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## ECO FRIENDLY ARCHITECTURE– A PRELUDE IN THE SULTANATE OF OMAN

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### Abstract

*In developed countries, the issue of green architecture and sustainability practices has been a major concern to building professionals and the community for many years. On the contrary, in the developing countries, the same issues are beyond public awareness. The Sultanate of Oman is one of the countries whose national economy is mainly based on nonrenewable energy resource, oil. In addition, the recent plummet in the price. of fossil fuel ushered Oman to seek alternative energy resources, and to think of adopting new policies. Unprecedented in the Third world, the national competition for Eco House Design was announced. Five examples of Eco Houses were designed and constructed during the first phase. This research aims to shed light on this remarkable Omani experience among the developing countries. The methodology of the research is incumbent on a theoretical foundation of previous related references analysis and a cross comparative case study. Other tools were used like interviews and site visits. The research succeeded in outlining the design criteria of eco-friendly architecture and clarifying the starting point taken by the Oman to adopt the green and issues. In addition, two examples of the Eco-houses in arid zones were provided. In the future, further steps have to be taken to re-direct the Omani society to adopt the green attitude.*

## Keywords

Eco House, Energy Efficient House, Eco House Design Criteria, Eco House Competition

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## 1. Introduction

### 1.1 The Devastation of the Natural Ecological Balance

At the end of the first decade of the 21<sup>st</sup> century, the world's population was approximately seven billion; nearly 450% as many as there were at the beginning of the twentieth century (Sayigh, 2014). The above vast acceleration of urbanization resulted in a break of the global ecological balance. Subsequent are the ozone layer problem, climate change, CO<sub>2</sub> emissions, and global warming all of which are considered as natural catastrophes (Mohammed, 2015).

Moreover, the rapid depletion of fossil fuels at unprecedented rates has resulted in a global trend in searching for alternatives of renewable energy resources (Al- Hiddabi, S., Al-Mugheiry, M., Al-Harthy, S., Al- Hinai, J., Al-Hinai, A., and Al-Hinai, B., 2011). Furthermore, the earth's supply of fresh water is rapidly decreasing while the demand for it is quickly increasing. A 2009 report prepared by the consulting firm Mckinsey& company revealed that global water needs will increase by 40% by the year 2030, whereas shrinking water sheds, droughts, and sea water rising levels are at the same time resulting in a negative impact of worldwide provisions (Henderson, 2012).

The said issues and the need for the limits of growth were discussed on global scale in United Nations Rio Earth Summit in 1992, followed by the final establishment of the Kyoto Protocol in 1996. These events warned the general public to the consequences of man's abuse of natural resources and the accelerated destruction of the eco systems.

### 1.2 The Eco Friendly Architecture- Adoptedby Advanced Countries

In western countries, there is a notable increase of green building activities during the past 40 years. Actually, through the past 25 years more actions, guidelines, policies and regulations have been adopted. Serious steps were taken to increase the green buildingactivities both top-down (government demands / corporate incentives) and bottom-up (consumer requirements)(Crocker & Lehmann, 2013)

It is clear that sustainability has become a disseminated concept in day-to-day life. For the most part in developed countries, when people say “green”, it is recognized as referring to an environmental attitude. On the contrary, in developing countries, for the most part when “green” is mentioned it indicates a crayon color. (Henderson, 2012)

### **1.3 The Need to Adopt Green Policies in Developing Countries**

It is worth mentioning that, developing countries often have the fastest growing population and rising requirements for better standards of housing. For example, in the Gulf Cooperation Countries (GCC), the discovery of oil accelerated the rate of construction and megaprojects. The people’s high precipitate income with cheap available electricity encouraged them to live in concrete constructions, which is dependent on imported steel and cement. This gave more comfort and led them to abandon the traditional adobe buildings with all their creative eco-friendly environmental characteristics. This type of urban development is described as being wasteful of energy.

In addition, due to the harsh climate, with mid-day temperatures, in the shade, during summer reaching more than 50°C, the mentioned high rise buildings require cooling (air conditioning) even in winter months.

Furthermore, the rapid expansion of the GCC towns raised more need for potable and non-potable water, taking into consideration that those countries have minimal rainfall without any natural source of water like lakes or rivers (Sayigh, 2014).

### **1.4 Starting the Green Path in the Sultanate of Oman**

Recently Oman faced serious problems resulting from the above mentioned factors that shared them with the GCC; the current constructing air conditioned buildings consume more than 70% of total electricity produced in Oman. Moreover, the horizontal expansion of urban development coupled with increased disposable income and increase of private car ownership made Oman one of the largest producers of greenhouse gases per capita that are blamed for global warming.

