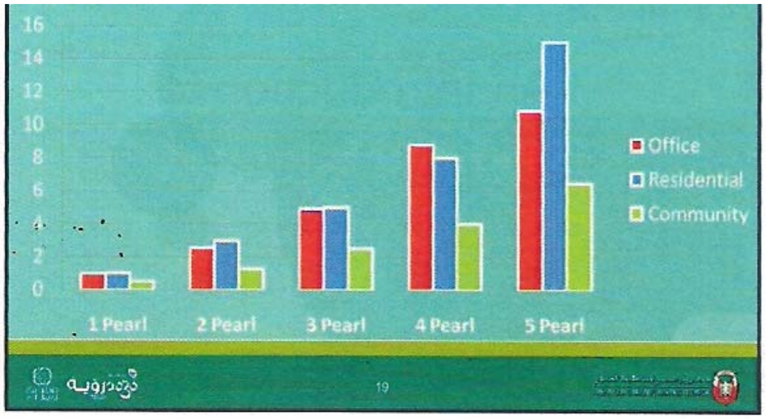

Figure 2.9 The Cost Impact of the application of Pearls Rating Schemes (Langdon, 2010)

2.8 Summary of Literature Review Findings

There is a considerable amount of research work done on Environmental Assessment schemes especially on LEED and BREEAM, but most of it only covers the energy performance aspects of the assessment, probably due to the high value of the energy credits in most of schemes, another reason is the possibility of measuring the energy performance before and after construction and the last is that its impact on the operational cost of the building.

On the other hand research work on IEQ is mainly conducted as post occupancy evaluations as it's mainly related to the occupant's satisfaction. Research work related to water efficiency seems to be rare probably due to the less reduced weight of its credits on the popular assessment schemes of LEED and BREEAM.

An observation was found is that there is a very limited research work on Estidama PRS, probably because it’s a newly born assessment scheme and the fact that it’s on a local scheme for the emirate of Abu Dhabi only. There is also what seems to be a research gap found in conducting a detailed comparative analysis between credits of different assessment schemes.

2.9 Research Aims and Objectives

2.9.1 Aim of the Research

This study aim is to benchmark PRS certification levels against LEED, BREEAM. This investigation will be based on comparing the three assessment scheme in terms of energy, water consumption, overall assessment and the cost effectiveness.

A case study Office building located in Abu Dhabi, UAE, designed in 2007 on the earlier local codes was chosen for the study. Office buildings are representative sample as they are one of main components of the construction market and the existing buildings stock of Abu Dhabi and it is predominantly characterized by being a "glazed high rise tower" (Elgendy, 2011)

2.9.2 Objectives of the Research

- To understand the concept behind the creation and development of every chosen assessment scheme through a historical factual review for the objectives and reasons behind the schemes development.
- To benchmark the performance of the building which was designed as per the buildings codes of Abu Dhabi prior to Estidama PRS against LEED, BREEAM and PRS.
- To examine the impact of selected upgrading approaches on the case study building and the possible certification levels in these assessment schemes.
- To Measure the certification levels of PRS towards relevant levels in other chosen assessment schemes.
- To evaluate the appropriateness of implementing these schemes on Abu Dhabi.

2.9.3 Expected Outcome

This study is expected to provide a clear picture for the professionals involved in the construction market of UAE of what's the pros and cons of applying three of most used building environmental assessment schemes in Abu Dhabi; it will relate selected certification levels of Estidama PRS towards the relevant levels in LEED/BREEAM schemes.

2.9.4 Developing Hypothesis

LEED is a US based system and was developed by US professionals, same for BREEAM, it’s a UK based system and was developed by UK Professionals, therefore these two systems are expected to perform better in their home countries, a customized Environmental assessment scheme which is developed in Abu Dhabi such as the pearls system is expected to perform better than other imported systems by producing more efficient buildings that are responsive to the local climate and with lower cost impact.

Chapter 3

Methodology

3.1 Reviews on Methodologies Selection

Diverse and wide nature of the Environmental assessment schemes was reflected on the methodologies that had been used on the reviewed research papers. Environmental assessment schemes covers different aspects related to construction industry of Green buildings such as energy, water, materials selection and IEQ, these topics have different natures and require different approaches for studying as reviewed below.

3.1.1 Methodologies used in papers comparing the overall of the assessment schemes

Comparing overall different assessment schemes were covered by following selected research papers.

Elgendy (2010) compared LEED/BREEAM/PRS altogether, the aim of the study was to find the overlaps and differences between these schemes, he had compared the credits categories and its weightings, reviewed the assessment and certification processes for the three assessment schemes, Elgendy used a direct overall credits review methodology for his research paper.

Sanders (2008) had conducted a study reviewing a multiple international assessment schemes for buildings, the aim was to review the most commonly used schemes around the world and compare it to the UK based system BREEAM assessment scheme, same like Elgendy, Sanders had used a direct Overall credits review methodology for his research paper.

The UK origin sustainability consultant Inbuilt had published a white paper in (2010) comparing LEED/BREEAM; they had followed the same methodology of the above mentioned papers in reviewing LEED against BREEAM.

In the above reviewed papers it was clear the need for a wide review methodology to be able to cover the all aspects of the schemes under study and the discussed topics were general such as (Certification process, Credit Weightings and Certification levels).

There were another set of research papers that are conducting a comparative analysis between environmental assessment schemes but they were focusing in one or two aspects only such as energy performance or Indoor Air Quality IAQ as it will be explained the following sections.

3.1.2 Methodologies used in Energy performance comparison papers

Energy performance has a big importance in the environmental assessment schemes, it is related to operational cost/natural resources saving and carbon emission reductions which are the synonyms of green buildings, and as a result most of the environmental schemes such as LEED, BREEAM and PRS give energy the highest values in its schemes. The perception of the importance of energy was also reflected in the amount of produced research work related to it, where the majority of research work on assessment schemes was mainly studying the energy performance aspect of it.

There were different methodologies used by the researches when they compare or study assessment schemes in terms of energy performance;

Roderick et al (2009) had used computational simulation when they compared LEED, BREEAM and Green Star in terms of energy performance, they used the energy model to evaluate and assess their case study building towards the baselines of the three schemes in study.

Also Tronchin and Fabri (2007) had taken the same approach in comparing environmental assessment schemes through focusing on energy performance.

Lee and Burnett (2008) had compared LEED, BREEAM against the Hong Kong based scheme HK-BEAM, they had also chosen energy performance as a basis of comparison, but in this paper literature review methodology was the used in studying and comparing the assessment schemes as the focus was only to compare the criteria and the energy assessment process of the system.

In another paper Lee (2012) had compared five assessment schemes; LEED, BREEAM, CASBEE, BEAM plus and the Chinese ESGB. His aim was also benchmarking the energy use of building environmental assessment schemes. A literature review approach was used; the study focus was in the five mentioned assessment schemes are comparable towards each other in terms of energy assessment.

Sabapathy et al. (2010) were only evaluating the energy performance of LEED buildings Information Technology facilities in Bangalore, India, since the study focus was specific the team of researchers had used a post occupancy survey to study the actual energy performance of their case study buildings.

Best Methodology for Energy Performance Comparisons

Building Assessments methods requires a big input in design phase, Computational Simulation Methodology is one of the main methodologies to study and evaluate buildings which is still under design, it gives the chance to the researcher to simulate the real life conditions that will be affecting the buildings in a relatively short time especially if its compared to field measurement. Simulation programs can provide users with "key building performance indicators such as energy use and demand, temperature, humidity, and costs" Crawley et al (2008). In the three selected assessment schemes, LEED assessment scheme recognizes the use of DOE-2 or BLAST or approved equivalent as simulation tool, for BREEAM there is no specific requirements and for PRS is following LEED standards in this area.

Lee and Burnett (2007), Roderick et al (2009) and Tronchin and Fabri (2007) research papers were comparing different assessment methods towards one another in terms of energy performance; the three papers used computational simulation in their research. In the research of Lee and Burnett (2007) they had used HTB2 and BECON simulation programs to study the effect of changing operational schedules on the overall annual energy performance of the building, they also dedicated a part of the research to compare between the results of the simulations programs itself and compared it against the relevant standard ASHRAE Standard 140 Standard method of Test (SMOT). In the paper of Roderick et al (2009), the aim was to compare three assessment schemes which are Green Star, LEED and BREEAM; they used computational simulation Integrated Environmental Solutions Virtual Enviroment (IESVE) in their research to model the case study as a typical office building in Dubai, they applied the requirements of the energy credits of every assessment scheme on the model then compared the results altogether, while for Tronchin and Fabri (2007) they used the environmental simulation softwares (Design Builder) and (Best Class) for their computer simulations for evaluation study on energy performance for building in Mediterranean countries.

3.1.3 Methodologies used in Papers reviewing the Water Savings

Research papers discussing water savings in green buildings seems to be rare, probably due to its minor importance in LEED and BREEAM, most the papers which had talked about water savings such as Elgendy (2010) paper and the Inbuilt report (2010) were just direct comparison between water credits with no real measurement for actual performance of green buildings, there is no dominant methodology covering this field of study.

3.1.4 Methodologies used in Papers reviewing the Indoor Environmental Quality (IEQ)

IEQ was put in environmental assessment schemes claiming that it will help transform the IEQ of buildings to be healthier and safer for the occupants; this was expected to lead to an increase in productivity and satisfaction levels. Most of the research work on IEQ is questioning the real achievement on this claim that's why most of the research work on IEQ was mainly post occupancy evaluation. Field measurement and experimental methodologies were sometimes used also to investigate this topic but the most common was Correlational based researches and social surveys as it relates to the occupants.

Best Methodology for Correlational based researches and social surveys

An important Part of evaluating the Indoor Environmental Quality of a building is the occupant satisfaction; thermal, visual and acoustical comfort, these three are all directly related to the occupants and depends on their activity and level of clothing. In previous research works, there were some trials to have post occupancy evaluation to make sure that buildings are performing as per design intentions. Hua et al (2010), Lee and Guerin (2009) both have used correlational based researches such as Social surveys in their studies to measure how much do green certified buildings satisfy the occupants needs.

Hua et al (2010) were studying in their research only one aspect of (IEQ) which is Daylight levels in a LEED Gold certified building, they conducted a social survey for the building to find out the percentage of occupant satisfaction in this building, the focus of this research was on one building only which allowed the researcher to back up his study with other multiple methods. In the other study which was conducted by Lee and Guerin (2009) , they aimed to compare three different and related aspects of Indoor Environmental quality which were; Indoor Air Quality (IAQ) , thermal quality, and lighting quality between 5 offices in different LEED certified buildings and the effect of these aspects on the environmental satisfaction and performance of the employees. To cover all of these aspects the researchers used secondary data developed by (the Center for the Built Environment (CBE)) these data was online surveys that was done by the mentioned center on the 5 selected buildings.

3.2 Methodologies selection and justification.

The research topic is wide and includes 6 variables, these variables are essential in having a complete understanding of the topic and to be able to have a fruitful evaluation of Pearls assessment scheme. A case study computer simulation method will help in providing a good basis of comparison, using a secondary data may be essential to be able to establish credible base for comparing the three assessment schemes. Time, cost and appropriateness to the research topic are main three limitations which the above mentioned methodologies had been selected and reviewed; it appears that a case study computer simulation with multiple methodologies can be an appropriate methodology for the research; multiple methodologies will be Interpretive-historical, simulation, occupant satisfaction surveys, interviews with key figures related to the field.

3.2.1 Historical-Interpretive research

This will be done for Assessment Methods in general then reviewing LEED-BREEAM and Estidama Pearl Rating System in specific.

In order to have better understanding of the chosen assessment methods and concept behind their credits structure, it's important to have a historical review on the formation of these assessment schemes. An interpretive historical review will be conducted using scientific research papers- text books on the formation and development of assessment schemes with a special focus on the selected three assessment schemes.

3.2.2 Case Study building as a focus of the study

To be able to compare the energy performance under the three assessment schemes, a case study building will be chosen in Abu Dhabi, the case study will be a typical office building in Abu Dhabi, shape and area will be generic and simple to be modeled in a timely and easy manner. Office buildings are representative sample as they are one of main components of the construction market and the existing buildings stock of Abu Dhabi and it is predominantly characterized by being a "glazed high rise tower" (Elgendy, 2011)

3.2.3 Computational Simulation

2 base line models for the case study will be generated as per the requirements of LEED, BREEAM and PRS; this will be generated using Computer Simulation software IESVE. This step is essential and is required by all assessment schemes in order to calculate the improvement in the energy performance in a later stage.

Establish an actual case

1 actual case will be generated and will be compared against the three baselines of PRS, LEED and BREEAM.

Computer Simulation Software

Two energy modeling softwares will be used in this analysis; the first one is Integrated Environmental Solutions Virtual Environment (IESVE) for the following reasons:

- The software is approved by the three assessment schemes LEED, BREEAM and PRS as shown in table 3.1 and follows their computational simulation standard requirements (Roderick et al., 2008).
- Easy to use with user-friendly interface, has plug-in to common architectural design softwares such as Sketchup.
- The wide possible studies that can be generated from the software such as Energy and water consumption calculations, life cycle assessment, day lighting and artificial light assessment.

Table 3.1 Simulation tool references in the three schemes

Assessment Scheme	PRS	LEED	BREEAM
Simulation Tool	ASHRAE Standard 140 Standard Method of Test	ASHRAE Standard 140 Standard Method of Test	No specific requirement on the simulation tool

And the other software will be Ecotect 2011 which will provide the required Weather data extracted from the US department of Energy (DOE) in a good graphical presentation.

3.2.4 Social Survey

In order to compare the satisfaction of occupants using buildings that are certified achieving the highest standards under LEED, BREEAM and Estidama assessment schemes, secondary data surveys will be used to cover this point in order to get credible and reliable comparison from a wide selection samples.

3.2.5 Conduct a set of Interviews with key industry professional

PRS is a relatively new assessment scheme in Abu Dhabi and by the time of the research topic there is a possibility that there will be no buildings constructed and operated to be studied, in that case a set of interviews with key industry professionals will be conducted and will be about their analysis and expectation of how the PRS certified buildings will be performing.

3.2.6 Overall Environmental Assessment of the case study building

The case study building will be studied with the above methods but will be assessed for compliance with the three reference standards of the selected schemes Pearls rating scheme, LEED and BREEAM. To perform an assessment a scorecard or checklist is developed by every scheme, this can be found available for free on the relevant websites of the assessment.

3.3 Case Study Introduction

3.3.1 Location

United Arab Emirates (UAE)

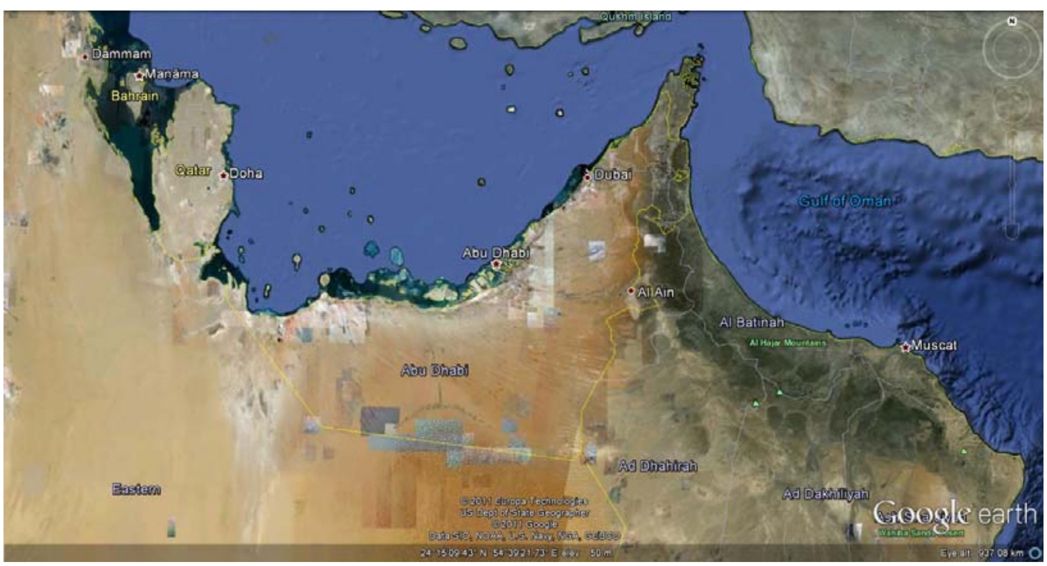

Fig 3.1 the Map of the United Arab Emirates (UAE) (Google Earth)

Located in the southeast of the Arabian Gulf, UAE is bordered by Saudi Arabia from the south and west, Sultanate Oman from the southeast and Qatar from the northeast. UAE was established in 1971 following an agreement between 7 Emirates (Abu Dhabi, Dubai, Al Sharjah, Ajman, Al Fujera and Ras Al khaimah which joined later in 1972). As of 2010 the population of UAE reached 8.26 millions with 11.5 % Emarati national (UAE Statistics Bureau, 2010), most of the population (82%) lives in the urban zones of the UAE (Abu Dhabi Tourism Authority). The economy of UAE is mainly depending on Oil exports where the oil and natural gas production represented 36% of the gross domestic production (GDP) in 2005 (Abu Dhabi Tourism Authority).

Abu Dhabi

The Emirate of Abu Dhabi Fig 3.2 is the capital of the UAE, the biggest Emirate; it occupies around 80% of the total area. Abu Dhabi is known for its massive oil reserves that drive its economy that made it a host for the major world wide oil companies and its passion of tourism and Culture where it hosts touristic attractions such as Formula one racing circuit, Ferrari world and cultural attractions such as the world class museums (Louvre and Guggenheim).

Fig 3.2 Abu Dhabi Map (Google Earth)

3.3.2 Abu Dhabi Built Environment

The Emirate is famous by its shoreline Fig 3.3 which is rich with sky scrapers and the down town area which is located close to it, also Abu Dhabi is known by its iconic mosques such as the great mosque and a world class infrastructure that encourages a lot of international companies and organizations to consider having their Head Quarters and investments in the emirate.

Fig 3.3 Waterfront of Abu Dhabi

To support their ambition for growth, Abu Dhabi and UAE had and still consuming a huge amount of energy and water, where as per UPC (2010) in their justification for Estidama initiative, UAE requires 5 planets same like earth to maintain its current life style (UPC, 2010)

Abu Dhabi Water and Electricity Authority (ADWEA) had made a forecast for the future consumption for electricity and water as per the current rate of growth, it found that demand for electricity is expected to be tripled Fig. 3.4 and nearly doubled for water Fig. 3.5 in the next 10 years. These facts all came as justification for the need for a quick transformation towards a more sustainable life style.

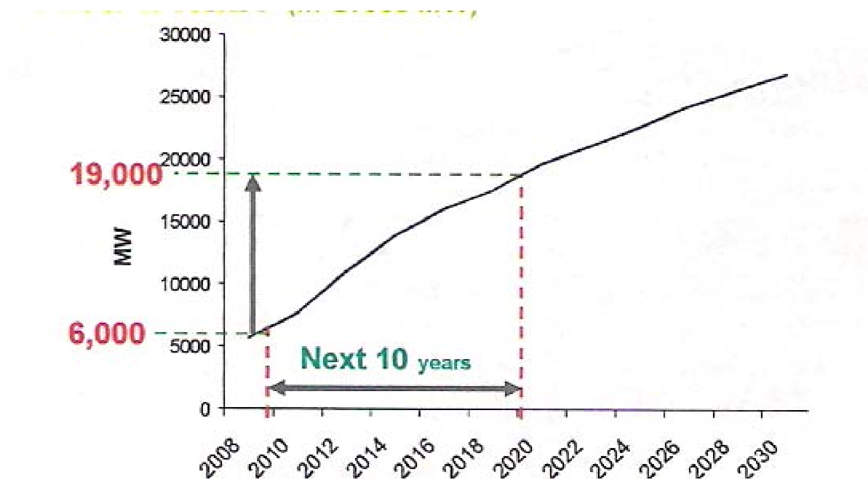

Figure 3.4 Forecast for energy peak demand for Abu Dhabi (ADWEA, 2010)

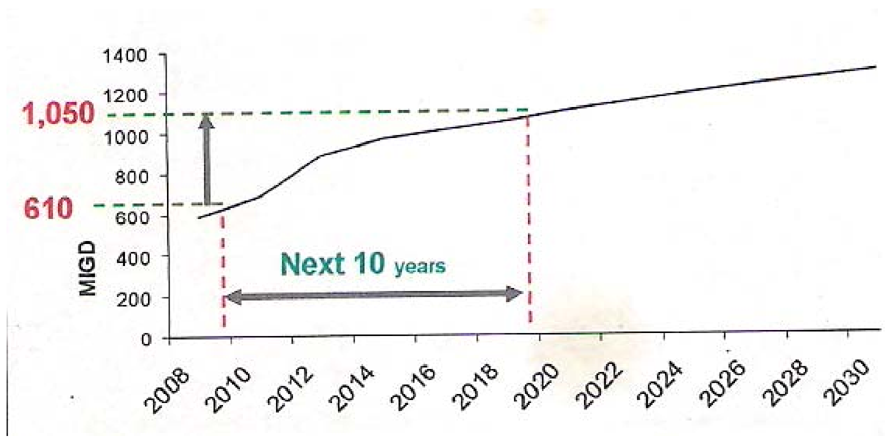

Figure 3.5 Forecast for Water peak demand for Abu Dhabi (ADWEA, 2010)

3.3.3 Current and future Green buildings codes and legislations in Abu Dhabi

The government of Abu Dhabi had the vision of transforming the emirate in to a sustainable city and to reduce the current dependency on fossil fuels, to achieve this vision they have out a future vision of the capital under the name of "Abu Dhabi 2030" which had put sustainability as an essential integrative part of every new to development under than of "Estidama initiative", one of the tools of this initiative is the Pearls Rating system, the government of Abu Dhabi had redrafted its building and planning codes to incorporate the mandatory requirements of the Pearls system , and by this any new development in the emirate must achieve at least the mandatory pearls certification before being built.

3.3.4 Abu Dhabi Climate

As per ASHRAE 90.1, Abu Dhabi climate is classified as "1B" which is "very hot and dry" and as per Köppen–Geiger climate classification system, the capital of UAE is classified as "BWh" which is "Dry: arid(deficient precipitation most of the year), Desert, Hot; arid (sub-tropical), True desert, xerophytic vegetation".

Psychometric chart was generated from Ecotect Fig. 3.6 to specify the exact comfort zone of Abu Dhabi.