Under the above mentioned conditions, The Sultanate’s eighth 5 years plan (2011-2015) included that conservation of energy, development of renewable alternatives, and environmental protection are amongst the national priorities (Al-Hiddabi et al, 2011). One of the governmental responses was exemplified in announcing the National Competition Eco-House Design in the year 2011. Students from higher Educational Institutions competed in designing an innovative

house based on the design criteria of the traditional Omani architectural heritage which dates back to the 13th century(<http://home.trc.gov.om>).The Research Council (TRC) awarded the winning teams of the Oman Eco-House Design Competition- first phase. The second phase (2015-2017) is currently proceeding.(Al-Busaidi, 2016).

This research aims to provide this experience which is unprecedented in developing countries to the Sultanate of Oman and other similar countries sharing the same challenges. Furthermore, the paper will be a source of information for designers, relevant professionals, architecture students, authorities, scholars, design makers, and enthusiasts worldwide. The author also endeavors to participate in raising the awareness of the Omani people for such global and national challenges.

The methodology of the research is based on a theoretical foundation of previous related reference analysis and a cross comparative case study. More tools were used like site visits, personal observation and interviews.

At the beginning, the main criteria in designing the eco-friendly construction will be clarified. Then, moving on to show the Omani governmental approach in adopting the green architecture trend. A case study of comparing between the winners projects of the first and second place will be discussed. Finally the conclusion and recommendations will be presented.

### **1.5 Literature Review**

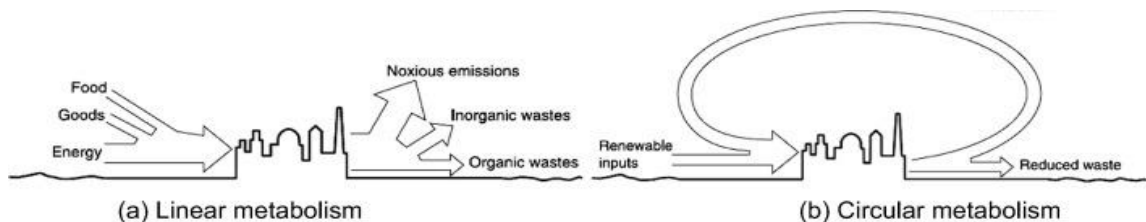
Taking a quick look at some examples of the relevant publications in the past few years; simple design techniques to build eco-friendly houses using natural materials were covered step by step through different books (Janssen, 1995), (Hunter and Kiffmeyer, 2004), (Snell and Callhan, 2009), (Crimmel and Thomson, 2014), (Rogue, 2016). Recycling and storage water was discussed as one of the necessities to build green was covered in many books (Jenkins, 1996), (Ludwig, 2005), (Lancaster and Marshall, 2007), (Fryer, 2011), (Ho & Lin, 2016), (Eckert, 2017).The issue of eco-friendly construction, sustainability and other relevant issues have been discussed from a comprehensive aspect (Walker 2005), (Orr, 2006),(Schröper, 2012),(Henderson, 2012), (Rawes, 2013), (Sayigh, 2014),(Mohammed, 2015),(Al-Zoklah,2015),(Wyk, 2017).The design criteria of establishing environmental friendly houses (Wilhide, 2003) (Johnston and Gibson, 2008),(Maeda, 2011). The eco-designing considering the social norm was also discussed (Conran, 2012), (Crocker and Lehmann, 2013)(Hegazy, 2015). Many literatures profiled examples of eco-friendly projects (Duran, 2007), (Broto, 2010),

(Serrats, 2011), (Goethe-Institute Shanghai, Tongii University and Himalayas Art Museum, 2010). Finally, some publications discussed the knowledge and understanding of the passive house standards as a potential solution to net-zero building (Chiras, 2002), (Jayamaha, 2006), Gibson, (Johnston, 2008) , Omar, 2014), (Cody, 2017), (Charan, 2017).

## 2. Main criteria in Designing Eco Houses

Through this point, the building design will be deconstructed into main criteria to be discussed from the aspect of eco-friendly design. Starting with the definition;