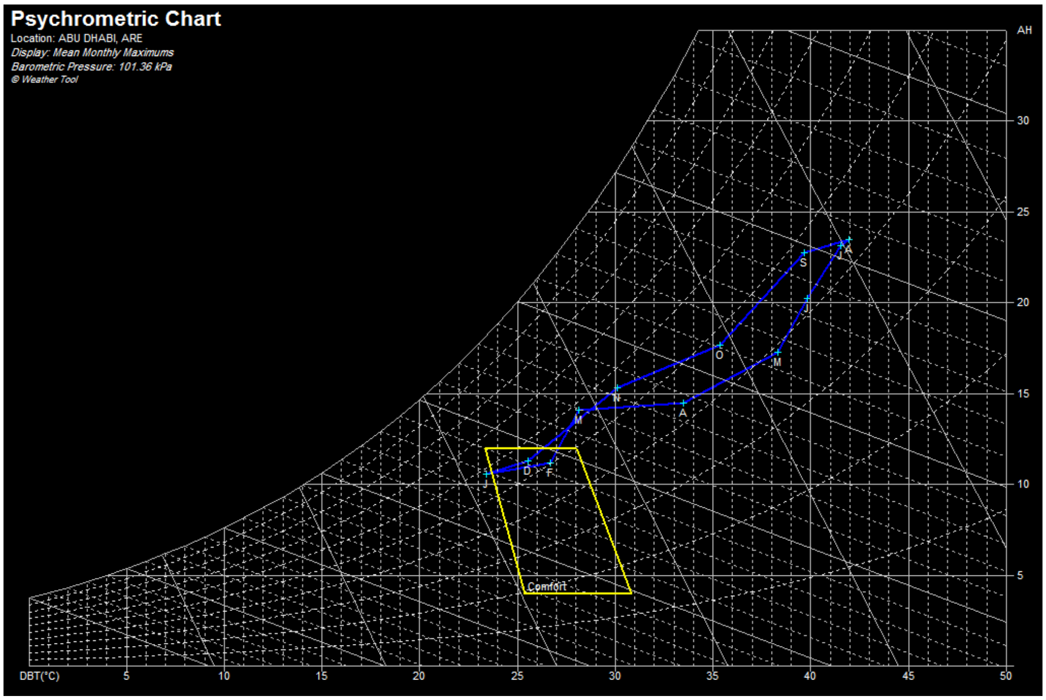

Figure 3.6 Psychometric Charts for Abu Dhabi (Generated from Ecotect 2011)

Fig. 3.6 shows that the Summer season most dominant and very hot with large diurnal range; humidity is often higher than comfortable levels while winter is warm, and as shown the average monthly maximum temperatures; and as the graph shows above, it seems like most of the year Abu Dhabi is out of the comfort zone expect for 3 months.

Wind

As per IESVE The wind "depends on distance from sea; trade winds from the east and local sea breezes. Daytime can be windless. Wind patterns: Typically strong midday/afternoon winds", wind speed average is 3.6 m/s which is "light breeze" as per IESVE classification.

Wind Rose was generated by Ecotect Fig to specify the prevailing wind directions Fig. 3.7 and wind temperature Fig. 3.8.

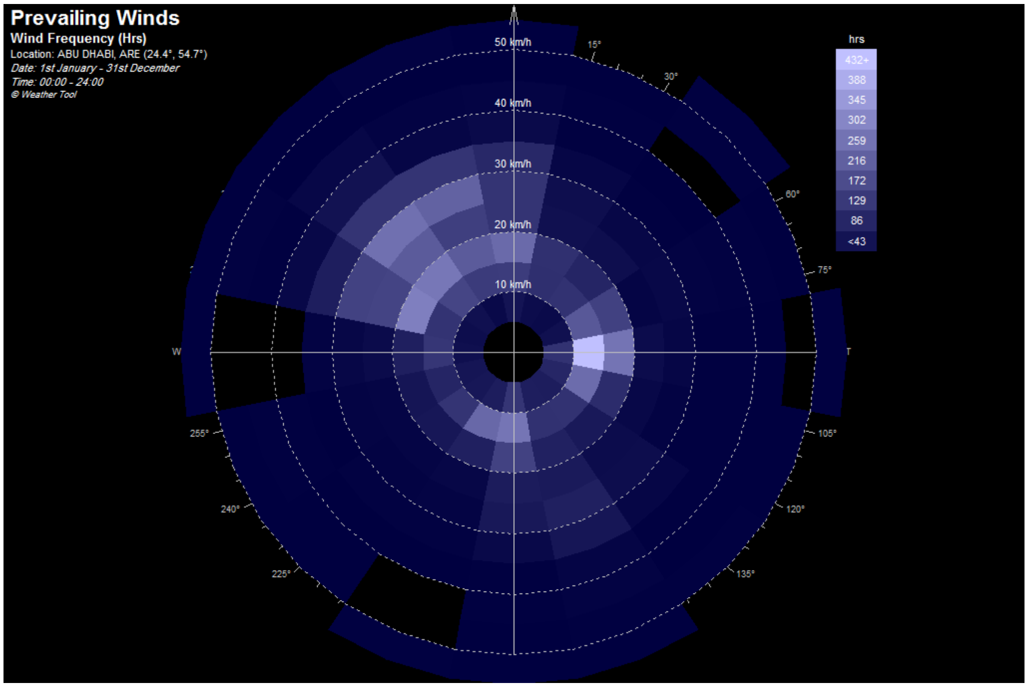

Figure 3.7 Prevailing Wind-All Year for Abu Dhabi (Generated from Ecotect 2011)

Fig. 3.8 shows that the temperature of the wind is relatively high most of the year which may require insulation and reduction of infiltrations inside buildings.

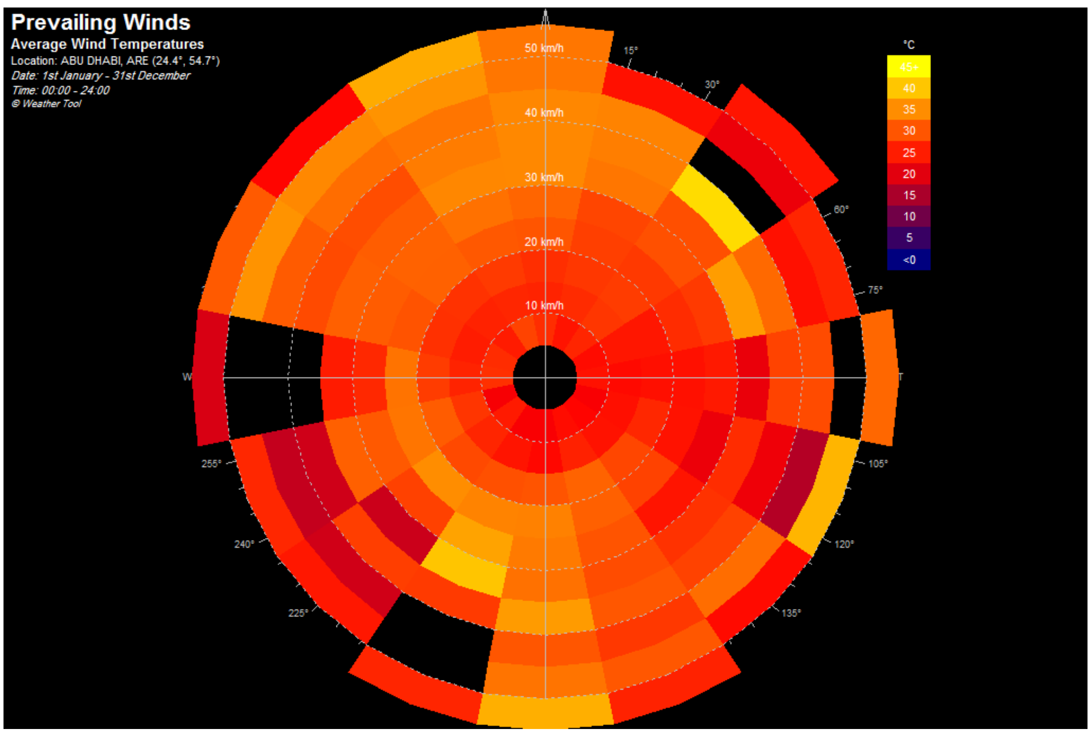

Figure 3.8 Prevailing Wind- Temperature-All Year for Abu Dhabi (Generated from Ecotect 2011)

Temperature

Fig. 3.9 shows the climate summary metris generated from IESVE, it shows that highest annual temperatures are 47c at July and the lowest is 5c at February. As per the Fig. 3.10 its clear the daytime will be in hot stress in most of the year.

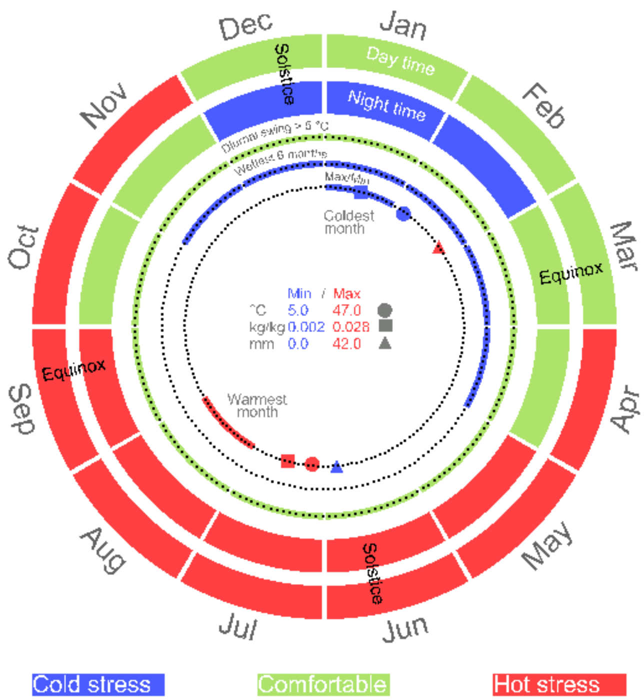

Figure 3.9 Climate Summary Metrics (Generated from IESVE 2011)

3.3.5 Case study Building Description

The selected office building for the case study aimed to be representative to the current construction market of office buildings in Abu Dhabi. The selected office building consists of 4 typical office floors, mezzanine floor, and ground floor.

The architecture of the building can be described as "modern"; it is a simple rectangular shape with no balconies and with typical floor area equals 446 sqm and total area equals around 3370 sqm

Most of the building is covered with glass which is a common feature in most of the office buildings in Abu Dhabi with some metal panels, and the side elevations are fully solid of metal panels

Chapter 4

Case Study

Configuration and Assessment Tools

4.1 Overall Environmental Assessment of the case study building

The current design of the building will be assessed against the three selected schemes Pearls rating scheme, LEED and BREEAM. This initial assessment will determine whether the case study building which was designed and built before the issuing of Estidama is good enough to be certified under the environmental assessment schemes which are currently available and used in the UAE Market.

4.1.1 Pearls rating system

Estidama had developed an excel sheet "scorecard", where the project team can put the targeted points at every credit. The scorecard is divided into basic information part and technical detailed part, and a summary part that concludes the assessment results from points and the achieved certification level.

To be able to fully fill the assessment, several steps is required such as (Energy Modeling) and the use of some PRS customized calculators for (Water, Waste), and the involvement of some specialists as a third party review such as (Commissioning Agent, Urban Assessor, Cost Analyst).

The first step in the assessment is to set targets on the scorecards by choosing specific credits, a sample of the scorecard is in (Appendix 1, Table 1). After choosing the required credits, the assessor can review the summary part of scorecard. This summary part includes several graphs and bar charts graphically explaining the building assessment.

4.1.2 LEED

LEED has nearly same style of assessment of Pearl Rating System, a downloadable excel sheet under the name of "Checklist" is available in the USGBC website as a tool for assessment. The Scorecard consists of two sheets, the first one is a one page summary of LEED credits and targets, the second sheet is the detailed credits, sample for LEED Score card is in (appendix 1, Table 2).

4.1.3 BREEAM

Similar to LEED and Pearls, BREEAM has its own customized pre assessment tool (Appendix 1, Table 3) with more interactive design to facilitate the pre assessment process. The tool is in an excel format and starts with five introductory questions such as scheme selection, building information. After completing the introduction section, the excel file opens two spread sheets, one for the assessment details where the assessor puts information such as project name, team, client, and the other spreadsheet shows the detailed credits of BREEAM.

4.2 Energy Model Setup and Validation

4.2.1 Model Description

The case study building is a Ground+Mezzanine+4 floors mixed use (Office and residential building, the dimension of the building footprint is 24m x 18 m and the total height is 30m, the building has two solid sides and two side half glazed, half solid. The floor areas are varying from 373sqm in the ground floor to 443 in the 4th floor. The model has been simplified to increase the speed of simulation runs; the simplification was done by removing the internal walls (Figure 4.1 and 4.2).

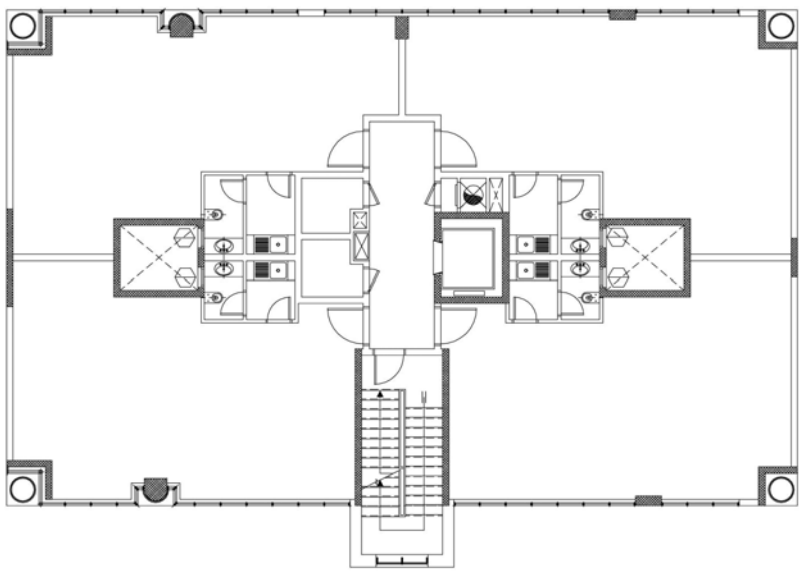

Figure 4.1 Project floor Plan before simplification

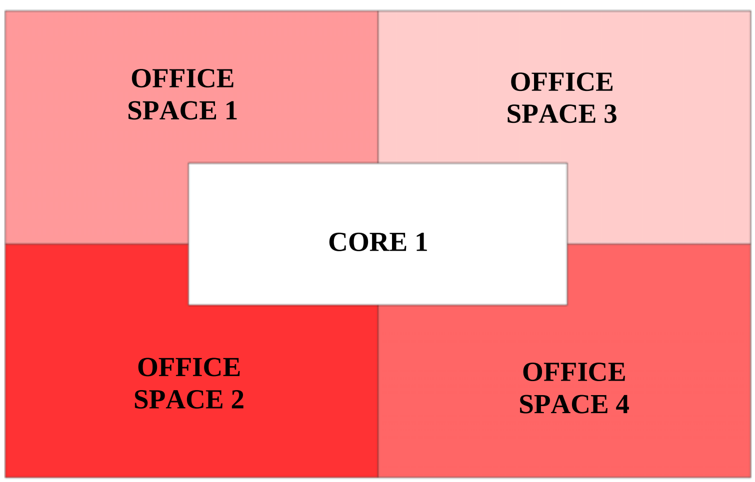

Figure 4.2 Project floor Plan after simplification

3 Models had to be prepared in order to perform the energy analysis, the Actual, the baseline of LEED and Pearls rating system and the baseline of BREEAM.

Step1. Sketch Up Modeling

The Model has been built in Google sketch 6, this program is an architectural program with compatibility with the environmental analysis software IESVE, and it has added some features under the name of IES in its main tool bar, features such as building template where the user can choose the location, building construction, type of HVAC system used and the use of the building, then there is the export to IES where is convert the model to thermal volumes ready for energy simulation/calculations in IES (Figure 4.3).

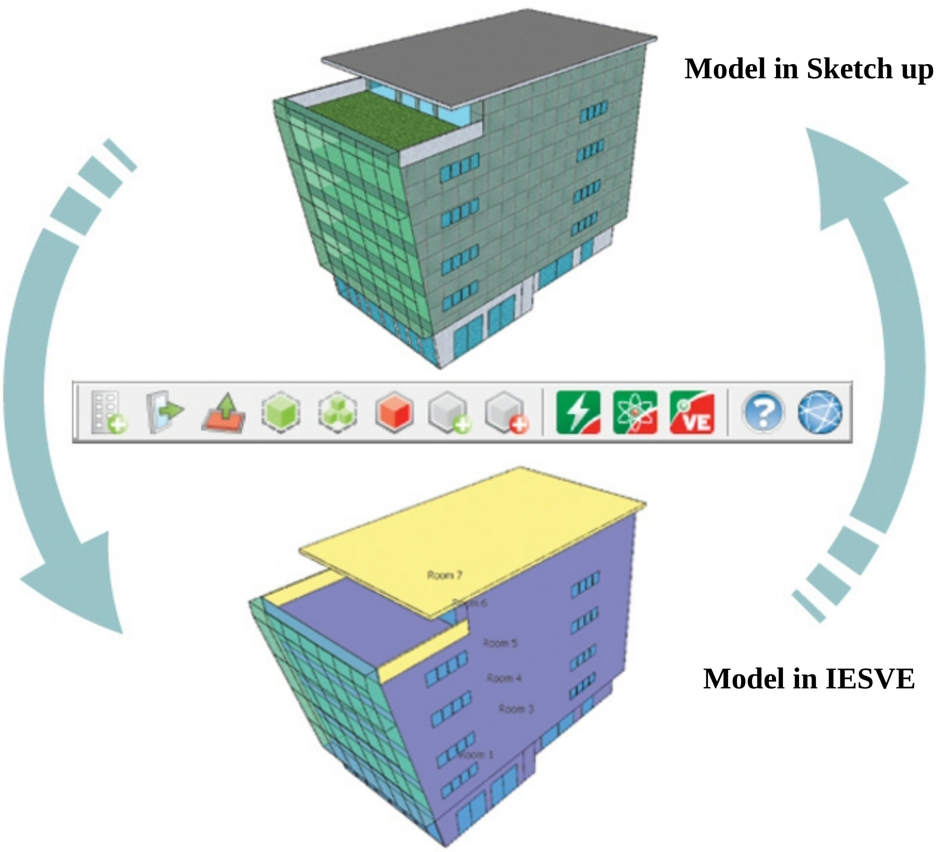

Figure 4.3 IES-Sketchup Plugin

Step2. IESVE Modeling

IESVE is Environmental Modeling and analysis software, and it is used for the energy analysis because it is complying with the requirement of LEED, BREEAM and Estidama Energy Modeling software requirements (Roderick, 2008) ; the software can perform multiple Environmental studies such as Shadow studies, Energy load calculations, and thermal analysis, cost and CO2 calculations through simple steps.

Finishes

Actual

The finishes of the case study were extracted from the building consultant and it is as shown in Table 4.1.

LEED/PRS/BREEAM Baseline

As shown in Table 4.1, the baseline of the LEED and PRS schemes is based on ASHRAE 90.1-2007 which sets the following U-values as a maximum, and BREEAM follows NCM standard.

Table 4.1 – Case study Construction and finishes

		Actual	ASHRAE 90.1-2007	NCM
			LEED/PRS	BREEAM
No.	Construction	U-value (W/m2K)	U-value (W/m2K)	U-value (W/m2K)
1	External wall	0.35	0.4996	0.35
2	Ground floor	0.016	1.1	0.25
3	External glazing	1.9	6.9326	2.2
4	Roof	0.25	0.36	0.25
5	Door	2.32	2.32	2.32
6	Internal wall	1.47	1.47	1.47
7	Ceiling	2.14	2.14	2.14

HVAC System

Actual

There is no heating system in the building, the cooling system is “Ducted Split Unit”, a refrigerant based system, this system is named also unit to unit system, because every indoor unit has a separate outdoor unit, fresh air supply comes as a different supply. This system is conventional in this type of buildings in Abu Dhabi because its unitary system, it allows the owner to divert all it expenses directly to the tenants.

HVAC Schematic from IES

In order to properly evaluate the energy performance of a building, it is essential to model in details the HVAC system. As shown in Fig. 4.4 the actual HVAC system for the case study was modeled in details for performing the energy calculations showing two cooling coils per thermal zone. The dotted line around the schematic is named "multiplex" which allows multiplying the system on all the spaces of the model.