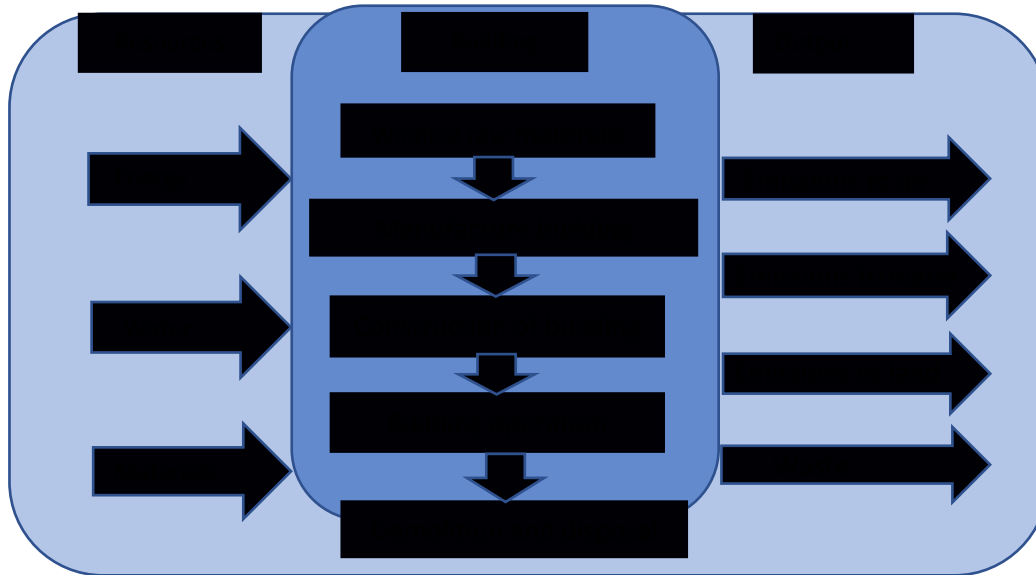
Eco” has a Greek etymology (oikos). The architectural profession’s explanations of “oikos” as the basis for building designs, technologies and material types that achieve environmental efficiency; for instance, by reducing CO2 emissions or using renewable energies (Rawes, 2013). Elizabeth Wilhide defines “ecological design” as “The design that uses resources that come from the earth without causing harm in a cycle that echoes the natural system of living things” (Wilhide, 2003). The main concept was expressed in a different way by Abdel Rahman Mohamed comparing the processes which human bodies use in producing energy via food in closing cycle (circular metabolism), with the linear metabolism of the city. It has been suggested that this linear urban metabolism should be changed to a form of circular metabolism through the actions of design and management(Mohamed, 2015) (figure 1).



**Figure1:** *Metabolism concept of cities (Mohamed, 2015)*

In general, eco-friendly building involves taking into account many criteria, for example the major environmental issues that are indicated in (figure 2) (Sayigh, 2014).

Through the coming discussion, a brief summary will be given on the main considerations to be taken into account in designing an eco-friendly building.



**Figure 2:** A wide ranges of environmental issues to be considered in eco-friendly building  
(Sayigh, 2014)

### 2.1 Material Selection and Use

Eco strategies that are advisable to be adopted include; reducing the used material and waste during the construction process, selecting the materials that have low environmental impact or recycled ones and avoiding materials and interior finishes with toxic components (Wilhide, 2003). Undoubtedly, local materials are a fundamental necessity for Eco-design strategy. This mode of ecological approach in architecture is characterized by a low-tech. or vernacular design, which considered time-tested solutions

Material ecology must be understood around the entire life cycle. Beginning with manufacturing process to its transportation including the embedded energy and environmental cost. (Schröper, 2012) It is worth mentioning that a third of the world's population lives in houses constructed from one of the most ecological materials of all time; Adobe and rammed earth. These types of houses work particularly well in moderate and warm regions.

### 2.2 Energy Efficiency (Passive Strategies)

It is a fundamental fact that buildings make their extremist impact on the environment through the consumed energy over their lifetime (Wilhide, 2003).

Environmental energy worries range from climate change impacts which may contribute to rising sea levels resulting eventually in displacing millions of people, to limited nonrenewable sources of energy such as fossil fuels, coal and gas (Henderson, 2012).

According to the raise in energy need and fast depletion of fossil fuel, eco strategies that are advisable to be adopted include clean and renewable energy resources to be used to meet demand of power in future (Charon, 2017). In arid zones, which Oman belongs to, the sun shines all year round, accordingly, solar energy will be the ideal source of energy, taking into account that an average solar powered house saves more than a ton of carbon dioxide a year. In addition, the produced energy could be connected to the national power grid (Wilhide, 2003).

From the other hand, a dramatic reduction in energy consumption could be achieved via depending on natural ventilation. Promoting indoor air movement through the traditional methods has many options; windows or doors opposite one another. The stack effect can also be exploited by venting warm air at high level windows and skylights. Another option is to install a heat recovery ventilator and heat exchange system.

Furthermore, one of the effective traditional practices to reduce the air temperature is using a water item like fountains or pools. Air that travels over water is naturally cooled and provides a fresh cooling breeze to living spaces.

Another important and the most critical strategy of energy efficiency is insulation. It was estimated that just by insulating walls and the roof space; heat gain could be reduced by 50%. (Wilhide, 2003).

Window's design, size, composition, position, glazing coat and shading can be used to minimize solar gain. Triple glazing is the best choice for long-term energy saving. In addition, adding an inert gas sealed between the panes is also appropriate. A low-emissive coating "Low-E" on the outside pane helps in reflecting heat out of the building reducing cooling costs.

Concerning the window's frame, the ideal one should be made of sustainably-sourced timber, prefaced treated soft wood or hard wood. PVC is not advisable because of its liability to crack, inflexibility and the risk of dioxin pollution with risks when it is sent to landfills.