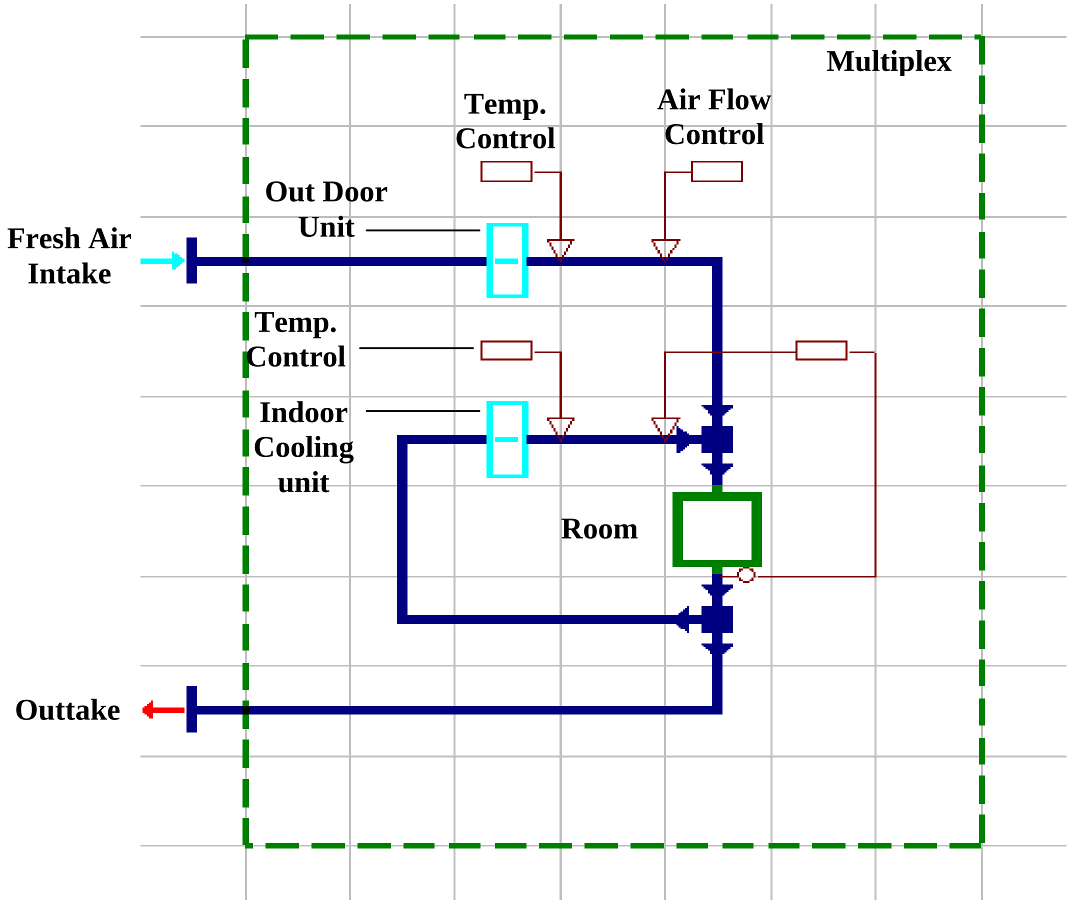

Figure 4.4 Actual System Schematic from ApacheHVAC

.LEED/PRS

The baseline of the LEED and PRS is based on ASHRAE 90.1-2007 which sets the following HVAC systems, as per the mentioned standard the HVAC baseline system must be VAV+PFP , IES has a preset templates for the baselines of ASHRAE which was used in this study. (Figure 4.5)

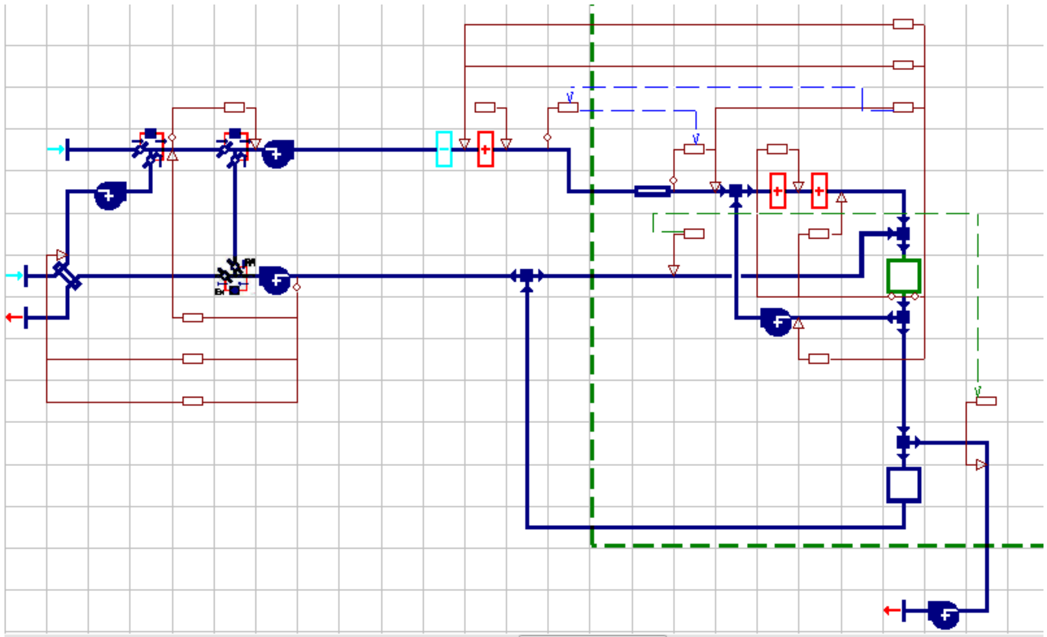

Figure 4.5 HVAC LEED Baseline Schematic from IES

BREEAM

The baseline model of BREEAM is named “Reference Building” and based on National Calculation Methodology (NCM), Heating fuel type must be gas. Heating SCoP must be 0.73 and auxiliary energy must be taken as 0.61W/m2. Cooling set point is fixed at 27 oC and the cooling SSEER must be taken as 2.25. As per National Calculation methods (NCM), the design of BREEAM reference building shall be the same as the actual but with different inputs for finishes as shown in Table 4.1 and source of energy shall be gas.

Due to the complexity of the HVAC systems design and level of accuracy of modeling which is required by the LEED, BREEAM and PRS to calculate energy performance and the requirement of the input of an expert HVAC design engineer, only actual case and its baselines was be modeled.

Lighting

Default lighting of the software will be used which is fluorescent 60x60 lighting tiles; the lighting levels will be estimated at 500 lux

Weather Data

The Environmental Analysis software IES has a built in weather and climate analysis tool under the name "AP Locate", its data is based on standard tables published by CIBSE and ASHRAE. The chosen case study is in Abu Dhabi, IES has four files for Abu Dhabi the closest one to the case study site is "Abu Dhabi, Al Bateen Airport, UAE. ASHRAE Fundamental Design Weather Data".

"The weather file has values of the following variables measured at hourly intervals over a year: Dry-bulb temperature, Wet-bulb temperature, Direct beam solar radiation, Diffuse solar radiation, Wind speed, Wind direction, Cloud cover "

Orientation and time

The building actual orientation is facing North West as show in Fig. 4.6; it will be simulated once on its actual orientation and another 4 simulations facing each (north, east, south, and west) to take the average that represents the Baseline case for LEED and Pearls Rating, this is required to be able to calculate the percentage of energy saving.

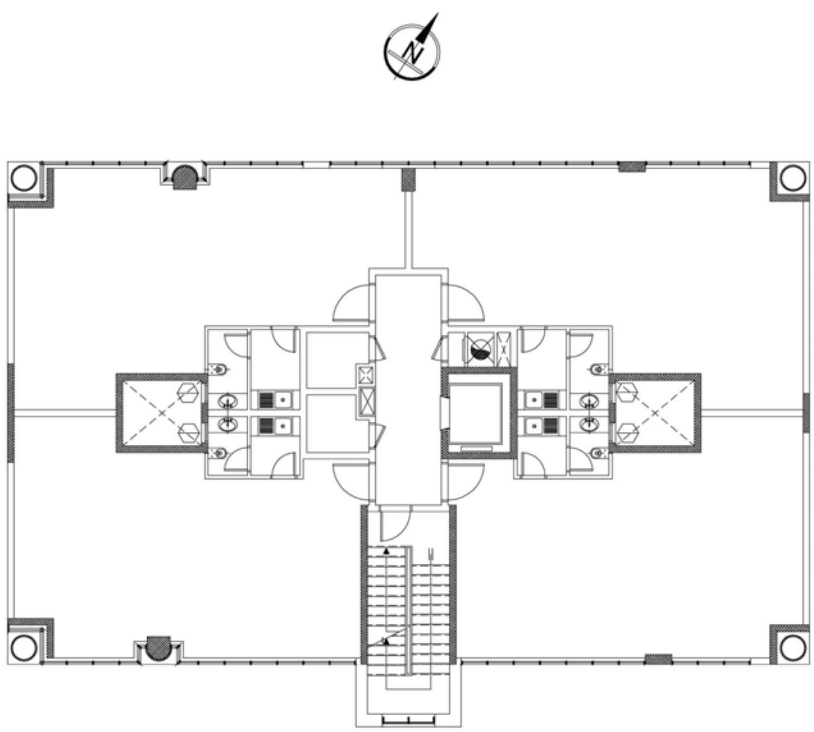

Figure 4.6 Actual Orientation

Operational times

Building Office operation time will be following common operation times in Abu Dhabi (8am to 6 pm) as shown in Fig. 4.7 with Friday and Saturday off. However some systems are designed to remain on 24 hours such AC system and that even if no one is in the space.

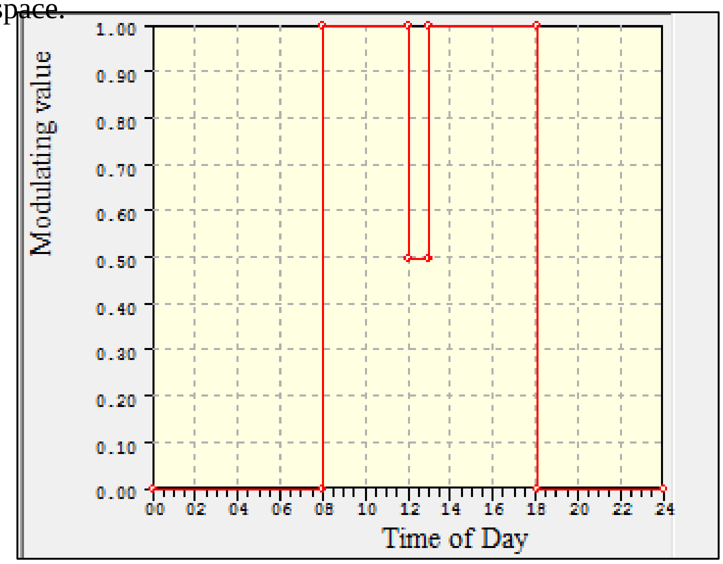

Figure 4.7 Daily operational profile (8am to 6pm with lunch break)

4.2.2 Simulation configuration

3 Models have been made to perform the energy calculations required from the dissertations:

1- Actual Model: this will be modeled as per the actual design, some simplification will be done on the internal partitioning of the building to increase the simulations speed.

2- Pearls rating / LEED Baselines: the two baselines of LEED and Pearls are the same and following ASHRAE 20.1-2007 Appendix G, the building will be simulation in 4 different orientations (North, East, South and West), average will be taken and compared with the actual model to calculate the energy performance. Materials and construction must follow the specified U-Values in ASHRAE.

3- BREEAM Baseline: a reference building will be modeling for the calculations of this scheme, Materials and construction must follow the specified U-Values in National Calculation Methodology (NCM), orientation shall be the same as the Actual design.

4- Validation Model: a full detailed floor will be model in two softwares as a validation for the calculations.

4.2.3 Modeling Process

The result of the modeling is below and as shown in Fig. 4.8 and Fig. 4.9

Energy/Carbon Simulation:

- Building floor area 2160.00 m2
- Conditioned floor area 2160.00 m2
- Unconditioned floor area 0.00 m2
- Number of rooms 30

Analysis Details:

- Location: Abu Dhabi Bateen Airport :1 :N.A. :N.A., United Arab Emirates (24.43N,54.47E)
- Climate file: AbuDhabiIWEC.fwt
- Calculated: 07/Jan/2012,23:08
- Calculation Period: 01/Jan - 31/Dec

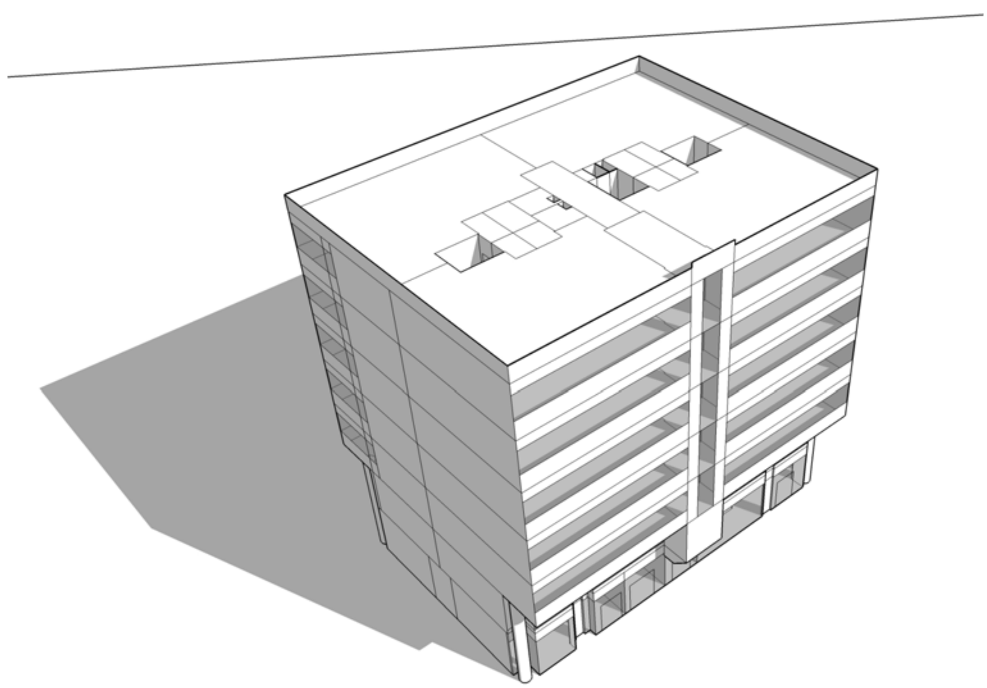

Figure 4.8 Sketchup Model of the Case Study

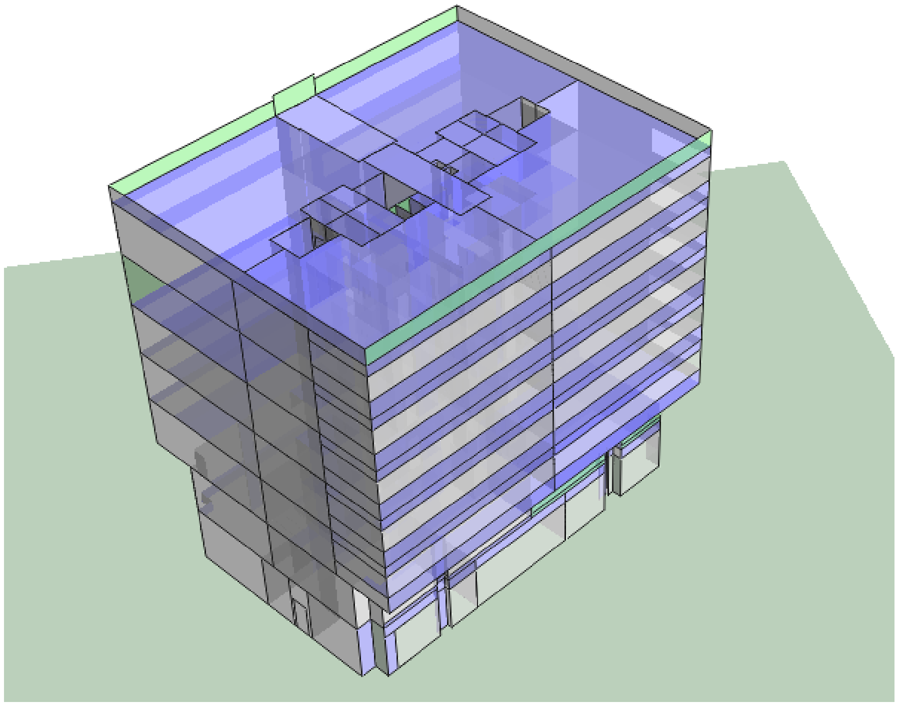

Figure 4.9 IES Model of the Case Study

4.2.4 Model Validation

Two approaches had been taken to validate the energy model. The first one is reviewing the modeling it self, this was done by forwarding to the (IES), the creator of the software model to review the building overall modeling including its systems and inputs and auditing the results.

The Second approach was to check the results with the commonly used software in energy consumption analysis in Abu Dhabi which is "Carrier HAP", this was done by forwarding the same input data of the model to an MEP Engineer in a consultant office in Abu Dhabi “Hanover” to perform a energy load calculations for a sample space in the building which was one of the shops shown in Fig. 4.10.

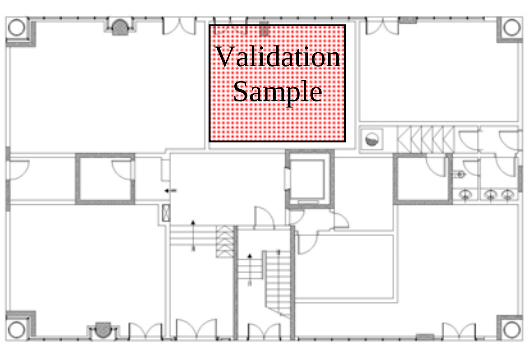

Figure 4.10 The validation sample space

MEP Engineer results generated from HAP shows that this space consumes around 33.4 MWh annually (Appendix 3, Table 4.1), the study model results shows that this space consumes 33.8 MWh (Appendix 3, Table 4.2).

4.3 Water Demand

To be able to estimate the water consumption a formula shall be used to calculate the number of full time users for the building, in LEED and PRS its known as Full Time Equivalent (FTE), only BREEAM has a default occupancy rates related to the occupied areas.

4.3.1 Actual Input Data

Actual Input Data

- Actual Water Fixtures performance.
    1. Water Closets 6 liters per minute (single flush)
    2. Water Taps 6 litres/min at 413.7 kPa (reference pressure)
- There is no exterior use for water or irrigation.
- Full Time Equivalent (FTE) = 280

4.3.2 Pearls Rating System Water Calculator and Baseline Input data

The pearls system has customized Calculators (Appendix 2, Table 1) downloadable free from the website of Estidama. The water consumption depends on comparing the actual or the design case to a baseline case. The inputs are **Full-Time Equivalent (FTE)** and transit occupant and appropriate water fixture flow and use. The calculator is organized in 7 steps; the user has to fill it by providing information such as project details, occupancy type, schedules, interior water consumption, exterior water consumption and water balance. After filling the steps the results can be shown in three summary tabs.

Baseline Input Data:

- PRS Baseline For Water Fixtures
    1. Water Closets 6/4 liters per flush (Full/Half)
    2. Water Taps 1.9 litres/min at 413.7 kPa (reference pressure)
- There is no exterior use for water or irrigation.

- Full Time Equivalent = 280

4.3.3 LEED Water Calculator and Baseline Input data

The water credits in LEED have the same concept as the Pearls system in calculation the water consumption; a water consumption calculator is available for download after registering a project in LEED online. (Appendix 2, Table 2)

Baseline Input Data:

- LEED Baseline For Water Fixtures
    1. Water Closets 6 liters per Flush (Full)
    2. Water Taps 1.9 litres/min at 413.7 kPa (reference pressure)
- There is no exterior use for water or irrigation.
- Full Time Equivalent = 280

4.3.4 BREEAM Water Calculator and Baseline Input data

The water calculation for BREEAM will be done with Wat 01 credit template (Appendix 2, Table 3). In BREEAM water calculators uses "default usage and occupancy rates to provide a benchmark of the typical consumption given the specified fittings (in litres/person/day and m3/person/year) and their impact on the buildings overall water efficiency" (BREEAM, 2011), it compares the (litres/person/day) in design case to the record baseline values.

4.3.5 Benchmarking the potable water saving assessment process between PRS, LEED and BREEAM

The water calculators of the three schemes shows that the strategies that are contributing to the potable water savings are different as shown in Table 4.2.

Table 4.2 Strategies that contributes to potable water saving calculation per scheme

Potable Water Use Reduction	PRS	LEED	BREEAM
Using low flow fixtures	x	x	x
Using Rainwater	x		x
Using Onsite treated Grey water	x		x
Using Municipal treated Grey water	x		

The potable water consumption assessment shows that PRS is most flexible and accept more strategies that contributes to potable water saving then comes BREEAM that awards for the same strategies expect for Municipal supply of grey water, while in LEED any use for recycled water is awarded in different credit “Innovative Waste Water Technologies “and not related to water use reduction calculations awards.

Chapter 5

Case Study Assessment

Results and Disscusion

5.1 The Assessment

To conduct the overall assessment of the case study building, several steps have to be done prior to it such as energy modeling, water calculation, construction and operational waste generation. For the scope of this study only the energy and water calculations part will be conducted before the step of the overall assessment.

5.2 Energy Simulation

A common between PRS/LEED and BREEAM, is the importance that these schemes give to energy efficiency; in fact one of the highest emphasis in these schemes is for energy. In order to be able to measure and compare the energy performance of the case study building, an energy simulation has been conducted using IES energy modeling software as explained in the methodology.

5.2.1 Actual Design Model

Actual Design Model

The actual design model has been simulated and was found that the annual energy consumption of the building as 951 MWh. Full results is shown in (Appendix 3, Table 1.1).

5.2.2 Pearls Rating System (PRS)

As a partial requirement for a getting certified under PRS, "RE-R1, Minimum Energy performance" required credit has to be assessed. As per PRS there are two paths for analyzing the performance, one is the "prescriptive method" for buildings less than 5000 sqm of total area, and the "performance method" where and energy model has to be done, one as per the design and one as baseline to measure the energy performance. The case study building qualifies to be studied under the two methods; however the performance method will be used of the study; the reason is that performance method is an available method in the PRS, LEED and BREEAM which allows that comparison between the three schemes.

The comparison between the different methods of energy performance credits in PRS is a topic that requires further study in more details in future studies.

<u>Baseline Model</u>

The year energy consumption of the building was simulated four times with different orientations and the results show that the average annual energy consumption for the baseline case equals 669 MWh for Estidama, detailed report is attached in (appendix 3, Table 2)

When the Baseline case is compared to the Actual design case it appears that the case study building performance is having the same performance of the Baseline and the improvements required by PRS required credits is 12 %, in the annual energy consumption, therefore the actual case is not fulfilling the minimum requirements.

As explained the majority of the energy in the case study was consumed in the HVAC system which is a "Ducted Split Unit" which has a constant supply of air no matter the occupancy or activity level, while in the Baseline case as per ASHRAE a VAV system with and economizer is used which resulted to significant reduction in the energy consumption.

5.2.3 LEED

As a prerequisite, any building applying for LEED must fulfill the mandatory requirements of " EA Prerequisite 2: Minimum Energy Performance ". This credits as options for calculating the energy performance, the case study building qualifies for option 1 " Whole Building Energy Simulation " and option 2 " Prescriptive Compliance Path: ASHRAE Advanced Energy Design Guide ", option 1 will be used for the energy performance analysis. Baseline model of LEED is prepared as per ASHRAE 90.1-2007 same as PRS, the Energy tariff in Abu Dhabi as per ADDC is (0.15 dhs per KW/h). The total annual energy cost for the Actual case is AED 142,650 while the baseline case equals AED 100,222 this means that the building systems used in the actual case study are not performing as or better than ASHRAE standards which is mandatory for LEED compliance. (Appendix 3, Table 2)

5.2.4 BREEAM

The building energy performance in BREEAM is calculated as per its Carbon emissions to fulfill the credit "Ene 01 Reduction of CO2 emissions", this credit is only mandatory for buildings targeting starting from "Very Good". Baseline model for this credit is calculated as per NCM. The results show that the average annual energy consumption for the baseline case equals 71.9 tones of total carbon emissions (Appendix 3, Table 3), the carbon emissions of the actual case 207 tones (Appendix 3, Table 1.2) which is far more than the baseline case and not achieving any points under BREEAM

Findings

It was found from the case study analysis towards the three baselines of PRS, LEED and BREEAM that it’s not achieving the minimum requirements of these schemes and with HVAC the major component of the energy consumption, a major design upgrade is essential for improving the overall performance of the building.

The building system's operational schedules must be adjusted as per the requirements of the occupants while in the actual case it's on 24 hours, more energy efficient HVAC systems shall be installed instead of the current unitary system.

Lighting can be an area of energy saving but in the higher levels of certifications, this can be done through by techniques such as adding occupancy sensors and providing task lighting for desks.

5.3 WATER CALCULATIONS

One of the most critical issues in the Middle East is water, PRS has responded to this fact and made water credits equal to energy credits the highest percentage "25%", and although water consumption reduction is mentioned in LEED and BREEAM but it in a reduced importance.

As an office building and since the HVAC system is air cooled, the main water consumption of the building comes from Bathroom taps and toilets.

5.3.1 Pearls Rating System (PRS)

To check the compliance of the case study with the Precious water required water credits of improved water consumption, the Water Calculator template of PRS has been used, the case study building failed to pass the mandatory requirements, where the building is using 2,111,760 litre per year while the baseline is only 1,234,884 litre per year. (Appendix 2, Table 4)

The actual used water fixtures is high consuming, where the toilets have a single flush only and used taps is exceeding the baseline flow rate of taps, where the actual taps flow rate was (6) l/min while the baseline was (1.9) l/min.

Although the building did not achieve the mandatory credits it managed to score over all of (18) points in water saving due to other strategies such as the absence of exterior landscaping, water fountains and the use of air based chillers which are all awarded in PRS.

5.3.2 LEED

Although LEED gives less attention to water issues than PRS as it dedicates only 5.5% of its credit points to water, but still it has it as a prerequisites where any project can't get certified with proving to save more than 20% of the baseline case.

The WE-P1 calculator was used for the calculations of the baseline and actual case of the case study building, from the results (Appendix 2, Table 5) the building failed to achieve the minimum requirement of LEED which is saving 20%, the baseline was 265.44 (KGal) and the actual consumption is 376.32 (KGal)

The baseline flow rates of LEED are the same as PRS, therefore the same remark was observed which is that the actual used flow rates for Taps and Toilets is higher than the baseline.

5.3.3 BREEAM

BREEAM is least in the three schemes in addressing the water consumption issue where 2.5% only of the credits are related to water, probably because it was designed for UK where there is no problem in the availability of water but more in the energy consumption. The current design of the building failed to achieve any points under BREEAM as it must achieve a minimum of 12.5% and it only managed to achieve 12.05% (Appendix 2, Table 6), however water saving isn't a mandatory requirement to achieve the minimum ratings of BRREAM but required for upper levels of certifications.

Findings

The analysis of the case study building towards the three baselines of PRS, LEED and BREEAM showed that it's not achieving the minimum requirements of the first two systems in the Water consumption, for BREEAM the building can get the lowest certificate without having water saving measurements. The main reason for the bad performance of the case study was the used water fixtures where it’s highly exceeding the baseline.

It was also noticed that although the baseline flow rates of PRS and LEED, FTE and days of operation are the same, still the baseline performance of LEED is 1,003,167 Liter which is less than that of PRS which is 1,234,884 litre, the reason for this is that in PRS water calculator it has a default value for visitors added automatically which increases the overall consumption of water.

The approaches that can be used to reduce the water consumption is variable, it can be done by specifying new fixtures that has lower flow rate or by adding regulators to the existing fixtures, another technique is by using recycled water to be used in the toilet flush instead of using potable water.

5.4 OVERALL ASSESSMENT RESULTS

Initial assessments had been conducted to the case study building using the relevant scorecards for Pearls Rating System, LEED and BREEAM, it has been conducted after the energy and water consumption calculations which is required for compliance with some energy and water credits, below is the results:

5.4.1 Pearls Rating System

As shown in Table 5.1 and 5.2, the case study building with its current design and specification failed to achieve the lowest level of the scheme which is (1 Pearl).

The building failed to achieve half of the required credits 10 out of 20, the failed required credits are mentioned in Table 5.1:

Table 5.1 PRS assessment: non achievable required credits

Environmental Aspect			Credits
IDP: Integrated Development Process			
	IDP-R1: Integrated Development Strategy		Not Achieved
	IDP-R2: Tenant Fit-Out Design & Construction Guide		Not Achieved
	IDP-R3: Basic Commissioning		Not Achieved
PW: Precious Water			
	PW-R1: Minimum Water Use Reduction		Not Achieved
RE: Resourceful Energy			
	RE-R1: Minimum Energy Performance		Not Achieved
	RE-R2: Energy Monitoring & Reporting		Not Achieved
	RE-R3: Ozone Impacts of Refrigerants & Fire Suppression Systems		Not Achieved
SM: Stewarding Materials			
	SM-R1: Hazardous Materials Elimination		Not Achieved
	SM-R2: Basic Construction Waste Management		Not Achieved
	SM-R3: Basic Operational Waste Management		Not Achieved

Nearly all of the not achieved credits are directly related to the used MEP systems, while the rest is partially related. Some credits were not achieved due to absence of specialist such as the credit of “Basic Commissioning” was not possible to achieve as it’s a third party review to be done by a professional "commissioning agent" which wasn't available or required at the time of the design of the building.

Waste Management concepts were known at the time of the building design but were not mandatory or popular to the market as it was considered as a cost added.

Still the case study building managed to achieve some required credits such as:

Table 5.2 PRS assessment: achieved required credits

Environmental Aspect			Credits
NS: Natural Systems			
	NS-R1: Natural Systems Assessment		Achieved
	NS-R2: Natural Systems Protection		Achieved
	NS-R3: Natural Systems Design & Management Strategy		Achieved
LB: Livable Buildings			
LBo: Livable Outdoors			
	LBo-R1: Plan 2030		Achieved
	LBo-R2: Urban Systems Assessment		Achieved
	LBo-R3: Outdoor Thermal Comfort Strategy		Achieved
LBi: Livable Indoors			
	LBi-R1: Healthy Ventilation Delivery		Achieved
	LBi-R2: Smoking Control		Achieved
	LBi-R3: Legionella Prevention		Achieved
PW: Precious Water			
	PW-R2: Exterior Water Monitoring		Achieved

As shown in Table 5.2, almost all of the fulfilled required credits were not due to design compliance but was due to non applicability or accidentally complying. The first three credits of the natural assessment are only activated when the building is built on a Greenland or an ecologically important site. The fourth and fifth mentioned credits are related to the site potentials such as being close to services and public transportation. Another set of credits were achieved due to the absence of its point of concern such as (not using water fountains, the absence of exterior landscaping and swimming pools).

The only achieved points through actual intentional design initiatives were the required credits of “Healthy Ventilation Delivery” and “Smoking Control”, where the local codes already requires compliance with it.

Assessment shown in Table 5.3 shows that the case study building failed to score a single point under the 5 categories of PRS:

Table 5.3 PRS assessment: Categories with no points achieved

Environmental Aspect		Possible	Achieved
IDP: Integrated Development Process		13	0
NS: Natural Systems		12	0
RE: Resourceful Energy		44	0
SM: Stewarding Materials		29	0
IP: Innovating Practice		6	0
Total		104	0

However the case study building had succeeded to score total of 24 points of available 177 points, 6 points in the section of LB - Livable buildings and 18 points only under the section of PW – Precious Water.

Although the building envelope construction and U-vales are better than what's required by ASHRAE, still the systems of the building cannot be considered as energy efficient and affected the overall energy performance of the building, for instance the HVAC system is ducted split system, this system saved water as it uses air for cooling but still its wasting energy as its most of the time on with the a constant rate of refrigerant supply.

For the Indoor Air Quality that the building will more likely have a partially good Indoor Air quality due to achieve the credits of minimum ventilation and daylight levels but from the materials side, it may be a risk as low VOC materials were not specified.

Therefore to get this building successfully certified at least with the lowest level of PRS which is (1 Pearl) around 20 required credits, major design changes are needed to be done to the building and with Water and Energy credits representing a 50% of the PRS system, strategies such as upgrading the HVAC and plumbing systems seems essential to get certified. But for the first Pearl level, its not only about deign and site assessment, it also requires the involvement of specialists which Commissioning agent, Urban Assessor and an Ecologist, the first one is to review the building systems as per the owner project requirements, the second and the third to analyze the impact and integration of the project with the surrounding urban and environment.

In order to target more points and to get certified as 2 Pearls or more (more than 60 points) more work has to be done especially to get the first 60 points, this level seems to be the hardest as it includes the introduction of new initiatives to the building design while to get more than 2 Pearls seems to be easier, because the differences between the higher Pearls tend to be less (from 25 to 35 points) and using almost same achieved credits but with increasing the percentage of achieving these credits.

5.4.2 LEED

The Case study building had been assessed as per LEED criteria where a building must fulfill 10 prerequisites plus scoring 40 points.

Table 5.4 LEED assessment: Non achievable Prerequisites

Environmental Aspect		Credits
Sustainable sites (SS)		
	SS-Pre1: Construction activity pollution prevention	Prerequisite
Water efficiency (WE)		
	WE-Pre1: Water-use reduction	Prerequisite
Energy and atmosphere (EA)		
	EA-Pre1: Fundamental commissioning of the building energy systems	Prerequisite
	EA-Pre2: Minimum energy performance	Prerequisite
	EA-Pre3: Fundamental refrigerant management	Prerequisite
Material and resources (MR)		
	MR-Pre1: Storage and collection of recyclables	Prerequisite

As per Table 5.4 the building failed to get at least certified under LEED due to the failure to achieve at least the prerequisites and the required minimum points, but managed to achieve the prerequisite of the Minimum Indoor Air Quality Performance and the Environmental Tobacco Smoke (ETS) Control.

Table 5.5 LEED assessment: points Achieved

Environmental Aspect		Possible	Achieved
Sustainable sites		26	14
	Site selection		1
	Development density and community connectivity		5
	Public transportation access and use		6
	Parking capacity		2
Water efficiency		10	4
	Water-efficient landscaping		4
Indoor Environmental Quality		15	2
	Daylight and Views—Daylight		1
	Daylight and Views—Views		1
Total		110	20

Similar to the Pearls, the design of the HVAC and plumbing systems were the main defects that led to not achieving the Prerequisites of LEED, also failing to achieve minimum 40 points was another defect which was partially achieved as only 20 points as mentioned in Table 5.5, it was noted also that although water consumption failed in prerequisite, still it was possible to achieve 4 points under water category due to absence of Landscaping.

The case study building failed to score any points under:

1. Energy and Atmosphere
2. Materials and Resources
3. Innovation and Design Process
4. Regional Priority Credits

With LEED having the highest emphasis on Energy (35 points) the core improvements in the Case study building shall be related to the HVAC systems accompanied with a wide selection of other credits related to Water, Materials and IEQ, very limited can be done to sustainable sites credit as most of it is not related to the design such as site selection, connectivity or public transportation.

5.4.3 BREEAM

The Case study we assessed as per the BREEAM 2011 assessment tool and failed to achieve the lowest certification level which is PASS (30 % including the mandatory credits).

Table 5.6 BREEAM assessment: achieved points

Environmental Aspect	Credits
Health and Wellbeing	
At least 80% of net lettable office floor area has adequate daylight	1.15%
Evidence provided demonstrates that all desks are within a 7m radius of windows	1.15%
Evidence provided demonstrates that an occupant-controlled glare control system	1.15%
Transport	
Good access is available to and from public transport networks for commuting	2.40%
Good access to Local amenities	0.80%
Land use	
Evidence is provided to demonstrate that the construction zone is defined	1.00%
as land of low ecological value	
Total	7.65%

As shown in Table 5.6. The case study managed only to score 7.65 % of the total credits where is required to achieve at least equal or more than 30% including the mandatory credits, in spite of the achieved percentage still the building failed to achieve any of the mandatory credits required for the PASS grade.

Similar to LEED/PRS In order to get the building certified with BREEAM it’s essential to do multiple revisions to the HVAC system as the energy consumption is representing 33 % of BREEAM credits. Water credits have a minor importance around 2.5% and not Mandatory in the lower certification level. IEQ and Materials selection would be the second effective design changes after the HVAC Upgrade.

5.5 The Actual Design Case Assessment Conclusion

In the light of the results of the assessment of the case study building, it appears that the legislations or building codes in Abu Dhabi weren't enough to guide the building owners with their team of consultants and contractors to produce what we can call a green energy efficient building which is healthy for its occupants. The building was assessed based on three different schemes from three different origins, one of them which is PRS is a local scheme developed especially for Abu Dhabi.

<u>Minimum Certification Level</u>

The building assessment results showed it cannot be certified under LEED, BREEAM or PRS badly as it’s not meeting even the minimum requirements in these schemes, overall level wasn’t efficient.

The building didn't the minimum performance requirements of the mandatory credits, didn’t use recycled, regional, or reused materials; it didn't specify low VOC materials and did not involve a commissioning agent in the design process which led to the absence of design systems that can be monitored or commissioned and re commissioned post occupancy.

<u>Water Consumption</u>

Although the baselines of different schemes are different, the case study building water consumption rates was exceeding the three baselines; however it was found that scoring in PRS in this category is easier than LEED and BREEAM.

<u>Energy Consumption</u>

Energy related strategies are the core of environmental assessment schemes and gives the highest percentage of points; the current energy related strategies were not enough to qualify the building to score more points in the assessment schemes.

Overall achieved points

Table 5.7 Overall Points Comparisons

Assessment Scheme	Water points only	Energy points only	Overall points
PRS	18	0	26
LEED	4	0	18
BREEAM	0	0	7.65%

As shown in Table 5.7 the hardest scheme to score in was BREEAM then LEED then PRS, it also showed that the Case Study building required an intensive upgrading process in terms of:

1. Energy Consumption
2. Water Consumption

And other important aspects such as:

3. Indoor Environmental Quality
4. Materials Management
5. Reducing or elimination sources of pollution

The above mentioned topics can only be covered and implemented through a collaborative effort of the project team including (Owner, Project Manager, and Commissioning agent, Sustainability Professional, Team of Consultants and the Contractor) through and integrative development process (IDP). This process is highly important as it allows the interaction and exchange of information, ideas and experience between the team which maximizes the input. IDP is highly appreciated by the three schemes and even was included as a mandatory requirement in PRS.

After completing the Assessment scheme of the case study, it was clear that although the three schemes has different credits structure and different points scale but still there are big over laps between the schemes. Also LEED and BREEAM proved to be harder for certification due to mandating scoring a minimum credit plus the prerequisites or mandatory credits.

In the next chapter an upgrade will be done to the building to get it certified through PRS, the certification will be measure against LEED and BREEAM scale to understand how a green PRS building would be designed under schemes.

Chapter 6

Suggested Improvements in the Case Study

Assessment Results and Discussion

This Chapter aims to explore the different areas of possible upgrades required to improve the conventional case study building in order to achieve the different certification levels of PRS, the will be done by recommending different setups for the building, then the next step will be measuring levels of these different setups on LEED and BREEAM.

6.1 Case Study Upgrading Phase 1 : Getting the Case Study Building Certified through PRS

The building upgrading will be phased based upon the requirements of every level in PRS, in order to achieve the first PRS rating (1 Pearl) the building must achieve 20 required credits with majority of credits must be done in design phase, the following will be implemented on the building:

1. Integrated Development Strategy

Starting from the design process, the Sustainability Engineer who must be approved by Estidama UPC "the reviewing authority of PRS" will be appointed to lead a the project team in setting and achieving sustainability targets, this professional is known as Pearl Qualified Professional (PQP), he will be responsible for documenting the integrative design process through documents and meetings.

2. Tenant Fit-Out Design & Construction Guide

This guide will include the necessary data that will be required by the future tenants about the building, it will explain the building sustainability measures and how systems are working, also information about any operational requirements such as waste management.

3. Basic Commissioning.

A Commissioning agent will be appointed to join the team starting from the design till operation; this specialist will initially make sure that the building has provisions that allow the building systems to be commissioned. He will be will reporting to the owner and will make the building systems are operating as per the design intent. He will prepare a commissioning plan for the project document which will include Owner project requirement (OPR) and Basis of Design (BOD).

4. Minimum Interior Water Use Reduction

Low flow water fixture will be used such as:

a. Self closable Bathroom taps of 1.9 L/m water flow, this type of taps saves a lot of water and convenient for office use.

b. Half and full flush water closet of 4/6 l per flush will be used instead of the full flush.

5. Minimum Energy Performance

Energy was one of the main concerns that was concluded in the assessment of the original case study; the main major load was cooling load, ASHRAE guide for building in hot and humid climates had listed a 10 strategies to reduce the cooling loads inside buildings, some of it are already implemented but the following will be followed to improve the energy performance through reducing the major load which is the cooling load, the following shall be conducted:

a. Design and construct the exterior enclosure so that it is air tight.
b. Reducing the heat gain by reducing the U-Values of the Glass by using triple glass
c. Seal up all duct connections and make all supply and return plenums air tight using mastic.
d. Changing the HVAC system to a more energy efficient system
e. Using heat recovery methods in the HVAC system.
f. Avoiding overcooling.
g. Invest in constant commission of the building to make it is performing as per the design intent.

The actual HVAC system cannot achieve the above requirements; therefore it will be changed from ducted split units into All Air system with package units. These units are not expensive and will be placed on a secondary roof of the building. Ducts will supply different spaces with cool air, this air will be controlled through valves to reduce and increase the flow as per need.

6. Energy Monitoring & Reporting

Including provisions of metering facilities that allow the building energy consumption to recorded and monitored, as per PRS 90% of the estimated energy consumption shall be monitored through clearly labeled and accessible sub meters.

7. Ozone Impacts of Refrigerants & Fire Suppression Systems

Using refrigerants and fire suppression systems that has Ozone depletion factor (ODP) of zero.

8. Hazardous Materials Elimination

Prohibit the use of Asbestos Contain Materials (ACM) and Chromated Copper Arsenate (CCA) treated timber in the project. This can be done through the project specifications and a later confirmation from the suppliers of these materials.

9. Basic Construction Waste Management

Prepare along with the contractor a waste management plan that can divert 30% weight of volume of the generated construction waste. This can be done by contractor through adopting good practice techniques such as reducing, reusing and recycling of materials. i.e.: Contractor can crush the excess or waste concrete and reuse it again as road base for roads, reuse the waste of steel bars by reselling it for reproduction.

10. Basic Operational Waste Management

Prepare a waste management plan that will aim to "reduce the long-term environmental impacts associated with operational waste collection, transport and disposal", the building has an accessible, properly sized and accessible spaces that allow storage and segregation of waste, specialist will be appointed to calculate the annual estimate of operation waste, for achieving the minimum certification 40% of the operational waste shall be diverted from landfill.

6.2 Phase 1 Assessment through PRS

Water Consumption

Water consumption has been reduced to match the baseline of PRS which is a mandatory requirement (appendix 2, Tables 7); the annual consumption was 1,234,884 l/year while baseline is exactly the same 1,234,884 l/year as the same fixtures were used.

Energy Consumption

Phase 1 of the case study upgrades has saved the required amount of energy to achieve the required credit, and the consumption after these upgrades reached 587 MWh annually which is less than the baseline by 12 percent.

Overall Assessment

Phase 1 of the upgrading has succeeded to get certified by adopting several sustainability strategies and managed to achieve all the required credits.

Table 6.1 PRS assessment: achieved required credits

Environmental Aspect			Credits
IDP: Integrated Development Process			
	IDP-R1: Integrated Development Strategy		Achieved
	IDP-R2: Tenant Fit-Out Design & Construction Guide		Achieved
	IDP-R3: Basic Commissioning		Achieved
NS: Natural Systems			
	NS-R1: Natural Systems Assessment		Achieved
	NS-R2: Natural Systems Protection		Achieved
	NS-R3: Natural Systems Design & Management Strategy		Achieved
LB: Livable Buildings			
LBo: Livable Outdoors			
	LBo-R1: Plan 2030		Achieved
	LBo-R2: Urban Systems Assessment		Achieved
	LBo-R3: Outdoor Thermal Comfort Strategy		Achieved
LBi: Livable Indoors			
	LBi-R1: Healthy Ventilation Delivery		Achieved
	LBi-R2: Smoking Control		Achieved
	LBi-R3: Legionella Prevention		Achieved
PW: Precious Water			
	PW-R1: Minimum Water Use Reduction		Achieved
	PW-R2: Exterior Water Monitoring		Achieved
RE: Resourceful Energy			
	RE-R1: Minimum Energy Performance		Achieved
	RE-R2: Energy Monitoring & Reporting		Achieved
	RE-R3: Ozone Impacts of Refrigerants & Fire Suppression Systems		Achieved
SM: Stewarding Materials			
	SM-R1: Hazardous Materials Elimination		Achieved
	SM-R2: Basic Construction Waste Management		Achieved
	SM-R3: Basic Operational Waste Management		Achieved
		Achieved level = 1 Pearls	

6.3 Case Study Upgrading Phase 2 : The Case Study Building Achieving 2 Pearls through PRS

2 Pearls is an essential level of certification in PRS as all new governmental buildings in Abu Dhabi are required to achieve this rating in order to get a building permit. The level requires the building to achieve the full required credits for Pearl 1 plus 60 points of optional credits. The case study building design had been upgraded in order to achieve the 2 pearls certificate; the strategy to get the building get two pearls was to focus on the water credits and a selection of necessary credits that is required to have a green efficient building. The suggest upgrades for the building will be categorized as per the PRS categories as follows:

1. Integrated Development process

In this the category several essential credits were chosen such as "IDP-1 life cycle costing" as the economical side is very important when upgrading a design of a building, also there is "IDP-3 Construction Environmental Management" which makes sure that an environmental ISO certified contractor is on board and that he has a plan that can reduce or eliminate negative impact of construction activities, another targeted credit was "IPD-4 Building Envelope Verification" which make sure that the building envelope is meeting the design intent and has been tested by a third party to minimize building impacts from condensation, water ingress, air infiltration and improper drainage, that last credit to be chosen from this category is "IDP-6 Sustainability Communication" where a handbook for future occupants will be prepared to make sure they are using the systems the best way they can.

2. Natural Systems

There are no points targeted at this category at this stage.

3. Livable Buildings

The first strategy was “LBo-1: Improved Outdoor Thermal Comfort” by increasing the shading for the pedestrian walkways around the building by adding canopies around the perimeter. The second strategy is “LBo-3: accessible community facility” which is automatically achieved because the site lies in a 350 safe walking distance to Mosque, Gym, Supermarket, ATM and school. The third one is “LBo-6: Public Transport”, in this one the case study building got two points out of three where the building is within a 350 meter of a bus stop.”LBo-7: Bicycle Facilities”, two points were targeted by making simple design changes such as adding Bicycle racks and showers for the building to encourage the use of bicycles. The fifth targeted credit is “LBo-8: preferred parking spaces” by providing a 6% of the parking for preferred cars such as cars supplied with (electricity, LPG or CNG gas and hybrid cars) or for those who are forming a group of a defined and approved car sharing program, it shall be supplied with electric points for charging and in an optimal location to main entrances after the disabled parking places, it shall also be provided with an enforcement mechanism.

Upgrading will be done in terms of indoor environmental quality (IEQ) by targeting credits in the Livable Building indoors (LBi) category. The case study building will be specified to use the five credits from (LBi-2), the main aim is to use materials that have low VOC content. Also the design of the case study building allows it to achieve the point of “LBi-8: views”.

4. Precious Water

In order to save more water than the baseline, a lower flush WC will be used 3/6 l per flush and a 100% sensor taps will be used, in addition to this the building is eligible to get credits in “PW-2: Exterior water use” due to using air based cooling system and absence of outdoor landscaping or water fountains.

5. Resourceful Energy

In this phase, the building will not undergo or apply for a major energy upgrades and will only target one point out of three from “RE-4: Vertical transportation” which is achieving by providing a day lighted staircase which visible from the main entrance of the building.

6. Stewarding Materials

Five material credits had been targeted by changing the specifications, the material credits are (SM-1: Non-Polluting Materials, SM-5: Modular Flooring Systems, SM-9: Regional Materials and SM-11: Rapidly Renewable Materials)

6.4 Phase 2 Assessments through PRS

Water Consumption

On the water side the building managed to save 20 more the baseline % (246,976.8 Liters/y). (Appendix 2, Table 8)

Energy Consumption

No energy credits had been approached at this stage.