Furthermore, it is recommended to specify windows made with 33% of recycled glass ([www.superhomes.org.uk](http://www.superhomes.org.uk)). Windows placed high up in a wall provide light to penetrate further than windows at normal height. Similarly, raising the height of a window to provide more light rather than widening it.

The more day light the interior receives, there will be a lesser need to count on artificial lighting and accordingly this will give rise to lower energy consumption (Wilhide, 2003). There are many techniques that can help to reduce lighting costs by 30-50%, whereas avoiding the

overheating and adding light shelves to reflect more light deeper into the space(www.superhomes.org.uk).

Finally, reflective or white external finishes also serve to reduce the amount of heat absorbed by the building. Considerable savings can be achieved by using energy efficient lighting sources like LED lamps and similar ones (Wildhide, 2003).

### **2.3 Water Management**

A 2009 report by the consulting firm McKinesy& Company demonstrated that global water needs will increase by 40% by the year 2030 (Henderson, 2012). To extend sources, alternative provenances of water, such as recycled water, or desalination, may be sought (Ho&Lin, 2016).

The eco-strategies that may be adopted include, using water-efficient appliances and plumbing systems, collecting rain water (not applicable in most of Oman), recycling gray and black water and installing composting toilets. To clarify some of the above technical terms; “Gray water” is the water that is defiled from washing and showering while “Black water” is the water flushed from toilets, water from kitchen sinks, dishwashers and washing machines are also considered as black water. Recycled water could be used to flush toilets and garden irrigation.

Finally, using composting toilets- water-less system that breakdown human waste objects into organic compost (Wilhide, 2003).

### **2.4 Building Orientation and Efficient Space Use**

The location of the building has a direct influence on its thermal performance. The ideal site for an eco-house in the southern hemisphere is north-facing that provides opportunities for avoiding passive solar gain. The north side should be up to 60% window, while the south-facing side should be more enclosed with minimal openings. Furthermore, living areas have to face the north side of the house while service areas are better to be located on the south. Open internal court yards offer maximum surface area for cooling (Wilhide, 2003).

Rectangular lots usually allow for the most functionality land use, particularly small ones-less than 300 m<sup>2</sup>. Compact housing forms are more energy efficient as there are fewer exposed external surfaces for heat to penetrate. However, longer, narrow building forms are preferable in high humid climates because they help passive cooling.

Controlling the house’s economic and environmental cost requires choosing an appropriate size. Each square meter has its construction’s cost besides yearly lighting and



cooling budget. Well-designed spaces with clever furnishing patterns and clever storage can allow a size reduction of up to 30% without loss of comfort ([www.superhours.org.uk](http://www.superhours.org.uk))

## 2.5 Eco Gardening and landscape Design

Within the recent decades, landscape has increasingly been integrated and connected to architecture. From the eco design perspective, planting vegetation, climbers, trees, and creepers next to the house is a way of providing shade and cooling the surrounding area through reducing reflected heat (Wilhide, 2003).

Green façades that are made up of climbing plants either growing directly on a wall or in specially designed supporting construction is one of the common relevant applications (Al-Zoklah, 2015). However, Eco gardening means planning and designing the garden with regard to local conditions, taking into account the type of soil, the amount of rain fall, the prevailing winds and temperature. By choosing plants that naturally endure the above mentioned set of conditions; the plants will thrive better and need less intervention in the form of maintenance and control.

“Xeriscaping” is an example of gardening in very arid states. A group of strategies are applied for maximum water efficiency, such as enhancing the soil with organic matter to improve water retention as in the case of using sawdust and similar items. In addition, terracing or sloping the site to retain water, gathering plants with similar water needs, mulching and above all, choosing native drought tolerant species (Wilhide, 2003).

## 3. The New Omani Governmental Orientation of Adopting the Eco Construction

### 3.1 The Cultural Sustainability between Traditional and Contemporary Omani Architecture

The traditional architecture of Oman was shaped by forces of natural environment and culture that affected faith, mood, lifestyle and identity (Al Zubair, 2013). The climate of Oman – that lies in an arid zone- is known by very hot summers, where the temperatures have been recognized to reach 50° C. Omani people have learned to react with their climate and build houses with thick walls with very limited small opening to keep out hot air and sun glare. Wooden lattices fill larger opening to suppress the sun glare while allowing the breeze to pass through (figure3).



**Figure 3:** Traditional Omani constructions with thick walls and very limited small screened openings(<http://www.muscatdaily.com>)

Another technique of selecting materials with high thermal insulating nature like adobe brick was also used (Hegazy, 2015).

From the above mentioned, it is obvious that Oman's traditional architecture did incorporate the key attributes of environmentally friendly buildings in terms of their layout, design and used materials (Al Hiddabi et al, 2011)

Starting from 1980s, the government issued a set of regulations and guidelines that specified new buildings to abide by “*traditional Omani and Islamic Forms*”. More regulations in the building code were also enforced, unprecedented in the Gulf region, limiting the height of buildings to a maximum of three stories for residential buildings and ten for commercial buildings, specific light colors are also obligatory. The above specifications hold the amazing sensitive appreciation of the natural environment of the contemporary Omani architecture as the traditional one (Hegazy, 2015) (Figure 4).