Overall Assessment

The building management to achieve the 2 pearls rating which governmental building mandatory rating for buildings in Abu Dhabi.

Table 6.2 Phase 2 assessment through PRS assessment: achieved credits

Environmental Aspect		Achieved Points	Available Points
IDP: Integrated Development Process		8	
	Life Cycle Costing	4	4
	Construction Environmental Management	2	2
	Building Envelope Verification	1	1
	Sustainability Communication	1	1
LB: Livable Buildings			
LBo: Livable Outdoors		8	
	Improved Outdoor Thermal Comfort	2	2
	Accessible Community Facilities	1	1
	Public Transport	2	3
	Bicycle Facilities	2	2
	Preferred Car Parking Spaces	1	1
LBi: Livable Indoors		7	
	Materials Emissions : Adhesives & Sealants	1	1
	Materials Emissions : Paints & Coatings	1	1
	Materials Emissions: Carpet & Hard Flooring	1	1
	Materials Emissions : Ceiling Systems	1	1
	Materials Emissions : Formaldehyde Reduction	2	2
	Views	1	1

PW: Precious Water		29	
	Improved Interior Water Use Reduction	5	15
	Exterior Water Use Reduction: Landscaping	8	8
	Exterior Water Use Reduction: Heat Rejection	8	8
	Exterior Water Use Reduction: Water Features	4	4
	Water Monitoring & Leak Detection	4	4
RE: Resourceful Energy		3	
	Vertical Transportation	3	3
SM: Stewarding Materials		5	
	Non-Polluting Materials	1	3
	Modular Flooring Systems	1	1
	Regional Materials	2	2
	Rapidly Renewable Materials	1	1
Total		**60**	177
	Achieved level = 2 Pearls		

As Shown in Table 6.2, the 2 Pearls level was achieved through mainly water credits as the building is using air cooled systems and no exterior water use applications, this is plus using the taps with sensors and reducing the flush rate of the toilets. The second highest area for scoring points was the LB category where the building managed to score credits due to its location in the downtown in Abu Dhabi which made it near to bus stops and community facilities, a various selected credit had been chosen then to reach the 2 pearls bottom-line which is 60 points.

6.5 Case Study Upgrading Phase 3 : The Case Study Building Achieving the Maximum Rating in PRS which is 5 Pearls

In order to get a building certified with the highest standard in a specific rating, it must be very high complying with it plus it shall be fulfilling most of the aspects of green buildings which is the main goal and any environmental assessment scheme. In PRS 1 and 2 Pearls rating are considered to be mandatory for the code, upgrading the building from these levels to higher optional certification levels can still be achieved easily without major design changes as the points difference in between is not high, where to upgrade a 2 Pearls building to 3 Pearls only 25 extra points out of 178 available points, however going higher to 4 and 5 pearls seems to be challenging as the minimum points will be 115 for 4 pearls and 140 or more for 5.

To target 5 Pearls rating, major design changes have to be implemented in order to improve the building assessment.

1. Integrated Development process

One of the main things that help in improving the overall building performance in all aspects is making sure it is working properly after construction as per the design intent, this will be assured by implementing "IDP-5: Re-commissioning " where the building systems must be tuned 1 year after completion and re commissioned after 2 years. The second strategy is "IDP-6: Sustainability communication" which was partially implemented in Phase 2 upgrades. In this phase a feed back mechanism will be added to every tenancy and all to be connected to Building Management System (BMS).

2. Natural Systems

Since there was no ecological value for the project site, to enhance it we had to introduce some natural systems through the architecture of the building.

In this category, a roof garden will be added to the building which improve the building in a multiple aspects, "NS-3: Ecological enhancement" will be one of the benefits of adopting a roof garden system as 70 % of the plants which will be used will be native or adaptive species comprising 10 different types as per the credit requirement.

3. Livable Buildings

By adding a roof garden to the building in addition to a gym will be qualify it to achieve "LBo-4: Active Urban Environment" as it will enhance the life styles of its occupants. Another strategy will be adopted in the LBo which "LBo-10: Light pollution reduction" due its importance in mitigating the negative impact of unnecessary emitted lighting from the building.

In the Indoor Environmental quality multiple strategies had been suggested. “LBi-1: Ventilation quality” will be targeted by installing Co2 sensors in the building and that CO2 levels shall not exceed 1000 pm, and part of this credit is increasing the fresh air supply by 15% more than the minimum requirement of the ventilation. The full points of “LBi-5: Thermal Comfort and controls” had been targeted by implementing thermal modeling, logical Thermal zoning and allowing for occupant controls on all over the systems. No incandescent lamps and only high frequency florescent lamps will be used in the project as a requirement to achieve “LBi-6: High frequency lighting”. By maximizing the use of day lighting to achieve 250 lux over 75% of the occupied areas, adding occupancy sensors and installing glare control devices, “LBi-7: Day lighting and glare” will be achieved. “LBi-9: Indoor noise pollution” will be achieve by hiring an acoustical consultant to make sure that the building noise levels are within the comfort levels. The project will be able achieve the credit of “LBi-10: Safe and secure environment” as it’s a mandatory requirement for Abu Dhabi Police civil defense authority.

4. Precious Water

Maximum water savings is an essential component of the upgrades, and will use rainwater and recycled grey water for:

1. The roof gardens that implemented for to achieve credits “NS-3: Ecological enhancement" and "LBo-4: Active Urban Environment".
2. Flush for toilets to reduce the demand for potable water.

5. Resourceful Energy

Energy efficiency is a major component in green buildings, it starts with the design of the systems of the building, in this phase major design changes shall be made in the HVAC systems, Lighting, building envelope and architecture to improve the overall building energy performance and to reduce the heat gain. This will allow the building scoring points in “RE-1: Improved Energy Performance” and “RE-2: Cool building strategies”.

A multiple renewable energies can be introduced to the project that can help in saving energy such as:

1. Generating electricity from photovoltaic cells
2. Solar thermal water heaters
3. Geothermal

But the introduced type was Photo Voltaic (PV) cells. PVWATTS calculator was used to determine the amount of energy that can be generated from the whole roof area which is 400 sqm and for a PV system that can generate a 1 KW per 9 sqm, in Abu Dhabi region.

The total possible generated energy is mentioned in Table 6.3.

Table 6.3 PVWATTS calculator results

Station Identification	
City:	Abu Dhabi
Country/Province:	ARE
Latitude:	24.43° N
Longitude:	54.65° E
Elevation:	27 m
Weather Data:	IWEC
PV System Specifications	
DC Rating:	46.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	35.4 kW
Array Type:	Fixed Tilt
Array Tilt:	24.4°
Array Azimuth:	180.0°
Energy Specifications	
Energy Cost:	0.1500 dirham/kWh

Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value (dirham)
1	5.68	5695	854.25
2	6.67	5978	896.70
3	6.14	6112	916.80
4	6.56	6139	920.85
5	7.17	6764	1014.60
6	7.03	6333	949.95
7	6.85	6301	945.15
8	7.10	6533	979.95
9	7.13	6373	955.95
10	6.81	6472	970.80
11	5.98	5699	854.85
12	5.39	5426	813.90
Year	6.54	73827	11074.05

Table 6.3 shows that the 400 sqm of the roof area of the case study can generate around 73,827 KWh which is around 12% of the baseline, that will be assessed in order to calculate how many points the case study can achieve.

From the operational side:

1. Only Energy efficient appliances will be used by the tenants by adding it as mandatory clause in their tenancy contracts. This appliance can be energy star rated or a minimum (A) rating under the EU Energy Efficiency Labeling Scheme or an appropriate level that is comparable and meets or exceeds the other rating schemes. (PRS,2010)
2. No materials with global warming impacts will be used (PRS,2010):

- HVAC refrigerants to be installed within the project have an equivalent Global Warming Potential (GWP) of 1 or less.
- Installing permanent refrigerant leak detection.

- Installing an automatic refrigerant pump down system to a dedicated storage tank with isolation valves
- All gaseous fire suppression systems have a GWP of 1 or less.

6. Stewarding Materials

Multiple approaches had been used to in this category such as:

- Materials management

By using techniques Such as; reducing the required materials through making modular designs, design for flexibility, adaptability and durability.

- The use of recycled content materials

Using recycled steel, supplementary cementitious materials & materials with recycled aggregates.

- Improved construction waste management and operational waster management.

6.6 Phase 3 Assessments through PRS

Water Consumption

On the water, the building managed to save 84.8 % of the used potable water in addition to 23.3% reduction in the interior water consumption. (Appendix 2, Table 9)

Energy Consumption

Phase 3 of the case study upgrades has saved 60 % of its energy consumption compared to the baseline; this qualifies the case study building to achieve the full credits of the energy credits.

In terms of renewable energy, the installed PV system can generate around. …. Percent of the total energy consumption after reduction and that qualify the building for a ….. points for the renewable energy credit.

Overall Assessment

The Upgrades of phase 3 had succeeded to achieve a major difference on the building design and on the performance.

Table 6.4 Phase 3 assessment through PRS assessment: achieved credits

Environmental Aspect		Achieved Points	Available Points
IDP: Integrated Development Process		11	
	Life Cycle Costing	4	4
	Construction Environmental Management	2	2
	Building Envelope Verification	1	1
	Re-Commissioning	2	2
	Sustainability Communication	2	2
NS: Natural Systems		2	
	Ecological Enhancement	2	2
LB: Livable Buildings			
LBo: Livable Outdoors		9	
	Improved Outdoor Thermal Comfort	2	2
	Accessible Community Facilities	1	1
	Public Transport	2	3
	Bicycle Facilities	2	2
	Preferred Car Parking Spaces	1	1
	Light Pollution Reduction	1	1
LBi: Livable Indoors		20	
	Ventilation Quality	3	3
	Materials Emissions : Adhesives & Sealants	1	1
	Materials Emissions : Paints & Coatings	1	1
	Materials Emissions: Carpet & Hard Flooring	1	1
	Materials Emissions : Ceiling Systems	1	1
	Materials Emissions : Formaldehyde Reduction	2	2
	Thermal Comfort & Controls: Thermal Zoning	1	1
	Thermal Comfort & Controls: Occupant Control	2	2
	Thermal Comfort & Controls: Thermal Comfort Modeling	2	2
	High Frequency Lighting	1	1
	Daylight & Glare	2	2
	Views	1	1
	Indoor Noise Pollution	1	1
	Safe & Secure Environment	1	1
PW: Precious Water		39	
	Improved Interior Water Use Reduction	15	15

	Exterior Water Use Reduction: Landscaping	8	8
	Exterior Water Use Reduction: Heat Rejection	8	8
	Exterior Water Use Reduction: Water Features	4	4
	Water Monitoring & Leak Detection	4	4
RE: Resourceful Energy		40	
	Improved Energy Performance	15	15
	Cool Building Strategies	6	6
	Energy Efficient Appliances	3	3
	Vertical Transportation	3	3
	Renewable Energy	9	9
	Global Warming Impacts of Refrigerants & Fire Suppression Systems	4	4
SM: Stewarding Materials		20	
	Non-Polluting Materials	1	1
	Design for Flexibility & Adaptability	1	1
	Design for Disassembly	1	1
	Modular Flooring Systems	1	1
	Design for Durability	1	1
	Regional Materials	2	2
	Recycled Materials	6	6
	Rapidly Renewable Materials	1	1
	Reused or Certified Timber	2	2
	Improved Construction Waste Management	2	2
	Improved Operational Waste Management	2	2
Total		**141**	177
	Achieved level = 5 Pearls		

The building had scored 141 points out of 178 available points which made it applicable to get the 5 pearls certificate, the highest two categories in terms of possible points achieved are "Resourceful Energy" and "Precious Water" (Table 6.4)

6.7 The Assessment of the three Phases of upgrades towards LEED

In this stage of the Assessment the three phases of grades that was done for the case study building will be assessed on LEED.

6.7.1 Phase 1 upgrades : (1) Pearl

Water Consumption

This phase of upgrades was successful in achieving the minimum requirement of LEED prerequisites for water saving credits which is 20% and eligible now for certification from the water consumption side. (Appendix 2, Table 10)

Energy Consumption

Since the baseline of LEED and PRS are similar, the building managed to save 12% which is more than the minimum requirements of Energy performance in LEED which is 10%, the building is quality to achieve one more point in the advanced energy performance.

Overall Performance

Table 6.5 Phase 1 assessment through LEED assessment: Prerequisites

Environmental Aspect			Credits
Sustainable sites (SS)			
	SS-Pre1: Construction activity pollution prevention		Not Achieved
Water efficiency (WE)			
	WE-Pre1: Water-use reduction		Prereq. Achieved
Energy and atmosphere (EA)			
	EA-Pre1: Fundamental commissioning of the building energy systems		Prereq. Achieved
	EA-Pre2: Minimum energy performance		Prereq. Achieved
	EA-Pre3: Fundamental refrigerant management		Prereq. Achieved
Material and resources (MR)			
	MR-Pre1: Storage and collection of recyclables		Prereq. Achieved
Minimum Indoor Air Quality Performance (IEQ)			Prereq. Achieved
	IEQ-Pre1: Minimum Indoor Air Quality Performance		Prereq. Achieved
	IEQ-Pre2: Environmental Tobacco Smoke (ETS) Control		Prereq. Achieved
		Achieved level = Not Certified	

LEED and PRS share most of the same mandatory credits, it was expected that a 1 Pearl building would at least fulfill the "Prerequisites" of LEED, which was mostly true except that it didn't achieve " SS Prerequisite 1: Construction Activity Pollution

Prevention " as in PRS it's an optional credit that awards two points"IDP-3: Construction Environmental Management". Although the PRS Mandatory credits are 20 which are more than that in LEED which has only 8 Prerequisites still didn't qualify the project to any certificate in LEED as its system consists of both Prerequisites plus minimum number of 40 points, therefore a 1 Pearls building is not a LEED certified Building, even if it achieves all the prerequisites.

6.7.2 Phase 2 upgrades : (2) Pearls

Water Consumption

This phase of upgrades was not successful to score any points as the minimum for scoring points is 30% while phase 2 is achieving only 24%. (Appendix 2, Table 11)

Energy Consumption

Since there was no energy upgrades on this phase of upgrades, energy performance is the same, 1 point has been achieved.

Overall Performance

Pearls building managed to achieve to fulfill all the Prerequisites of LEED (by intentionally using the optional credit of PRS "IDP-3: Construction Environmental Management" as this is a prerequisite in LEED) ignoring this optional credit of PRS will keep PRS certified building away from getting a LEED recognition.

After achieving the Prerequisites of LEED, credits point assessment was conducted.

Table 6.6 Phase 2 assessment through LEED assessment: Credits

Environmental Aspect		Achieved	Possible
Sustainable sites		18	26
	Site selection	1	1
	Development density and community connectivity	5	5
	Public transportation access and use	6	6
	Bicycle Storage and Changing Rooms	1	1
	Low-Emitting and Fuel-Efficient Vehicles	3	3
	Parking capacity	2	2
Water efficiency		4	10
	Water-efficient landscaping	4	4
Energy and atmosphere (EA)		1	35
	Optimize Energy Performance	1	1

Material and resources (MR)		3	14
	Regional materials (20%)	2	2
	Rapidly Renewable Materials	1	1
Indoor Environmental Quality		6	15
	Low-Emitting Materials: Adhesives and Sealants	1	1
	Low emitting materials: paints and coatings	1	1
	Low-Emitting Materials: Flooring Systems	1	1
	Low-Emitting Materials: Composite Wood and Agrifiber Products	1	1
	Daylight and Views—Daylight	1	1
	Daylight and Views—Views	1	1
Total	Achieved level = not Certified	32	110

The case study building after reaching the bottom line of a 2 Pearls certification was still was not good enough to get it at least certified. The case study building with phase 2 upgrades still needed 8 points to reach the bottom line of getting certified Table 6.6. The reason is that the core of phase 2 upgrades was in water credits which did not payoff in LEED, however an upper 2 pearls building may be able to get certified under LEED but as per current condition not possible.

<u>6.7.3 Phase 3 upgrades : (5) Pearls</u>

<u>Water Consumption</u>

Although phase 3 is saving 89.5% of potable water in PRS due to using grey water from Municipality and without water use reduction, this phase was eligible for 2 extra points at “WE-2: Innovative waste water technologies” but no extra credits under “WE-3: Water use reduction” .

<u>Energy Consumption</u>

The building managed to save 60% from the baseline performance; however it will only be awarded till 48% achieving 19 points as that’s the maximum of the this credit. The use PV cells qualified the project to get 7 points under onsite renewable energy. This increase in energy saving is expected to have a high and positive impact on the building certification level as energy category in LEED has the highest weights.

Overall Performance

The case study building phase 3 upgrades was done mainly as per PRS guidelines, it managed to fulfill the minimum required points for a 5 Pearl Rating, when this was tested on LEED criteria, it achieved the credits shown in Table 6.7.

Table 6.7 Phase 3 assessment through LEED assessment: Credits

Environmental Aspect		Achieved	Possible
Sustainable sites		21	26
	Site selection	1	1
	Development density and community connectivity	5	5
	Public transportation access and use	6	6
	Bicycle Storage and Changing Rooms	1	1
	Low-Emitting and Fuel-Efficient Vehicles	3	3
	Parking capacity	2	2
	Site Development—Protect or Restore Habitat	1	1
	Heat Island Effect—Roof	1	1
	Light Pollution Reduction	1	1
Water efficiency		6	10
	Water-efficient landscaping	4	4
	Innovative Wastewater Technologies	2	2
Energy and atmosphere (EA)		33	35
	Optimize Energy Performance	19	19
	On-site Renewable Energy	7	7
	Enhanced Commissioning	2	2
	Enhanced Refrigerant Management	2	2
	Measurement and Verification	3	3
Material and resources (MR)		7	14
	Construction Waste Management	1	1
	Recycled Content	2	2
	Regional materials (20%)	2	2
	Rapidly Renewable Materials	1	1
	Certified Wood	1	1
Indoor Environmental Quality		13	15
	Outdoor Air Delivery Monitoring	1	1
	Increased Ventilation	1	1
	Low-Emitting Materials: Adhesives and Sealants	1	1
	Low emitting materials: paints and coatings	1	1
	Low-Emitting Materials: Flooring Systems	1	1
	Low-Emitting Materials: Composite Wood and Agrifiber Products	1	1

	Indoor Chemical and Pollutant Source Control	1	1
	Controllability of Systems—Lighting	1	1
	Controllability of Systems—Thermal Comfort	1	1
	Thermal Comfort—Design	1	1
	Thermal Comfort—Verification	1	1
	Daylight and Views—Daylight	1	1
	Daylight and Views—Views	1	1
Total	Achieved level = Platinum	80	110

The Case study at this level was successful to achieve the high LEED certification which is "Platinum" with total points of 80 as shown in Table 6.7.

6.8 The Assessment of the three Phases of upgrades towards BREEAM

6.8.1 Phase 1 upgrades : (1) Pearl

Water Consumption

There are no mandatory points for the lowest certification level in BREEAM; however this phase of upgrades managed to score 2 points by saving 38.09%. (Appendix 2, Table 13)

Energy Consumption

A 12% percent improvement in the phase 1 upgrades of case study was measured against the BREEAM energy calculators, due to this and as shown in (Appendix 1, Table 27), the building managed to achieve an Energy Performance Ratio (EPR) of 0.235 which qualifies the building for 2 points under BREEAM scheme.

Overall Performance

As explained in previous chapters BREEAM and PRS structure is different, same as LEED, the first certification level of PRS which "1 Pearl" was anticipated to match with the first level of BREEAM which is "Pass".

Table 6.8 Phase 1 assessment through BREEAM assessment: Credits

Environmental Aspect		Credits
Building management		2.40%
	An appropriate project team member has been pointed to monitor commissioning in line with current Building Regulations and guidelines	1
	Provision of a simple guide that covers information relevant to the tenant/occupants and non-technical building manager on the operation and environmental performance of the building.	1
Health and Wellbeing		5.77%
	At least 80% of net lettable office floor area has adequate daylight	1

	Evidence provided demonstrates that all desks are within a 7m radius of windows	1
	Evidence provided demonstrates that an occupant-controlled glare control system	1
	Air intakes serving occupied areas avoid major sources of external pollution and recirculation of exhaust air.	1
	Legionella prevention	1
Energy		2.38%
	Reduction of Co2 emissions	2
	Energy-efficient external lighting is specified and all light fittings are controlled for the presence of daylight.	1
Transport		3.20%
	Good access is available to and from public transport networks for commuting	3
	Good access to Local amenities	1
Water		2.00%
	Improvement over standard specification of water fittings based on standards and legislation specifications	2
Waste		4.28%
	Evidence provided demonstrates that the amount of non-hazardous construction waste (m3/100m2 or tonnes 100m2)generated on site by the development is the same as or better than good or best practice levels	3
	Dedicated space is provided for the storage of the building's recyclable waste streams.	1
Land use		
	Evidence is provided to demonstrate that the construction zone is defined	3.00%
	as land of low ecological value	1
	No negative change in the site's existing ecological value as a result of development.	2
Total		23.03%
	Achieved level = not certified	

Although the Pass certification level seems possible to achieve but as shown in Table 6.8, the mandatory credits were not met as the focus of BREEAM is different than that of PRS.

Phase 1 of the upgrades did allow the building to fulfill mandatory credits such as "Man 01: Sustainable procurement" as it requires extended commissioning, "Hea 01: Visual comfort" because of not using high frequency lamps and "Mat 03: Responsible Sourcing" which is about sourcing of material such as wood and that is has to follow UK Government procurement policy. Also Phase 1 did not achieve the required minimum percentage for the lowest certification which is (30%) and achieved only (23.03%).

6.8.2 Phase 2 upgrades : (2) Pearls

Water Consumption

In this phase 2 of upgrades, there is a slight improvement in water consumption (from 38.09% to 38.89%) but still was not enough still to achieve more than 2 points. (Appendix 2, Table 14)

Energy Consumption

There is no energy improvement as it wasn't targeted at this credit.

Overall Performance

The focus in this phase was in water consumption reduction which is not mandatory for BREEAM,

Table 6.9 Phase 2 assessment through BREEAM assessment: Credits

Environmental Aspect		Credits
Building management		4.80%
	An appropriate project team member has been pointed to monitor commissioning in line with current Building Regulations and guidelines	1
	Evidence provided demonstrates that there is a commitment to go beyond best practice site management principles.	2
	provision of a simple guide that covers information relevant to the tenant/occupants and Non-technical building manager on the operation and environmental performance of the building	1
Health and Wellbeing		8.08%
	At least 80% of net lettable office floor area has adequate daylight	1
	Evidence provided demonstrates that all desks are within a 7m radius of windows	1
	Evidence provided demonstrates that an occupant-controlled glare control system	1
	air intakes serving occupied areas avoid major sources of external pollution and recirculation of exhaust air.	1
	Emissions of VOCs and other substances from key internal finishes and fittings comply with best practice levels	1
	The risk of waterborne and airborne legionella contamination has been minimized.	1
	High Frequency lighting	1
Energy		2.38%
	Reduction of Co2 emissions	2
	Energy-efficient external lighting is specified and all light fittings are controlled for the presence of daylight.	1
Transport		4.80%
	Good access is available to and from public transport networks for commuting	3
	Good access to Local amenities	1
	Covered, secure and well-lit cycle storage facilities are provided for all building users.	1

	Adequate changing facilities are provided for staff use.	1
Water		4.00%
	Improvement over standard specification of water fittings based on standards and legislation specifications	2
	A water meter with a pulsed output will be installed on the mains supply to each building/unit.	1
	A leak detection system is specified or installed on the building's water supply.	1
Waste		4.28%
	Evidence provided demonstrates that the amount of non-hazardous construction waste (m3/100m2 or tonnes 100m2) generated on site by the development is the same as or better than good or best practice levels.	3
	Dedicated space is provided for the storage of the building's recyclable waste streams.	1
Land use		
	Evidence is provided to demonstrate that the construction zone is defined	3.00%
	as land of low ecological value	1
	No negative change in the site's existing ecological value as a result of development.	2
Pollution		1.67%
	Land located in a low area of probability of flooding	
Total		32.98%
	Achieved level = Pass	

Primary assessment showed that phase 2 was not able to achieve any certification level due to missing one mandatory credit "high frequency lighting" which is an optional credit in PRS. When this strategy considered as included, the case study fulfilled all the highlight mandatory credits in Table 6.9 for pass and good grades and managed to achieve a "PASS" grade with only "32.98%".

6.8.3 Phase 3 upgrades : (5) Pearls

Water Consumption

In this phase grey water was used, but only the recycled water from building was possible to add, in PRS there is an option of having a municipal grey water supply. The current changes in design managed to get the building 3 points under BREEAM with percentage improvement 41.91 %. (Appendix 2, Table 15)

Energy Consumption

A 60 % percent improvement in the phase 3 upgrades of case study was measured against the BREEAM energy calculators. The building managed to achieve an Energy

Performance Ratio (EPR) of 0.941 which qualifies the building for the full 15 points under BREEAM scheme. (Appendix 3, Table 30)

Overall Performance

A bottom line 5 Pearls building was assessed against the BREEAM standards, Table (6.10) shows the achieved credit.

Table 6.10 Phase 3 assessment through BREEAM assessment: Credits

Environmental Aspect		Credits
Building management		7.20%
	An appropriate project team member has been pointed to monitor commissioning in line with current Building Regulations and guidelines	1
	seasonal commissioning will be carried out during the first year of occupation, post construction	1
	Evidence provided demonstrates that there is a commitment to go beyond best practice site management principles.	2
	Provision of a simple guide that covers information relevant to the tenant/occupants and Non-technical building manager on the operation and environmental performance of the building.	1
	An Architectural Liaison Officer (ALO) or Crime Prevention Design Advisor (CPDA) from the local police force has been consulted at the design stage and their recommendations incorporated into the design of the building and its parking facilities	1
Health and Wellbeing		12.69%
	At least 80% of net lettable office floor area has adequate daylight	1
	Evidence provided demonstrates that all desks are within a 7m radius of windows	1
	Evidence provided demonstrates that an occupant-controlled glare control system	1
	Fresh air is capable of being delivered to the occupied spaces of the building via a natural ventilation strategy, and there is sufficient user-control of the supply of fresh air.	1
	air intakes serving occupied areas avoid major sources of external pollution and recirculation of exhaust air.	1
	Emissions of VOCs and other substances from key internal finishes and fittings comply with best practice levels	1
	Thermal comfort levels in occupied spaces of the building are assessed at the design stage to evaluate appropriate servicing options; ensuring appropriate thermal comfort levels are achieved.	1
	Local occupant control is available for temperature adjustment in each occupied space to reflect differing user demands.	1
	The risk of waterborne and airborne legionella contamination has been minimized.	1
	High Frequency lighting	1
	The building achieves appropriate indoor ambient noise levels in offices areas.	1
Energy		15.83%
	Reduction of Co2 emissions	15
	Provision of direct sub-metering of energy uses within the building.	1
	Sub-metering of energy consumption by tenancy/building function area is	1

	installed within the building.	
	Energy-efficient external lighting is specified and all light fittings are controlled for the presence of daylight.	1
	The installation of energy-efficient lift(s).	1
Transport		4.80%
	Good access is available to and from public transport networks for commuting	3
	Good access to Local ammenities	1
	Covered, secure and well-lit cycle storage facilities are provided for all building users.	1
	Adequate changing facilities are provided for staff use.	1
Water		5.00%
	Improvement over standard specification of water fittings based on standards and legislation specifications	3
	A water meter with a pulsed output will be installed on the mains supply to each building/unit.	1
	A leak detection system is specified or installed on the building's water supply.	1
Materials		1.92%
	Thermal insulation products used in the building have a low embodied impact relative to their thermal properties.	2
Waste		5.37%
	Evidence provided demonstrates that the amount of non-hazardous construction waste (m3/100m2 or tonnes 100m2)generated on site by the development is the same as or better than good or best practice levels	3
	significant use of recycled materials	1
	Dedicated space is provided for the storage of the building's recyclable waste streams.	1
Land use		
	Evidence is provided to demonstrate that the construction zone is defined	3.00%
	as land of low ecological value	1
	No negative change in the site's existing ecological value as a result of development.	2
Pollution		5.00%
	Use of refrigerants with a global warming potential (GWP) of less than 5 or where there are no refrigerants specified for use in building services.	1
	That refrigerant leaks can be detected	1
	Automatic refrigerant pump down is made to a heat exchanger (or dedicated storage tanks) with isolation valves.	1
	The assessed development is located in a zone defined as having a low annual probability of flooding.	2
	Reduction for nighttime pollution	1
	New sources of noise from the development do not give rise to the likelihood of complaints from existing noise-sensitive premises and amenity or wildlife areas that are within the locality of the site.	1
Total		61.64%
	Achieved level = Very Good	

A bottom line 5 Pearls building succeeded to fulfill all the mandatory requirements of BREEAM, but it managed to score high to achieve only a very good Rating with total percentage of (61.64%) as shown in Table 6.10. There are still to higher levels of certifications in BREEAM, Excellent and outstanding for scoring equal or more than (70% and 85%) respectively.

6.9 Benchmarking PRS against LEED and BREEAM based on the case study building

Table 6.11 Benchmarking PRS against LEED and BREEAM based on the case study building

Environmental Assessment				
PRS				
	Water	Energy	Overall	Certification Level
Actual	18	0	0	Not Certified
Phase 1	18	0	0	Certified
Phase 2	29	3	60	Two Pearls
Phase 3	39	40	141	Five Pearls
LEED				
	Water	Energy	Overall	Certification Level
Actual	4	0	0	Not Certified
Phase 1	4	1	0	Not Certified
Phase 2	4	1	32	Not Certified
Phase 3	6	33	80	Platinum
BREEAM				
	Water	Energy	Overall	Certification Level
Actual	0	0	0	Not Certified
Phase 1	2%	2.28%	0	Not Certified
Phase 2	4%	2.38%	32.98%	Pass
Phase 3	5%	15.83%	61.64%	Very Good

Water

Table 6.11 shows that although the actual case study did not achieve any certifications still it managed to score some points under every scheme due to absence of water features, landscaping and water cooled AC systems (note: a building can score points but still cant be certified if it missed any of the mandatory requirements).

Phase one upgrades had passed the minimum requirements of the three schemes but still, Phase 2 and 3 upgrades had majorly affected the points of PRS while a lower impact was noticed on LEED and BREEAM .

The water consumption related credits shows clearly the effect of the regional priorities of every assessment scheme where the investment in increase the efficiency in water consumption will score differently between PRS in one side and LEED, BREEAM on the other side.

Energy

From the study, it appears that energy consumption is most comparable between the 3 three assessment schemes. And shown in Table 6.3, it proved that any investment in energy efficiency will help the building to score high schemes which is not the same case for other items such as Water.

Overall

Prerequisites, Required and Mandatory Credits

It seemed after having a detailed review and testing for the three assessment Systems that it's somehow not easy to compare, one of the main reasons is because of the prerequisites or mandatory credits, a building can be scoring very high in a specific system but not certified due to missing a single prerequisite as shown in Fig. 6.1, What's a mandatory in UK is considered to be an optional in UAE and US. Adding to that, the complexity of comparing BREEAM is that its mandatory credits are not constant; it changes with every higher level of certification. Also there is a necessity of involvement of multiple construction specialists to be able to compare all aspects of the schemes.

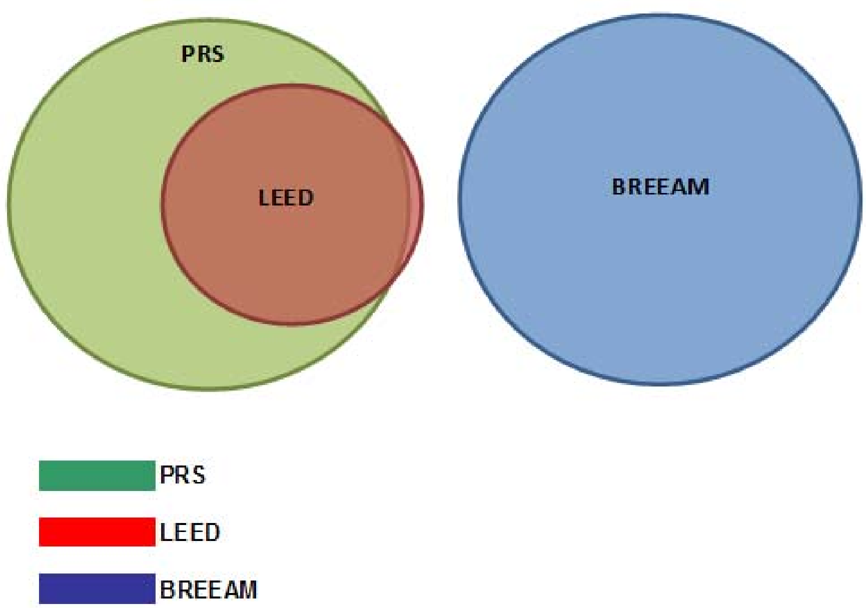

Figure 6.1 Illustration showing the relation between the mandatory part in three assessment schemes

Optional credits

The part of the assessment schemes shows how complicated is to compare the three schemes altogether. The three schemes are voluntary based credits choice can make a difference in comparing the three schemes. In this research, the aim was to choose credits that has regional importance such as water credits but when ignoring the local priorities "which not a sustainable choice" and using the overlaps as shown in Fig. 6.2, coordinated choices may have different results and probably less local certification level but probably achieving recognition levels in the international based schemes.

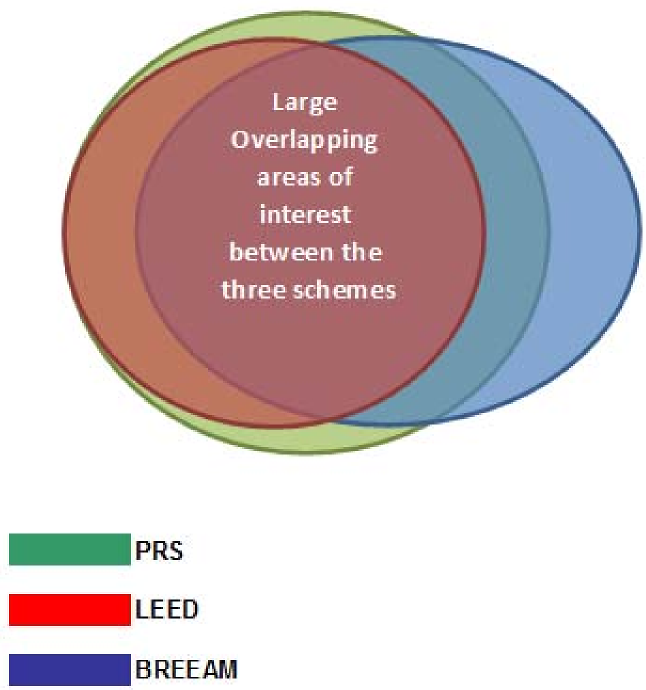

Figure 6.2 Illustration showing the overlaps between the three assessment schemes

However, it although it seems BREEAM is the more stringent system as highest level in PRS and LEED achieved only a "Very Good" level and missed two higher levels. Still it is not necessary to be tagged as harder as this result happened due to two facts The first is that there are a group of credits (more than ten sustainable strategies) are not addressed by PRS or LEED such as monitoring and reporting CO2 rising from construction activities, the internal and external lighting levels are designed in an appropriate lux levels and recommended to follow Chartered Institution of Building

Services Engineers (CIBSE) standards, lighting zones and controls, Low zero carbon technologies, Pedestrian and cyclist safety, sanitary supply shutoff, Material specifications as per "Green Guide" which is a UK materials standard system, responsible sourcing of materials, Floor finishes to be specified by future tenants or occupant and NOx emissions from heating sources. The second fact is that the credit structure with its mandatory credits of BREEAM is totally different than that of LEED or PRS.

This means that although the three schemes appeared to be similar, the detailed comparison showed that only LEED and PRS are more comparable while BREEAM is a little far from them.

This contradicts somehow with some of what was found in the literature review, where Elgendy (2010) had compared the same three schemes and concluded that they have many similarities, also in the Inbuilt report (2010) who although they mentioned that "its not straight forward to compare" however but still they mentioned that "If a building has scored well under LEED, it is likely that it will score well under BREEAM. The converse relationship does not hold quite as well".

Saunders (2008) had also concluded similar findings of this research as he mentioned in his research "The results demonstrate much higher levels of variation between systems for the same “grade” " and that "Thus buildings designed to achieve high LEED and Green Star scores in the UK will generally not score as well against BREEAM". Also Lee and Burnett (2008) when compared HK-BEAM against LEED and BREEAM, they stated that " It is most difficult to score credits under BREEAM " but also highlighted that in terms of energy assessment " The difference in energy use assessment methods, baseline buildings, simulation tools and performance criteria do not affect the assessment results" and that was similar to what was found in this research paper.

The effect of mandatory credits to the comparability between the assessment schemes seems to be not mentioned by any of the reviewed papers, they all seem to analyze schemes as a bunch of credits that represents sustainable strategies without really trying to undergo the certification process of every scheme. In this paper it was found that mandatory schemes require an essential alienation and coordination in order to increase the comparability between schemes.

Chapter 7

Conclusion and Further Study

Buildings are a huge investment not only on the economical side but also on the natural environment side. The three studied schemes and the organizations behind them put this into consideration and aimed to work diligently on mitigating the negative impacts of construction industry on the natural environment.

Since the study is a comparative analysis between environmental assessment schemes, actual design and assessment process had to be conducted for the case study building as per every assessment scheme. Due to time limitation the focus had been given to Water, Energy and Overall all assessment of the schemes.

The study has started with a literature review that showed the history of environmental assessment schemes in general and the reasons behind its creation and development; this was one of the main research objectives which were necessary to provide a good basis and the required background knowledge that can allow fulfilling the main research aim and objectives.

The main aim was to benchmark PRS against LEED and BREEAM, it was found that PRS is a standalone system that combines most of the other two schemes credits, thus has big overall laps in terms of sustainability strategies with them. PRS also gives more recognition to the buildings who respond to local and regional priorities of the Gulf such as energy and water saving. It was also noticed that BREEAM is the least in terms of popularity in the region with no buildings certified in UAE that led BREEAM to withdraw its customized assessment scheme which was developed for the Gulf. From an application and certification levels side, LEED and PRS are more comparable and especially in the higher certification levels, that’s why it was found that both were assessed by nearly the same professionals as the structure, credits and references are much similar. BREEAM proved to be less comparable and presents the hardest scheme of the three to score under. On the Cultural and social side, it was observed that PRS is the only scheme who claims to dedicate points for the cultural values of credits. Still it was found that in general, the three schemes are far from being related to the current behaviors of occupants and assumes that all occupants are educated and will use the building exactly as designed.

In overall look after the study the three environmental assessment schemes even with its differences; all showed in overall a definite positive impact on the building design, performance, a positive impact on the occupants of the rated buildings and positive impact on the environment.

Further Study

- The Impact of the HVAC design on the overall energy performance of the building.
- The differences between the prescriptive and performance based methods in assessing the energy performance in PRS and the impact on the actual performance of buildings.
- The impact of water saving on the energy savings.
- Post occupancy evaluations for PRS certified buildings.
- Cost impact of applying LEED/BREEAM and PRS on the buildings in UAE.
- The efficiency of using renewable energies on the buildings of Abu Dhabi and the impact on cost.

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Appendices

APPENDIX 1

Environmental Assessments Scorecards

1. Pearl Rating System Score Card
2. LEED Score Card
3. BREEAM Score Card

1. Pearl Rating System Score Card

Pearl Building Rating System Version 2

Project Details	
Project Name	Office Building
Project ID	1
Building Use	Office
Pearl Rating Stage	Design
Pearl QP Name	Ahmed Effat Mokhtar Abdelsalam Mosa
Pearl QP Number	1
Date	7/4/1905

Report a Template Bug : PRS_scorecard@upc.gov.ae

Credit Points Summary

Credit Reference	Credit Title	Credit Points Available	Design			Construction			Comments
			Yes	Maybe	No	Yes	Maybe	No	
IDP	**Integrated Development Process**								
IDP-R1	Integrated Development Strategy	Required	No						
IDP-R2	Tenant Fit-Out Design & Construction Guide	Required	No						
IDP-R3	Basic Commissioning	Required	No						
IDP-1	Life Cycle Costing	4			0				
IDP-2	Guest Worker Accommodation	2			0				
IDP-3	Construction Environmental Management	2			0				
IDP-4	Building Envelope Verification	1			0				
IDP-5	Re-Commissioning	2			0				
IDP-6	Sustainability Communication	2			0				
	TOTAL	**13**	**0**	**0**	**0**	0	0	0	

Credit Reference	Credit Title	Credit Points Available	Design Yes	Design Maybe	Design No	Construction Yes	Construction Maybe	Construction No	Comments
NS	**Natural Systems**								
NS-R1	Natural Systems Assessment	Required	Yes			No required submission			
NS-R2	Natural Systems Protection	Required	Yes						
NS-R3	Natural Systems Design & Management Strategy	Required	Yes						
NS-1	Reuse of Land	2			0				
NS-2	Remediation of Contaminated Land	2			0				
NS-3	Ecological Enhancement	2			0				
NS-4	Habitat Creation & Restoration	6			0				
	TOTAL	**12**	**0**	**0**	**0**	0	0	0	

Credit Reference	Credit Title	Credit Points Available	Design Yes	Design Maybe	Design No	Construction Yes	Construction Maybe	Construction No	Comments
LBo	**Livable Buildings : Outdoors**								
LBo-R1	Plan 2030	Required	Yes			No required submission			
LBo-R2	Urban Systems Assessment	Required	Yes			No required submission			
LBo-R3	Outdoor Thermal Comfort Strategy	Required	Yes						
LBo-1	Improved Outdoor Thermal Comfort	2							
LBo-2	Pearl Rated Communities	1			0				
LBo-3	Accessible Community Facilities	1							
LBo-4	Active Urban Environments	1			0				
LBo-5	Private Outdoor Space	n/a							
LBo-6	Public Transport	3							

LBo-7	Bicycle Facilities	2			0				
LBo-8	Preferred Car Parking Spaces	1			0				
LBo-9	Travel Plan	1			0				
LBo-10	Light Pollution Reduction	1			0				
	SUB-TOTAL	**13**	**0**	**0**	**0**	0	0	0	
LBi	**Livable Buildings : Indoors**								
LBi-R1	Healthy Ventilation Delivery	Required	No						
LBi-R2	Smoking Control	Required	Yes						
LBi-R3	Legionella Prevention	Required	No						
LBi-1	Ventilation Quality	3			0				
LBi-2.1	Materials Emissions : Adhesives & Sealants	1			0				
LBi-2.2	Materials Emissions : Paints & Coatings	1			0				
LBi-2.3	Materials Emissions: Carpet & Hard Flooring	1			0				
LBi-2.4	Materials Emissions : Ceiling Systems	1			0				
LBi-2.5	Materials Emissions : Formaldehyde Reduction	2			0				
LBi-3	Construction Indoor Air Quality Management	2			0				
LBi-4	Car Park Air Quality Management	1			0				
LBi-5.1	Thermal Comfort & Controls: Thermal Zoning	1			0				
LBi-5.2	Thermal Comfort & Controls: Occupant Control	2			0				
LBi-5.3	Thermal Comfort & Controls: Thermal Comfort Modeling	2			0				
LBi-6	High Frequency Lighting	1			0				
LBi-7	Daylight & Glare	2			0				
LBi-8	Views	1							
LBi-9	Indoor Noise Pollution	1			0				
LBi-10	Safe & Secure Environment	1			0				
	SUB-TOTAL	**23**	**0**	**0**	**0**	0	0	0	
PW	**Precious Water**								
PW-R1	Minimum Interior Water Use Reduction	Required	No						
PW-R2	Exterior Water Monitoring	Required	Yes						
PW-1	Improved Interior Water Use Reduction	15			0				
PW-2.1	Exterior Water Use Reduction: Landscaping	8			0				
PW-2.2	Exterior Water Use Reduction: Heat Rejection	8			0				
PW-2.3	Exterior Water Use Reduction: Water Features	4			0				
PW-3	Water Monitoring & Leak Detection	4			0				
PW-4	Stormwater Management	4			0				
	TOTAL	**43**	**0**	**0**	**0**	0	0	0	
RE	**Resourceful Energy**								
RE-R1	Minimum Energy Performance	Required	No						
RE-R2	Energy Monitoring & Reporting	Required	No						
RE-R3	Ozone Impacts of Refrigerants & Fire Suppression Systems	Required	No						
RE-1	Improved Energy Performance	15			0				
RE-2	Cool Building Strategies	6			0				
RE-3	Energy Efficient Appliances	3			0				
RE-4	Vertical Transportation	3			0				
RE-5	Peak Load Reduction	4			0				
RE-6	Renewable Energy	9			0				

RE-7	Global Warming Impacts of Refrigerants & Fire Suppression Systems	4			0				
	TOTAL	44	0	0	0	0	0	0	
SM	**Stewarding Materials**								
SM-R1	Hazardous Materials Elimination	Required	No						
SM-R2	Basic Construction Waste Management	Required	No						
SM-R3	Basic Operational Waste Management	Required	No						
SM-1	Non-Polluting Materials	3			0				
SM-2	Design for Materials Reduction	1			0				
SM-3	Design for Flexibility & Adaptability	1			0				
SM-4	Design for Disassembly	1			0				
SM-5	Modular Flooring Systems	1			0				
SM-6	Design for Durability	1			0				
SM-7	Building Reuse	2			0				
SM-8	Material Reuse	1			0				
SM-9	Regional Materials	2			0				
SM-10	Recycled Materials	6			0				
SM-11	Rapidly Renewable Materials	1			0				
SM-12	Reused or Certified Timber	2			0				
SM-13	Improved Construction Waste Management	2			0				
SM-14	Improved Operational Waste Management	2			0				
SM-15	Organic Waste Management	2			0				
	TOTAL	28	0	0	0	0	0	0	
IP	**Innovating Practice**								
IP-1	Innovative Cultural & Regional Practices	3			0				
IP-2	Innovating Practice	3			0				
	TOTAL	6	0	0	0	0	0	0	