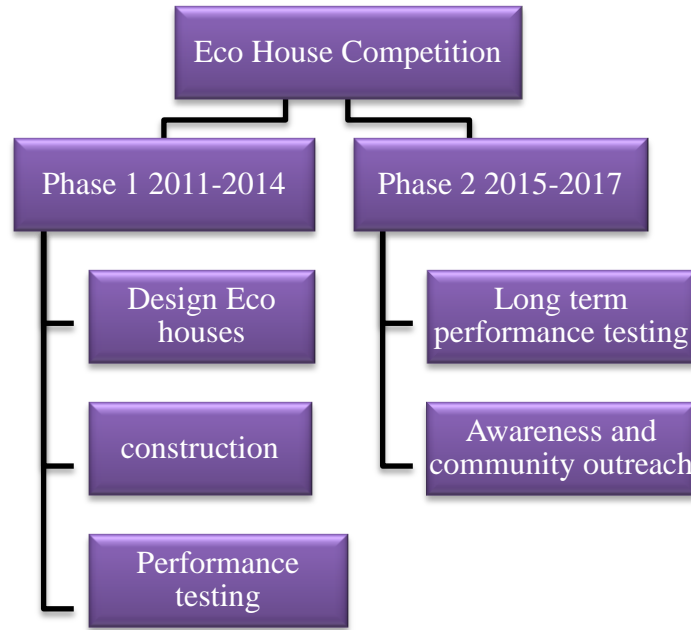
**Figure 4:** Contemporary Omani architecture in line with the traditional one ([www.everythingspossible.wordpress.com](http://www.everythingspossible.wordpress.com))

### 3.2 The Steps Taken by the Government to Adopt Eco Friendly Buildings

The dramatic development of the Sultanate, like other similar countries with a fast rate of development, is achieved at the expense of excessive consumption of natural resources and damage to the ecological environment (Goethe-Institute Shnghi et al, 2011)

Accordingly, the Sultanate of Oman's eighth 5-year plan (2011-2015) pointed out that conservation of energy, development of renewable alternatives and environmental protection are among the national priorities. In 2010 the RCT in Oman organized a national competition for an eco-friendly house (Al-Hiddabi, 2011). The competition is an award-winning program that challenges collegiate teams to design, build, and operate Eco-Friendly houses that are energy-efficient, cost effective and attractive (<http://home.trc.gov.om>)

The strategic goal of the competition is developing an effective National Research and Innovation System with programs to be implemented in a phased approach. This work would contribute significantly to a comprehensive socioeconomic development. Such a competition served some important areas of the national policies for the 5-year plan (2011-2015) including the following; enhanced oil recovery: to make investments in diversifying the national economy. Water desalination, to address the challenges of decreasing supply of potable water for drinking and agriculture. Alternative or renewable energy: the passive effects of fossil fuel on environment, human health, climate change and depletion of natural oil. Environmental protection; creating environmentally-friendly solutions to realize sustainable development for the coming generations (Research Council, 2016). At the societal level, the main objectives of the competition can be clarified as; foster a culture of innovation and research in cost-effective, high quality and cost-efficient eco construction design, supporting creativity and innovation in higher education (<http://home.trc.gov.om>) The competition was divided into three phases; the first two phases are represented in the following chart:



**Figure 5:** The first two phases of Eco House National Competition (Al-Busaidi, 2016)

The third phase (10-15 years) includes building a future to exceed within on going global trends. This phase will focus on broadening the variation of national economy and erecting bridges for local, regional and international collaboration to place the Sultanate within the global research and innovation network (Al-Hiddabi et al, 2011).

### 3.3 Announcement of the Winning Teams (Phase I)

In January, 2015 the RCT awarded the winning teams of the Omani Eco-House design Competition. The winning teams were placed as follows; First Place: Higher College of Technology, Second Place: German University of Technology in Oman (GUtech). Third Place: University of Nizwa, Fourth Place: Dhofar University, and Fifth Place: Sultan Qaboos University. (Figure 6)



**Figure 6:** The five participating teams in the Omani Eco-House Design competition (The Research Council Annual Report, 2016)

The second phase of the Oman Eco-house Design Competition was started in 2015 so as to assess the effectiveness and performance at different periods throughout the year over twenty

months. (The Research Council annual report, 2016) as per Dr. Al-Busaidi, the program manager of Strategic Renewable Energy at the RCT, during an interview that was conducted on the 17th of October, 2016, professional experts are participating in the assessment of phase II.