Pearl Building Rating System

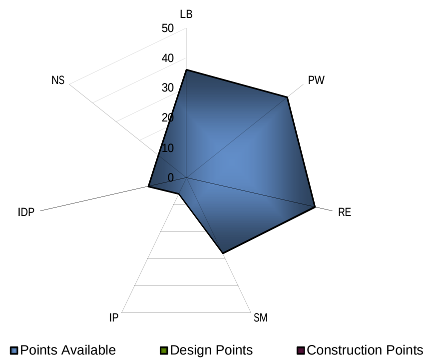
Project Summary	
Project Name	Office Building
Project ID	1/1/1900
Building Use	Office
Pearl Rating Stage	Design
Pearl QP Name	Ahmed Effat Mokhtar Abdelsalam Mosa
Pearl QP Number	1/1/1900
Date	7/4/1905

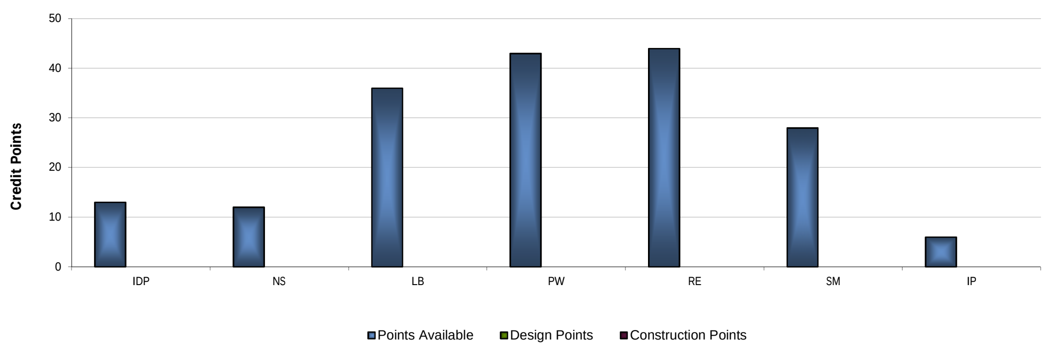
Pearl Rating Levels

Total Credit Points	Pearl Rating
Required credits only	1
60	2
85	3
115	4
140	5

Credit Section	Credit Points Available	Design Credit Points	Construction Credit Points
IDP - Integrated Development Process	13	0	0
NS - Natural Systems	12	0	0
LB - Livable Buildings	36	0	0
PW - Precious Water	43	0	0
RE - Resourceful Energy	44	0	0
SM - Stewarding Materials	28	0	0
IP - Innovating Practice	6	0	0
Total		**0**	**0**

Design Pearl Rating	Unrated
Construction Pearl Rating	Unrated





2. LEED Score Card

LEED 2009 for New Construction and Major Renovations

Project Checklist

Office Building in Abu Dhabi

2012

Sustainable Sites — Possible Points: 26

Y	?	N			
Y			Prereq 1	Construction Activity Pollution Prevention	
			Credit 1	Site Selection	1
			Credit 2	Development Density and Community Connectivity	5
			Credit 3	Brownfield Redevelopment	1
			Credit 4.1	Alternative Transportation—Public Transportation Access	6
			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
			Credit 4.4	Alternative Transportation—Parking Capacity	2
			Credit 5.1	Site Development—Protect or Restore Habitat	1
			Credit 5.2	Site Development—Maximize Open Space	1
			Credit 6.1	Stormwater Design—Quantity Control	1
			Credit 6.2	Stormwater Design—Quality Control	1
			Credit 7.1	Heat Island Effect—Non-roof	1
			Credit 7.2	Heat Island Effect—Roof	1
			Credit 8	Light Pollution Reduction	1

Water Efficiency — Possible Points: 10

Y	?	N			
Y			Prereq 1	Water Use Reduction—20% Reduction	
			Credit 1	Water Efficient Landscaping	2 to 4
			Credit 2	Innovative Wastewater Technologies	2
			Credit 3	Water Use Reduction	2 to 4

Energy and Atmosphere — Possible Points: 35

Y	?	N			
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
			Credit 1	Optimize Energy Performance	1 to 19
			Credit 2	On-Site Renewable Energy	1 to 7
			Credit 3	Enhanced Commissioning	2
			Credit 4	Enhanced Refrigerant Management	2
			Credit 5	Measurement and Verification	3
			Credit 6	Green Power	2

Materials and Resources — Possible Points: 14

Y	?	N			
Y			Prereq 1	Storage and Collection of Recyclables	
			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
			Credit 2	Construction Waste Management	1 to 2
			Credit 3	Materials Reuse	1 to 2

Materials and Resources, Continued

Y	?	N			
			Credit 4	Recycled Content	1 to 2
			Credit 5	Regional Materials	1 to 2
			Credit 6	Rapidly Renewable Materials	1
			Credit 7	Certified Wood	1

Indoor Environmental Quality — Possible Points: 15

Y	?	N			
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
			Credit 1	Outdoor Air Delivery Monitoring	1
			Credit 2	Increased Ventilation	1
			Credit 3.1	Construction IAQ Management Plan—During Construction	1
			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
			Credit 5	Indoor Chemical and Pollutant Source Control	1
			Credit 6.1	Controllability of Systems—Lighting	1
			Credit 6.2	Controllability of Systems—Thermal Comfort	1
			Credit 7.1	Thermal Comfort—Design	1
			Credit 7.2	Thermal Comfort—Verification	1
			Credit 8.1	Daylight and Views—Daylight	1
			Credit 8.2	Daylight and Views—Views	1

Innovation and Design Process — Possible Points: 6

Y	?	N			
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 1.5	Innovation in Design: Specific Title	1
			Credit 2	LEED Accredited Professional	1

Regional Priority Credits — Possible Points: 4

Y	?	N			
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1

Total — Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

3. BREEAM Score Card

breeam

Indicative Overall BREEAM Score

0.00%

BREEAM Rating Benchmarks

PASS	≥30%
GOOD	≥45%
VERY GOOD	≥55%
EXCELLENT	≥70%
OUTSTANDING*	≥85%

Minimum BREEAM Standards

	Pass	Good	Very Good	Excellent	Outstanding
Achieved?	NO	NO	NO	NO	NO

Ref	Title	Offices Criteria	Number of BREEAM credits available	Total predicted BREEAM credits achieved	Minimum required credits by BREEAM issue and rating: Pass	Good	Very Good	Excellent	Outstanding	Notes
Management										
Man 1	Commissioning	One credit where evidence provided demonstrates that an appropriate project team member has been appointed to monitor commissioning on behalf of the client to ensure commissioning will be carried out in line with current best practice. Two credits where, in addition to the above, evidence provided demonstrates that seasonal commissioning will be carried out during the first year of occupation, post construction (or post fit out).	2		1	1	1	1	2	
Man 2	Considerate Constructors	One credit where evidence provided demonstrates that there is a commitment to comply with best practice site management principles. Two credits where evidence provided demonstrates that there is a commitment to go beyond best practice site management principles.	2		-	-	-	1	2	
Man 3	Construction Site Impacts	One credit where evidence provided demonstrates that 2 or more of items a-g (listed below) are achieved. Two credits where evidence provided demonstrates that 4 or more of items a-g (listed below) are achieved. Three credits where evidence provided demonstrates that 6 or more of items a-g are achieved: a. Monitor, report and set targets for CO2 or energy arising from site activities b. Monitor, report and set targets for CO2 or energy arising from transport to and from site c. Monitor, report and set targets for water consumption arising from site activities d. Implement best practice policies in respect of air (dust) pollution arising from the site e. Implement best practice policies in respect of water (ground and surface) pollution occurring on the site f. Main contractor has an environmental materials policy, used for sourcing of construction materials to be utilised on site g. Main contractor operates an Environmental Management System. One additional credit where evidence provided demonstrates that at least 80% of site timber is responsibly sourced and 100% is legally sourced.	4		-	-	-	-	-	
Man 4	Building user guide	One credit where evidence provided demonstrates the provision of a simple guide that covers information relevant to the tenant/occupants and non-technical building manager on the operation and environmental performance of the building.	1		-	-	-	1	1	
Man 8	Security	One credit where evidence provided demonstrates that an Architectural Liaison Officer (ALO) or Crime Prevention Design Advisor (CPDA) from the local police force has been consulted at the design stage and their recommendations incorporated into the design of the building and its parking facilities (if relevant).	1		-	-	-	-	-	

Indicative Mangement (weighted) Section Score **0.00%**

Health & Wellbeing

Hea 1	Daylighting	One credit where evidence provided demonstrates that at least 80% of floor area in each occupied space is adequately daylit.	1		-	-	-	-	-	
Hea 2	View Out	One credit where evidence provided demonstrates that all relevant building areas have an adequate view out.	1		-	-	-	-	-	
Hea 3	Glare Control	One credit where evidence provided demonstrates that an occupant-controlled shading system (e.g. internal or external blinds) is fitted in relevant building areas.	1		-	-	-	-	-	
Hea 4	High frequency lighting	One credit where evidence provided demonstrates that high frequency ballasts are installed on all fluorescent and compact fluorescent lamps.	1		1	1	1	1	1	
Hea 5	Internal and external lighting levels	One credit where evidence provided demonstrates that all internal and external lighting, where relevant, is specified in accordance with the appropriate maintained illuminance levels (in lux) recommended by CIBSE.	1		-	-	-	-	-	
Hea 6	Lighting zones & controls	One credit where evidence provided demonstrates that, in all relevant building areas, lighting is appropriately zoned and occupant controllable.	1		-	-	-	-	-	
Hea 7	Potential for natural ventilation	One credit where evidence provided demonstrates that fresh air is capable of being delivered to the occupied spaces of the building via a natural ventilation strategy, and there is sufficient user-control of the supply of fresh air.	1		-	-	-	-	-	
Hea 8	Indoor air quality	One credit where air intakes serving occupied areas avoid major sources of external pollution and recirculation of exhaust air.	1		-	-	-	-	-	
Hea 9	Volatile Organic Compounds	One credit where evidence provided demonstrates that the emissions of VOCs and other substances from key internal finishes and fittings comply with best practice levels.	1		-	-	-	-	-	
Hea 10	Thermal comfort	One credit where evidence provided demonstrates that thermal comfort levels in occupied spaces of the building are assessed at the design stage to evaluate appropriate servicing options, ensuring appropriate thermal comfort levels are achieved.	1		-	-	-	-	-	
Hea 11	Thermal zoning	One credit where evidence provided demonstrates that local occupant control is available for temperature adjustment in each occupied space to reflect differing user demands.	1		-	-	-	-	-	
Hea 12	Microbial contamination	One credit where evidence provided demonstrates that the risk of waterborne and airborne legionella contamination has been minimised.	1		1	1	1	1	1	
Hea 13	Acoustic Performance	One credit where evidence provided demonstrates that the building achieves appropriate indoor ambient noise levels in offices areas. In addition, for fully fitted buildings only: Appropriate airborne sound insulation levels are achieved between acoustically sensitive spaces and occupied spaces, sufficient to ensure adequate privacy.	1		-	-	-	-	-	
		Indicative Health & Wellbeing (weighted) Section Score	**0.00%**							

Energy

Ene 1	Reduction of CO2 Emissions	Up to fifteen credits where evidence provided demonstrates an improvement in the energy efficiency of the building's fabric and services and therefore achieves lower building operational related CO2 emissions.	**15**		-	-	-	6	10	
Ene 2	Sub-metering of Substantial Energy Uses	One credit where evidence provided demonstrates the provision of direct sub-metering of energy uses within the building.	**1**		-	-	1	1	1	
Ene 3	Sub-metering of high energy load Areas and Tenancy	One credit where evidence provided demonstrates sub-metering of energy consumption by tenancy/building function area is installed within the building.	**1**		-	-	-	-	-	
Ene 4	External Lighting	One credit where energy-efficient external lighting is specified and all light fittings are controlled for the presence of daylight.	**1**		-	-	-	-	-	
Ene 5	Low zero carbon technologies	One credit where evidence provided demonstrates that a feasibility study considering local (on-site and/or near site) low or zero carbon (LZC) technologies has been carried out and the results implemented. Two credits where evidence provided demonstrates that the first credit has been achieved and there is a 10% reduction in the building's CO2 emissions as a result of the installation of a feasible local LZC technology. Three credits where evidence provided demonstrates that the first credit has been achieved and there is a 15% reduction in the building's CO2 emissions as a result of the installation of a feasible local LZC technology. Or alternatively: A maximum of one credit where evidence provided demonstrates that a contract with an energy supplier is in place to provide sufficient electricity used within the assessed building/development to meet the above criteria from a 100% renewable energy source. (Note: a standard Green Tariff will not comply)	**3**		-	-	-	1	1	
Ene 8	Lifts	Up to two credits are available where evidence provided demonstrates the installation of energy-efficient lift(s).	**2**		-	-	-	-	-	
Ene 9	Escalators & travelling walkways	One credit where evidence provided demonstrates that escalators reduce unnecessary operation when there is no passenger demand.	**1**		-	-	-	-	-	

Indicative Energy (weighted) Section Score **0.00%**

Transport

Tra 1	Provision of public transport	Up to three credits are awarded on a sliding scale based on the assessed buildings' accessibility to the public transport network.	**3**		-	-	-	-	-	
Tra 2	Proximity to amenities	One credit where evidence provided demonstrates that the building is located within 500m of accessible local amenities appropriate to the building type and its users.	**1**		-	-	-	-	-	
Tra 3	Cyclist Facilities	One credit where evidence provided demonstrates that covered, secure and well-lit cycle storage facilities are provided for all building users. Two credits where, in addition to the above, adequate changing facilities are provided for staff use.	**2**		-	-	-	-	-	
Tra 4	Pedestrian and cycle safety	One credit where evidence provided demonstrates that the site layout has been designed in accordance with best practice to ensure safe and adequate pedestrian and cycle access.	**1**		-	-	-	-	-	
Tra 5	Travel plan	One credit where evidence is provided to demonstrate that a travel plan has been developed and tailored to the specific needs of the building users.	**1**		-	-	-	-	-	
Tra 6	Maximum car parking capacity	One credit where evidence provided demonstrates no more than one parking space is provided for every three building users. Two credits where evidence provided demonstrates no more than one parking space is provided for every four building users.	**2**		-	-	-	-	-	

Indicative Transport (weighted) Section Score **0.00%**

Water

Wat 1	Water Consumption	Up to three credits where evidence provided demonstrates that the specification includes taps, urinals, WCs and showers that consume less potable water in use than standard specifications for the same type of fittings.	**3**		-	1	1	1	2	
Wat 2	Water meter	One credit where evidence provided demonstrates that a water meter with a pulsed output will be installed on the mains supply to each building/unit.	**1**		-	1	1	1	1	
Wat 3	Major leak detection	One credit where evidence provided demonstrates that a leak detection system is specified or installed on the building's water supply.	**1**		-	-	-	-	-	
Wat 4	Sanitary supply shut off	One credit where evidence provided demonstrates that proximity detection shut-off is provided to the water supply to all toilet areas.	**1**		-	-	-	-	-	

Indicative Water (weighted) Section Score **0.00%**

Materials

Mat 1	Materials Specification (major building elements)	Up to four credits are available, determined by the Green Guide to Specification ratings for the major building elements.	**4**		-	-	-	-	-	
Mat 2	Hard landscaping and boundary protection	One credit where evidence provided demonstrates that at least 80% of the combined area of external hard landscaping and boundary protection specifications achieve an A or A+ rating, as defined by the Green Guide to Specification.	**1**		-	-	-	-	-	
Mat 3	Re-use of building façade	One credit is awarded where evidence provided demonstrates that at least 50% of the total façade (by area) is reused and at least 80% of the reused façade (by mass) comprises in-situ reused material.	**1**		-	-	-	-	-	
Mat 4	Re-use of building structure	One credit is awarded where evidence provided demonstrates that a design reuses at least 80% of an existing primary structure and for part refurbishment and part new build, the volume of the reused structure comprises at least 50% of the final structure's volume.	**1**		-	-	-	-	-	
Mat 5	Responsible sourcing of materials	Up to 3 credits are available where evidence provided demonstrates that 80% of the assessed materials in the following building elements are responsibly sourced: a. Structural Frame b. Ground floor c. Upper floors (including separating floors) d. Roof e. External walls f. Internal walls g. Foundation/substructure h. Staircase Additionally 100% of any timber must be legally sourced.	**3**		-	-	-	-	-	
Mat 6	Insulation	One credit where evidence provided demonstrates that thermal insulation products used in the building have a low embodied impact relative to their thermal properties, determined by the Green Guide to Specification ratings. One credit where evidence provided demonstrates that thermal insulation products used in the building have been responsibly sourced.	**2**		-	-	-	-	-	
Mat 7	Designing For Robustness	One credit where protection is given to vulnerable parts of the building such as areas exposed to high pedestrian traffic, vehicular and trolley movements.	**1**		-	-	-	-	-	
		Indicative Materials (weighted) Section Score	**0.00%**							

Waste

Wst 1	Construction Site Waste Management	Up to three credits are available where evidence provided demonstrates that the amount of non-hazardous construction waste (m3/100m2 or tonnes100m2) generated on site by the development is the same as or better than good or best practice levels. One credit where evidence provided demonstrates that a significant majority of non-hazardous construction waste generated by the development will be diverted from landfill and reused or recycled.	**4**		-	-	-	-	-	
Wst 2	Recycled aggregates	One credit where evidence provided demonstrates the significant use of recycled or secondary aggregates in 'high-grade' building aggregate uses.	**1**		-	-	-	-	-	
Wst 3	Recyclable waste storage	One credit where a central, dedicated space is provided for the storage of the building's recyclable waste streams.	**1**		-	-	-	1	1	
Wst 6	Floor Finishes	One credit where carpets and other floor finishes are specified by the future occupant or, in tenanted areas of speculative buildings, where carpets or floor finishes are installed in a limited show area only.	**1**		-	-	-	-	-	
		Indicative Waste (weighted) Section Score	**0.00%**							

Land Use & Ecology

LE1	Re-use of land	One credit where evidence provided demonstrates that the majority of the footprint of the proposed development falls within the boundary of previously developed land.	1		-	-	-	-	-	
LE2	Contaminated land	One credit is awarded where evidence provided demonstrates that the land used for the new development has, prior to development, been defined as contaminated and where adequate remedial steps have been taken to decontaminate the site prior to construction.	1		-	-	-	-	-	
LE3	Ecological value of site AND Protection of ecological features	One credit is awarded where evidence provided demonstrates that the construction zone is defined as land of low ecological value and all existing features of ecological value will be fully protected from damage during site preparation and construction works.	1		-	-	-	-	-	
LE4	Mitigating Ecological impact	One credit where evidence provided demonstrates that the change in the site's existing ecological value, as a result of development, is minimal. Two credits where evidence provided demonstrates that there is no negative change in the site's existing ecological value as a result of development.	2		-	-	1	1	1	
LE5	Enhancing Site Ecology	One credit where the design team (or client) has appointed a suitably qualified ecologist to advise and report on enhancing and protecting the ecological value of the site; and implemented the professional's recommendations for general enhancement and protection of site ecology. Two credits where, in addition to the above, there is a positive increase in the ecological value of the site of up to (but not including) 6 species. Three credits where, in addition to the above, evidence is provided to demonstrate a positive increase in the ecological value of the site of 6 species or greater.	3		-	-	-	-	-	
LE6	Long term impact on biodiversity	One credit where the client has committed to achieving the mandatory requirements listed below and at least two of the additional requirements. Two credits where the client has committed to achieving the mandatory requirements listed below and at least four of the additional requirements.	2		-	-	-	-	-	
		Indicative Land Use & Ecology (weighted) Section Score	**0.00%**							

Pollution

Pol 1	Refrigerant GWP - Building services	One credit where evidence provided demonstrates the use of refrigerants with a global warming potential (GWP) of less than 5 or where there are no refrigerants specified for use in building services.	1		-	-	-	-	-	
Pol 2	Preventing refrigerant leaks	One credit where evidence provided demonstrates that refrigerant leaks can be detected or where there are no refrigerants specified for the development. One credit where evidence provided demonstrates that the provision of automatic refrigerant pump down is made to a heat exchanger (or dedicated storage tanks) with isolation valves. Or where there are no refrigerants specified for the development.	2		-	-	-	-	-	
Pol 4	NOx emissions from heating source	One credit where evidence provided demonstrates that the maximum dry NOx emissions from delivered space heating energy are ≤100 mg/kWh (at 0% excess O2). Twp credits where evidence provided demonstrates that the maximum dry NOx emissions from delivered space heating energy are ≤70 mg/kWh (at 0% excess O2). Three credits where evidence provided demonstrates that the maximum dry NOx emissions from delivered space heating energy are ≤40 mg/kWh (at 0% excess O2).	3		-	-	-	-	-	

Pol 5	Flood risk	Two credits where evidence provided demonstrates that the assessed development is located in a zone defined as having a low annual probability of flooding. One credit where evidence provided demonstrates that the assessed development is located in a zone defined as having a medium or high annual probability of flooding AND the ground level of the building, car parking and access is above the design flood level for the site's location. One further credit where evidence provided demonstrates that surface water run-off attenuation measures are specified to minimise the risk of localised flooding, resulting from a loss of flood storage on site due to development.	**3**		-	-	-	-	-	
Pol 6	Minimising watercourse pollution	One credit here evidence provided demonstrates that effective on site treatment such as Sustainable Drainage Systems (SUDs) or oil separators have been specified in areas that are or could be a source of watercourse pollution.	**1**		-	-	-	-	-	
Pol 7	Reduction of Night Time Light Pollution	One credit where evidence provided demonstrates that the external lighting design is in compliance with the guidance in the Institution of Lighting Engineers (ILE) Guidance notes for the reduction of obtrusive light, 2005.	**1**		-	-	-	-	-	
Pol 8	Noise Attenuation	One credit where evidence provided demonstrates that new sources of noise from the development do not give rise to the likelihood of complaints from existing noise-sensitive premises and amenity or wildlife areas that are within the locality of the site.	**1**		-	-	-	-	-	

Indicative Pollution (weighted) Section Score **0.00%**

Innovation - Exemplary Level Criteria

Innovation	Man 2: Considerate Constructors	Where post construction, a Considerate Constructors Scheme certificate can be provided demonstrating that the site achieved CCS Code of Considerate Practice with a score of at least 36. OR Where post construction, the site has complied in full with the alternative, independently assessed scheme, and the alternative scheme addresses all the mandatory and optional items in Checklist A2.	**1**		
Innovation	Hea 1: Daylighting	At least 80% of the floor area (for the building spaces/room identified above in the standard requirements) has an average daylight factor of 3% in multi-storey buildings and 4% in single-storey buildings.	**1**		
Innovation	Ene 1: Reduction of CO2 emissions	One additional innovation credit can be awarded where evidence provided demonstrates the building is designed to be a carbon neutral building as defined by the NCM (i.e. in terms of building services energy demand), as follows: a. A new building achieves a CO2 index less than 0 on the benchmark scale. b. A refurbished building achieves a CO2 index equal to or less than 0 on the benchmark scale. Two additional innovation credits can be awarded where evidence provided demonstrates the building is designed to be a True zero carbon building (in terms of building services and operational energy demand).	**2**		
Innovation	Ene 5: Low or Zero Carbon Technologies	A local LZC energy technology has been installed in line with the recommendations of a compliant feasibility study and this method of supply results in a 20% reduction in the building's CO2 emissions.	**1**		
Innovation	Wat 2: Water Meter	Where sub meters are fitted to allow individual water-consuming plant or building areas to be monitored such as cooling towers, car washes, catering areas, etc. If the building does not have any major water consuming plant this exemplar credit is not available. Each sub meter has a pulsed output to enable connection to a Building Management System (BMS) for the monitoring of water consumption. In addition to the above, for sites with multiple departments e.g. large health centres or acute hospitals, separate pulsed sub meters are fitted on the supply to the following areas where present: a. Staff and public areas b. Clinical areas and wards c. Letting areas: On the water supply to each tenant unit d. Laundries e. Main production kitchen f. Hydrotherapy pools g. Laboratories h. CSSD/HSDU, pathology, pharmacy, mortuary and any other major process water user.	**1**		

Innovation	Materials Specification	One exemplary BREEAM credit can be awarded as follows: a. Where assessing four or more applicable building elements, the building achieves at least two points additional to the total points required to achieve maximum credits under the standard BREEAM requirements. b. Where assessing fewer than four applicable building elements, the building achieves at least one point additional to the total points required to achieve maximum credits under the standard BREEAM requirements.	1		
Innovation	Responsible Sourcing of Materials	Where, in addition to the standard BREEAM requirements, 95% of the applicable materials, comprised within the applicable building elements, have been responsibly sourced.	1		
Innovation	Wst 1 Construction Site Waste Management	Where non-hazardous construction waste generated by the building's development meets or exceeds the resource efficiency benchmark required to achieve three credits (as outlined in the guidance). Where at least 90% by weight (80% by volume) of non-hazardous construction waste and 95% of demolition waste by weight (85% by volume) (if applicable) generated by the build has been diverted from landfill and either: a. Reused on site (in-situ or for new applications) b. Reused on other sites c. Salvaged/reclaimed for reuse d. Returned to the supplier via a 'take-back' scheme e. Recovered from site by an approved waste management contractor and recycled. Where all key waste groups are identified for diversion from landfill at pre-construction stage SWMP.	1		

Innovation - BREEAM Accredited Professional

Innovation	BREEAM Accredited Professional	Up to two credits are available for the comprehensive use of a BREEAM Accredited Professional (AP) throughout project work stages.	2		

Indicative Innovation (weighted) Section Score **0.00%**

APPENDIX 2

Water Calculations

1. Pearl Rating System (PRS) Water Calculator
2. LEED Water Calculator
3. BREEAM Water Calculator
4. PRS Water Case study – Phase 1
5. PRS Water Case study – Phase 2
6. PRS Water Case study – Phase 3
7. LEED Water Case study – Phase 1
8. LEED Water Case study – Phase 2
9. BREEAM Water Case study – Phase 1
10. BREEAM Water Case study – Phase 2
11. BREEAM Water Case study – Phase 3

APPENDIX 3

Energy Simulation Results

1. Actual Energy Assessment Results
2. LEED Assessment Baseline Results
3. BREEAM Assessment Baseline results

1. Actual Energy Assessment Results

<Virtual Environment> 6.4.0.8

Project File: actual.mit
Sim File: actual.aps 14/Mar/2012
Weather File: AbuDhabiIWEC.fwt

	Total electricity (misc.) (MWh)
	actual.aps
Date	
Jan 01-31	49.7227
Feb 01-28	49.1492
Mar 01-31	63.6741
Apr 01-30	71.8070
May 01-31	88.5238
Jun 01-30	96.5783
Jul 01-31	109.1167
Aug 01-31	108.3530
Sep 01-30	102.0545
Oct 01-31	85.7700
Nov 01-30	70.2967
Dec 01-31	56.0458
Summed total	951.0918

<Virtual Environment> 6.4.0.8

Project File: actual.mit
Sim File: actual.aps 14/Mar/2012
Weather File: AbuDhabiIWEC.fwt

	Total CE (kgC)
	actual.aps
Date	
Jan 01-31	10849
Feb 01-28	10723
Mar 01-31	13893
Apr 01-30	15667
May 01-31	19314
Jun 01-30	21072
Jul 01-31	23807
Aug 01-31	23641
Sep 01-30	22266
Oct 01-31	18713
Nov 01-30	15337
Dec 01-31	12228
Summed total	207511

	Total electricity (misc.) (MWh)	
Date		
Jan 01-31	49.8757	
Feb 01-28	47.6847	
Mar 01-31	58.2871	
Apr 01-30	63.7669	
May 01-31	77.9692	
Jun 01-30	84.017	
Jul 01-31	95.1918	
Aug 01-31	94.6724	
Sep 01-30	88.3825	
Oct 01-31	75.5352	
Nov 01-30	62.1136	
Dec 01-31	53.4443	Cost $
Summed total	**951**	AED 142,650.00

2. LEED Assessment Baseline Results

	Orientation 0	Orientation 90	Orientation 180	Orientation 270	Average	
	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	
Date						
Jan 01-31	45.3948	45.1541	45.3948	45.1541	45.27445	
Feb 01-28	43.9855	43.9557	43.9855	43.9557	43.9706	
Mar 01-31	52.9095	53.1411	52.9095	53.1411	53.0253	
Apr 01-30	57.033	57.226	57.033	57.226	57.1295	
May 01-31	61.3767	61.3884	61.3767	61.3884	61.38255	
Jun 01-30	59.6639	59.6639	59.6639	59.6639	59.6639	
Jul 01-31	61.8604	61.8604	61.8604	61.8604	61.8604	
Aug 01-31	61.9063	61.9063	61.9063	61.9063	61.9063	
Sep 01-30	59.6283	59.6283	59.6283	59.6283	59.6283	
Oct 01-31	60.9651	60.9681	60.9651	60.9681	60.9666	
Nov 01-30	55.7277	55.6953	55.7277	55.6953	55.7115	
Dec 01-31	49.0163	48.7444	49.0163	48.7444	48.88035	Cost $
Summed total	**669.4675**	**669.3319**	**669.4675**	**669.3319**	**669.3997**	AED 100,409.96

3. BREEAM Assessment Baseline results

<Virtual Environment> 6.4.0.8

Project File: actual.mit
Sim File: actual.aps 14/Mar/2012
Weather File: AbuDhabiIWEC.fwt

	Total CE (kgC)
	actual.aps
Date	
Jan 01-31	4372
Feb 01-28	4172
Mar 01-31	5117
Apr 01-30	5567
May 01-31	6547
Jun 01-30	6947
Jul 01-31	7736
Aug 01-31	7648
Sep 01-30	7280
Oct 01-31	6414
Nov 01-30	5436
Dec 01-31	4730
Summed total	71967

APPENDIX 4

Energy Model Validation with HAP

1. HAP Results
2. IES Results

1. HAP Results

Annual Cost Summary

Table 1. Annual Costs

Component	[B000] Shop 2 (DHS)	[B090] Shop 2 (DHS)	[B180] Shop 2 (DHS)	[B270] Shop 2 (DHS)	Shop 2 (DHS)
Air System Fans	0	0	0	0	0
Cooling	1,642	1,626	1,765	1,786	1,699
Heating	0	0	0	0	0
Pumps	0	0	0	0	0
Cooling Tower Fans	0	0	0	0	0
HVAC Sub-Total	**1,642**	**1,626**	**1,765**	**1,786**	**1,699**
Lights	226	226	226	226	418
Electric Equipment	2,578	2,578	2,578	2,578	2,578
Misc. Electric	321	321	321	321	321
Misc. Fuel Use	0	0	0	0	0
Non-HVAC Sub-Total	**3,124**	**3,124**	**3,124**	**3,124**	**3,317**
Grand Total	**4,766**	**4,749**	**4,889**	**4,909**	**5,016**

Table 2. Annual Cost per Unit Floor Area

Component	[B000] Shop 2 (DHS/ft²)	[B090] Shop 2 (DHS/ft²)	[B180] Shop 2 (DHS/ft²)	[B270] Shop 2 (DHS/ft²)	Shop 2 (DHS/ft²)
Air System Fans	0.000	0.000	0.000	0.000	0.000
Cooling	3.655	3.618	3.929	3.975	3.782
Heating	0.000	0.000	0.000	0.000	0.000
Pumps	0.000	0.000	0.000	0.000	0.000
Cooling Tower Fans	0.000	0.000	0.000	0.000	0.000
HVAC Sub-Total	**3.655**	**3.618**	**3.929**	**3.975**	**3.782**
Lights	0.502	0.502	0.502	0.502	0.931
Electric Equipment	5.737	5.737	5.737	5.737	5.737
Misc. Electric	0.714	0.714	0.714	0.714	0.714
Misc. Fuel Use	0.000	0.000	0.000	0.000	0.000
Non-HVAC Sub-Total	**6.953**	**6.953**	**6.953**	**6.953**	**7.382**
Grand Total	**10.608**	**10.570**	**10.881**	**10.927**	**11.164**
Gross Floor Area (ft²)	449.3	449.3	449.3	449.3	449.3
Conditioned Floor Area (ft²)	449.3	449.3	449.3	449.3	449.3

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	[B000] Shop 2 (%)	[B090] Shop 2 (%)	[B180] Shop 2 (%)	[B270] Shop 2 (%)	Shop 2 (%)
Air System Fans	0.0	0.0	0.0	0.0	0.0
Cooling	34.5	34.2	36.1	36.4	33.9
Heating	0.0	0.0	0.0	0.0	0.0
Pumps	0.0	0.0	0.0	0.0	0.0
Cooling Tower Fans	0.0	0.0	0.0	0.0	0.0
HVAC Sub-Total	**34.5**	**34.2**	**36.1**	**36.4**	**33.9**
Lights	4.7	4.7	4.6	4.6	8.3
Electric Equipment	54.1	54.3	52.7	52.5	51.4
Misc. Electric	6.7	6.8	6.6	6.5	6.4
Misc. Fuel Use	0.0	0.0	0.0	0.0	0.0
Non-HVAC Sub-Total	**65.5**	**65.8**	**63.9**	**63.6**	**66.1**
Grand Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Table 1. Annual Costs

Component	[B000] Shop 2 (DHS)	[B090] Shop 2 (DHS)	[B180] Shop 2 (DHS)	[B270] Shop 2 (DHS)	Shop 2 (DHS)
HVAC Components					
Electric	1,642	1,626	1,765	1,786	1,699
Natural Gas	0	0	0	0	0
Fuel Oil	0	0	0	0	0
Propane	0	0	0	0	0
Remote HW	0	0	0	0	0
Remote Steam	0	0	0	0	0
Remote CW	0	0	0	0	0
HVAC Sub-Total	**1,642**	**1,626**	**1,765**	**1,786**	**1,699**
Non-HVAC Components					
Electric	3,124	3,124	3,124	3,124	3,317
Natural Gas	0	0	0	0	0
Fuel Oil	0	0	0	0	0
Propane	0	0	0	0	0
Remote HW	0	0	0	0	0
Remote Steam	0	0	0	0	0
Non-HVAC Sub-Total	**3,124**	**3,124**	**3,124**	**3,124**	**3,317**
Grand Total	**4,766**	**4,749**	**4,889**	**4,909**	**5,016**

Table 2. Annual Energy Consumption

Component	[B000] Shop 2	[B090] Shop 2	[B180] Shop 2	[B270] Shop 2	Shop 2
HVAC Components					
Electric (kWh)	10,948	10,837	11,767	11,905	11,329
Natural Gas (na)	0	0	0	0	0
Fuel Oil (na)	0	0	0	0	0
Propane (na)	0	0	0	0	0
Remote HW (na)	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0
Remote CW (na)	0	0	0	0	0
Non-HVAC Components					
Electric (kWh)	20,825	20,825	20,825	20,825	22,110
Natural Gas (na)	0	0	0	0	0
Fuel Oil (na)	0	0	0	0	0
Propane (na)	0	0	0	0	0
Remote HW (na)	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0
Totals					
Electric (kWh)	31,773	31,662	32,592	32,730	33,439
Natural Gas (na)	0	0	0	0	0
Fuel Oil (na)	0	0	0	0	0
Propane (na)	0	0	0	0	0
Remote HW (na)	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0
Remote CW (na)	0	0	0	0	0

Table 3. Annual Emissions

Component	[B000] Shop 2	[B090] Shop 2	[B180] Shop 2	[B270] Shop 2	Shop 2
CO2 Equivalent (lb)	0	0	0	0	0

Table 4. Annual Cost per Unit Floor Area

Component	[B000] Shop 2 (DHS/ft²)	[B090] Shop 2 (DHS/ft²)	[B180] Shop 2 (DHS/ft²)	[B270] Shop 2 (DHS/ft²)	Shop 2 (DHS/ft²)
HVAC Components					
Electric	3.655	3.618	3.929	3.975	3.782
Natural Gas	0.000	0.000	0.000	0.000	0.000
Fuel Oil	0.000	0.000	0.000	0.000	0.000
Propane	0.000	0.000	0.000	0.000	0.000
Remote HW	0.000	0.000	0.000	0.000	0.000
Remote Steam	0.000	0.000	0.000	0.000	0.000
Remote CW	0.000	0.000	0.000	0.000	0.000
HVAC Sub-Total	**3.655**	**3.618**	**3.929**	**3.975**	**3.782**
Non-HVAC Components					
Electric	6.953	6.953	6.953	6.953	7.382
Natural Gas	0.000	0.000	0.000	0.000	0.000
Fuel Oil	0.000	0.000	0.000	0.000	0.000
Propane	0.000	0.000	0.000	0.000	0.000
Remote HW	0.000	0.000	0.000	0.000	0.000
Remote Steam	0.000	0.000	0.000	0.000	0.000
Non-HVAC Sub-Total	**6.953**	**6.953**	**6.953**	**6.953**	**7.382**
Grand Total	**10.608**	**10.570**	**10.881**	**10.927**	**11.164**
Gross Floor Area (ft²)	449.3	449.3	449.3	449.3	449.3
Conditioned Floor Area (ft²)	449.3	449.3	449.3	449.3	449.3

Note: Values in this table are calculated using the Gross Floor Area.

Table 5. Component Cost as a Percentage of Total Cost

Component	[B000] Shop 2 (%)	[B090] Shop 2 (%)	[B180] Shop 2 (%)	[B270] Shop 2 (%)	Shop 2 (%)
HVAC Components					
Electric	34.5	34.2	36.1	36.4	33.9
Natural Gas	0.0	0.0	0.0	0.0	0.0
Fuel Oil	0.0	0.0	0.0	0.0	0.0
Propane	0.0	0.0	0.0	0.0	0.0
Remote HW	0.0	0.0	0.0	0.0	0.0
Remote Steam	0.0	0.0	0.0	0.0	0.0
Remote CW	0.0	0.0	0.0	0.0	0.0
HVAC Sub-Total	**34.5**	**34.2**	**36.1**	**36.4**	**33.9**
Non-HVAC Components					
Electric	65.5	65.8	63.9	63.6	66.1
Natural Gas	0.0	0.0	0.0	0.0	0.0
Fuel Oil	0.0	0.0	0.0	0.0	0.0
Propane	0.0	0.0	0.0	0.0	0.0
Remote HW	0.0	0.0	0.0	0.0	0.0
Remote Steam	0.0	0.0	0.0	0.0	0.0
Non-HVAC Sub-Total	**65.5**	**65.8**	**63.9**	**63.6**	**66.1**
Grand Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

LEED 2009 EA Credit 1 Summary Report

General Information

Simulation Program Name and Version .... **Hourly Analysis Program v4.51**
Simulation Weather File Name ...... **Abu Dhabi, United Arab Emirates (IWC)**

Building Designations

Proposed Building .... **Shop 2**
Baseline - 0 degrees .... **[B000] Shop 2**
Baseline - 90 degrees .... **[B090] Shop 2**
Baseline - 180 degrees .... **[B180] Shop 2**
Baseline - 270 degrees .... **[B270] Shop 2**

Floor Areas and Window-to-Wall Ratios

	Proposed Design	Baseline
Total Conditioned Floor Area (ft²)	449	449
Total Floor Area (ft²)	449	449
Window to Wall Ratio	100 %	100 %
Gross Wall Area (ft²)	294	294
Vertical Window Area (ft²)	294	294

Advisory Messages

	Proposed Building	Baseline Building (0 deg. rotation)	Difference
Number of hours heating loads not met	0	0	0
Number of hours cooling loads not met	0	0	0

Energy Type Summary

Energy Type	Utility Rate Description	Units of Energy	Units of Demand
Electric	shop 2	kWh	kW

Energy Units:
1 kBTU = 1,000 BTU
1 kWh = 3.412 kBTU

Demand Units:
1 MBH = 1,000 BTU/h
1 kW = 3.412 MBH

Baseline Performance - Performance Rating Method Compliance

End Use	Process	Baseline Design Energy Type	Units of Annual Energy & Peak Demand	Baseline (0 deg rotation)	Baseline (90 deg rotation)	Baseline (180 deg rotation)	Baseline (270 deg rotation)	Baseline Design
Interior Lighting	No	Electric	Energy kWh	1,504	1,504	1,504	1,504	1,504
			Demand kW	0.4	0.4	0.4	0.4	0.4
Space Heating	No	Electric	Energy kWh	0	0	0	0	0
			Demand kW	0.0	0.0	0.0	0.0	0.0
Space Cooling	No	Electric	Energy kWh	10,948	10,837	11,767	11,905	11,364
			Demand kW	5.0	4.9	4.8	5.1	5.0
Pumps	No	Electric	Energy kWh	0	0	0	0	0
			Demand kW	0.0	0.0	0.0	0.0	0.0
Heat Rejection	No	Electric	Energy kWh	0	0	0	0	0
			Demand kW	0.0	0.0	0.0	0.0	0.0
Fans - Interior	No	Electric	Energy kWh	0	0	0	0	0
			Demand kW	0.0	0.0	0.0	0.0	0.0
Receptacle Equipment	Yes	Electric	Energy kWh	17,184	17,184	17,184	17,184	17,184
			Demand kW	2.5	2.5	2.5	2.5	2.5

Electrical instruments	Yes	Electric	Energy kWh	2,137	2,137	2,137	2,137	2,137
			Demand kW	0.4	0.4	0.4	0.4	0.4
Baseline Energy Totals	Total Annual Energy Use kBTU			108,411	108,030	111,206	111,675	109,830
	Annual Process Energy kBTU							65,925
	Process Energy Modeling Compliance							Y

(1) This form determines compliance using cost calculations from Section 1.9. Process Energy Costs should be modeled to accurately reflect the proposed building. Process Energy must be the same in the baseline and proposed cases, unless an exceptional calculation is used. Process energy costs must be at least 25% of the total baseline energy costs. Any exceptions must be supported by a narrative and/or other supporting doucmentation.
(2) In this project Process Energy is 60% of total baseline energy cost.

Baseline Energy Costs

Energy Type	Baseline Cost (0 deg rotation) (DHS)	Baseline Cost (90 deg rotation) (DHS)	Baseline Cost (180 deg rotation) (DHS)	Baseline Cost (270 deg rotation) (DHS)	Baseline Building Performance (DHS)
Electric	4,766	4,749	4,889	4,909	4,828
Total Baseline Costs	**4,766**	**4,749**	**4,889**	**4,909**	**4,828**

Performance Rating Table - Performance Rating Method Compliance

End Use	Process ?	Baseline Building Units	Baseline Building Results	Proposed Design Energy Type	Proposed Design Units	Proposed Building Results	Percent Savings
Interior Lighting	No	Energy kWh	1,504	Electric	Energy kWh	2,789	-85 %
		Demand kW	0.4		Demand kW	0.7	-85 %
Space Heating	No	Energy kWh	0	Electric	Energy kWh	0	n/a
		Demand kW	0.0		Demand kW	0.0	n/a
Space Cooling	No	Energy kWh	11,364	Electric	Energy kWh	11,329	0 %
		Demand kW	5.0		Demand kW	5.1	-4 %
Pumps	No	Energy kWh	0	Electric	Energy kWh	0	n/a
		Demand kW	0.0		Demand kW	0.0	n/a
Heat Rejection	No	Energy kWh	0	Electric	Energy kWh	0	n/a
		Demand kW	0.0		Demand kW	0.0	n/a
Fans - Interior	No	Energy kWh	0	Electric	Energy kWh	0	n/a
		Demand kW	0.0		Demand kW	0.0	n/a
Receptacle Equipment	Yes	Energy kWh	17,184	Electric	Energy kWh	17,184	0 %
		Demand kW	2.5		Demand kW	2.5	0 %
Electrical instruments	Yes	Energy kWh	2,137	Electric	Energy kWh	2,137	0 %
		Demand kW	0.4		Demand kW	0.4	0 %
Energy Totals	Baseline Total Energy Use (kBTU)		109,830	Proposed Total Energy Use (kBTU)		114,094	-4 %
	Baseline Annual Process Energy (kBTU)		65,925	Proposed Annual Process Energy (kBTU)		65,925	0 %

Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design		Baseline Design	
Energy Type	**Energy Use**	**Cost (DHS)**	**Energy Use**	**Cost (DHS)**
Electric	33,439 kWh	5,016	32,189 kWh	4,828
Subtotal (Model Outputs)	**114,094 kBTU**	**5,016**	**109,830 kBTU**	**4,828**
	Energy Generated	**Renewable Energy Cost Savings (DHS)**		
Total On Site Renewable Energy				
	Energy Savings	**Cost Savings (DHS)**		
Exceptional Calculation Totals				
	Energy Use	**Cost (DHS)**		
Net Proposed Design Total	**114,094 kBTU**	**5,016**		
	Percent Savings		**Energy Use Intensity**	
	Energy	**Cost**	**Proposed Design ($kBTU/ft^2$)**	**Baseline Design ($kBTU/ft^2$)**
Summary Data	**-3.9 %**	**-3.9 %**	**253.94**	**244.45**

LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

2. IES Results

<Virtual Environment> 6.4.0.8

Project File: Validation.mit
Sim File: validation.aps 14/Mar/2012
Weather File: AbuDhabiIWEC.fwt

	Total electricity (MWh)
	validation.aps
Date	
Jan 01-31	1.4275
Feb 01-28	1.4795
Mar 01-31	2.0774
Apr 01-30	2.4185
May 01-31	3.0995
Jun 01-30	3.6394
Jul 01-31	4.3501
Aug 01-31	4.3323
Sep 01-30	3.9761
Oct 01-31	2.9868
Nov 01-30	2.3684
Dec 01-31	1.7098
Summed total	33.8654