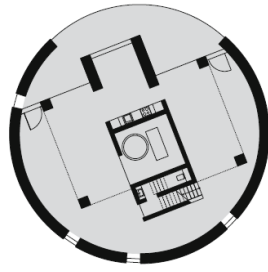
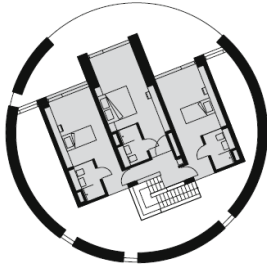
#### **4. Case Study - A Comparison between the First Two Winners of the Eco-House Competition**

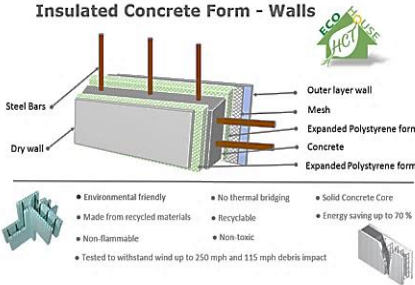
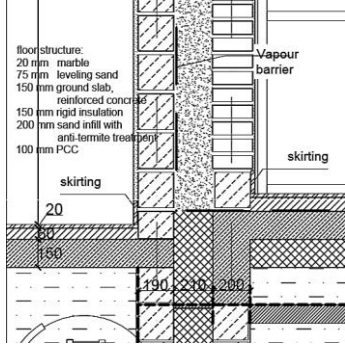


As it was mentioned in the previous point that the first two places of the national competition to design eco-friendly houses went to; Higher College of Technology (HCT) team and the second place was occupied by the German University in Oman (GUtech) team. The eco-friendly design criteria of the following comparison were derived mainly from the one set by the RCT (AL-Hiddabi et al., 2011) and those specified by Elizabeth Wilhide in her book “Eco- An Essential Source Book For Environmentally Friendly Design and Decoration” beside other sources. It’s worth mentioning that the following comparison is going to evaluate the application of the eco-design criteria not the efficiency of the performance as the last one is still underway in phase two of the competition.

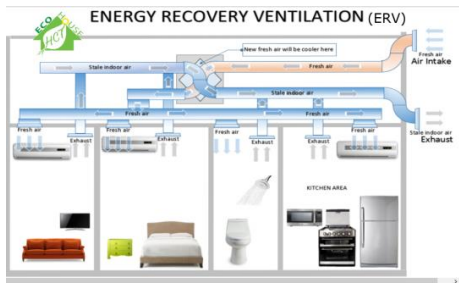
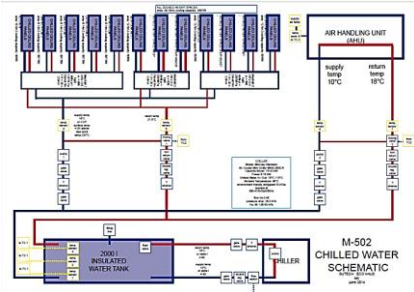
The main purpose of this comparison is to provide two successful examples of Eco-friendly houses that could be a blue- print or source of inspiration for the other similar countries sharing Oman’s environmental conditions in addition to the same cultural and societal situations. Moreover, this comparison will show how each project responded to the set of design criteria in a different way.

The information on the two projects were taken from their respective sites ([www. hct greenest.com](http://www.hctgreenest.com)) and ([www. echohouse competition.org](http://www.echohouse.competition.org)) More information was taken during two interviews conducted with Mrs. Mona Al farsi, Eco – house HCT project manager, on the 7th of October, 2016. Another interview was conducted with Assoc.Prof. Nikolaus Knebel, Eco- house project manager and the and the Head of the Architecture Dept., GUtech,

**Table 2:** A Comparisons between the first two winners of the Eco House Competition in Oman

The Eco-friendly design criteria	The HCT project 	The GUTech project 
<p><b>Form</b></p>	<p>-Rectangular form north-south orientation. -Area is 250 m<sup>2</sup>for the two floors.(Figures 7&amp;9)</p>  <p><b>Figure 7: Ground floor plan</b></p>  <p><b>Figure 9: first floor plan</b></p>	<p>-Cylindrical compact form and protective envelope.(Figures 8&amp;10) -Area is 210m<sup>2</sup> for the two floors.</p>  <p>ground floor</p> <p><b>Figure 8: Ground floor plan</b></p>  <p><b>Figure 10: first floor plan.</b></p>
<p><b>Orientation and sitting</b></p>	<p>-The main spaces and the entrance are facing the north direction. -The semi courtyard facing the north provides a source of cross ventilation. -Cancelling all the openings on the west direction where there is maximum exposure to the sun.</p>	<p>-The cylindrical form provides the minimum surface per volume to reduce the exposure for the external harsh climate. -Double height space to use the stack effect (review point 2.2).</p>
<p><b>Wall selection</b></p>	<p>-The walls were made of NUDURA (highly insulated concrete with air spaces)</p>	<p>-The cavity wall 60 cm thick of external layer made of Ponceblocmasonry wall, the internal layer is made of the clay brick.</p>
<p><b>Insulation</b></p>	<p>-The walls were made of highly insulated concrete with air spaces ( Figure 11)</p>	<p>-20 cm of Partite insulation is used for the walls( Figure 12).</p>

	<p>-A layer of 5cm thick of polystyrene added to the ground. -The house roof is insulated with 10cm thick layer of Polystyrene. -76 solar panels shade the roof.</p>  <p><b>Figure 11:</b> The walls were made of NUDURA (highly) insulated concrete with air spaces</p>	<p>-15cm rigid insulation used for the ground floor. -20 cm insulation board BASF-NEOPOD used on the roof. -The roof is shaded by solar panels.</p>  <p><b>Figure 12:</b> The cavity wall 60 cm thick using the traditional clay brick wall.</p>
<p><b>Paint</b></p>	<p>-Durable and glossy paint.</p>	<p>-Mud paint.</p>
<p><b>Flooring</b></p>	<p>-Terrazzo tiles.(low cost and local material)</p>	<p>-Omani marble.( local material)</p>
<p><b>Materials</b></p>	<p>-All the used materials during the whole construction process are eco-friendly and recycled.</p>	<p>-The walls frames and sheets used during the construction were re-used in furniture production.</p>
<p><b>Energy efficiency</b></p>	<p>-76 solar photo voltaic system for electrical power generation with a capability of supplying excess power to the grid.</p>	<p>-Solar photo voltaic system was used.No plan to provide extra energy to the campus as it was not one of the requirements.</p>
<p><b>Windows</b></p>	<p>-PVC double glass window. Air space between window panes. -Membranes shades used to cast shadows on the south openings(Figure 12).</p>  <p><b>Figure12:</b> Membrane shades on south windows &amp; facade</p>	<p>-The same PVC double glass windows were used. -Minimum openings used for the south and west directions (Figure 13).</p>  <p><b>Figure 13:</b>Minimum openings</p>

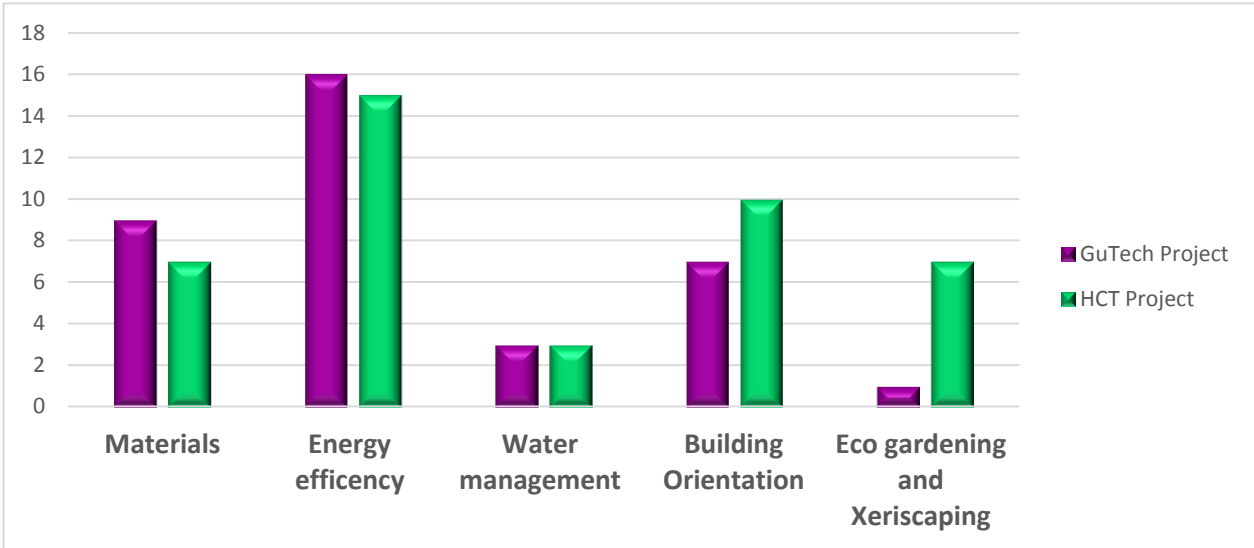
<p><b>Water Management</b></p> <p><b>Landscape</b></p> <p><b>Cooling System</b></p>	<p>-The house collected grey water waste for irrigation purpose.</p> <p>-Carefully selected plant life that acts as a natural heat barrier and harvest of organic produce like lemon from the garden.</p> <p>-Green wall 8 meters high was used to protect the western façade.</p> <p>-Energy recovery ventilation , efficient heating and air conditioning (HVAC) is used as shown in ( figure 14)</p>  <p><b>Figure 14: Energy Recovery ventilation air conditioning system.</b></p>	<p><i>used in the south and west.</i></p> <p>-Both of grey and black water are used for irrigation purposes.</p> <p>-Native plants that grew naturally will be included in the landscape area around the building during the coming period.</p> <p>-Hydraulic cooling &amp; energy recovery was used as shown in (Figure 15)</p>  <p><b>Figure 15: Hydraulic cooling &amp; energy recovery system.</b></p>
<p><b>Use of information technology and appliances</b></p>	<p>In both buildings, all the equipment are efficient in saving energy, and both buildings use LED lamps beside sensors to reduce used energy.</p>	

Concluding the above mentioned comparison between the design criteria of the first two winners of the eco house competition in Oman with the previously mentioned ones in point 2. The most desirable criteria were successfully applied; however, some criteria were missing as it will be shown in the following chart.

The following chart (Figure 16) translated the above comparison taking in consideration that the measuring scale of each sub-criterion of the main eco-design criteria included in the chart is simplified to: fulfilling the requirement (given 2), partly filling the requirement (given 1) and not meeting the requirement (given 0). The main design criteria are categorized as follows: Materials (Local, Re-cycled, Reduction in waste material, No toxic components, Renewable source), Energy Efficiency (Connected energy to the national power grid, Thermal Insulation,



Optimum volume to surface area, Natural ventilation, Heat exchange system, Using water item, Tipple or double glazing, Inert gas between layers of windows, Low – emissive coating, Recycled wooden window frame, 33% of recycled glass, light sleeves, White external finishes, Raising the height of windows, Efficient artificial lighting source ), Water management (Water efficient appliances, Recycled water, Installing composting toilets ,Collecting rain water), Building orientation(Green wall, North facing direction, More area for windows facing north , Living area facing the North & services facing south, Open internal court yard, Compact form Appropriate size) and Eco gardening &“Xeriscaping”(Vegetation next to the house for shading, Local plants, xeriscaping gardening, water retention, Gathering plants with similar water needs). GUtech project was given respectively[(1,2,2,2,2(total 9)], [0,2,2,2,2,0,2,0,0,0,0,2,2,2(total 16)], [1,2,0,0(total 3)], [2,2,2,2,1,0,1(total 10)], [0,1,0,0,0(total 1)] HRC project was given respectively[(1,2,1,1,2(total7)], [2,2,0,1,2,2,2,0,0,0,0,1,2,1(total15)], [1,2,0,0(total3)], [2,2,2,2,1,



0,1(total 10)], [2,1,2,2,0(total 7)].

**Figure 7:** Comparison between The GUtech and HCT Eco Houses in fulfilling the required design criteria

## 5. Conclusion & Recommendations

The global recent trends to adopt eco-system, sustainability and friendly environmental attitudes have been recognized as a priority at the political, economic, societal, and legislative levels worldwide, especially in developed countries. However, such trends are hardly considered

or even touched, neither on the official level nor on the public attitude of awareness in developing countries.

The Sultanate of Oman, as well as the Gulf countries, are facing many challenges nowadays that give no choice for the said countries, other than adopting the sustainable and eco- system polices. The recent collapse of oil prices, besides the expected diminishing supply of oil that represents the main or, even the only national source of income, is one of such challenges. Furthermore, the water scarcity accompanied by the exponential increase in demand is another major challenge. Moreover, the lifestyle of the people of the said region, which is completely extravagant and environmentally irresponsible, is a major challenge.

Responding to the above mentioned challenges, the Omani government took a very important leap to include the issues of energy conservation and supporting renewable alternatives and environmental protection among the national priorities in the Sultanate's eighth 5 year plan (2011-2015). The RCT organized a national competition for eco- friendly houses between the higher educational colleges and universities starting in 2011. Such a competition was targeted to build the national ability of both individuals and institutions in areas of sustainable development such as high quality and eco-friendly material production and alternative energy sources. Five eco- houses construction in different universities located in four different governorates were erected. The final results of the first phase (design, construction and performance testing) were announced in January, 2015. The second phase of long term performance testing, and raising the community awareness, is going on right now.

This paper succeeded in casting light on this unprecedented experience in developing countries as a model for other similar countries. Two projects- out of the five – were clarified in detail.

However it has to be clear that this experience is just planting a seed in the field of green attitudes in the Omani community. Future important steps have to be taken to re-orient the Omani society to adopt such trends. All parties have to contribute effectively, starting with the government to set a clear path map at the national level to specify the responsibilities of all parties and players, who contribute to planning and building construction mission. Furthermore, the government has to provide necessary information including the creation of internet portals to provide the recent data on best practices and a list of efficient green products. Some incentives could be provided like less tax on such requirements or providing encouraging loans for green

houses. Another significant factor is changing the building regulations and codes that the new buildings have to pass some sort of energy efficiency review. The media has a critical role to play in spreading the concept of sustainable awareness. Finally, the teaching of architecture must be changed to include the need to reduce CO<sub>2</sub> emissions to counteract climate change and global warming. Further researches to cover the above mentioned issues are recommended.

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