BUILDING A ZERO ENERGY HOUSE FOR UAE: TRADITIONAL
ARCHITECTURE REVISITED

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Abstract: The aim of this study is to look back, once again, into traditional architecture and learn the lessons of sustainability. It is through studying specific architectural concepts characterizing traditional architecture around the world that we can understand how that architecture sustained and provided appropriate environments for its inhabitants. The sustainability discourse now a days is mainly concerned with inventing new technologies and materials which could save some of the energy required to operate utilities. Usually it is an additional cost which we initially invest in order to achieve this added value to our buildings. This study will briefly introduce a design approach which is based on achieving sustainability through implementing traditional solutions for the issues of heat, ventilation and natural light. Although those solutions were traditionally embodied in forms that can have significant cultural and social connotations, they are employed here to be tested for their environmental role and to a certain degree their influence on the building envelop as formal elements participating in the making of architectural character. Such elements where extensively used in contemporary Arab Architecture as formalistic stylish elements in order to localize the identity of that architecture. To evaluate the appropriateness of the abovementioned traditional concepts in achieving environmental sustainability within the contemporary circumstances, a Zero Energy House (ZEH) shall be built and tested as an empirical aspect to prove the preposition of this study. The house will be built in the American University of Ras AL-Khaimah (AURAK) campus in collaboration with other colleagues in the School of Engineering. The place is rich with traditional architectural elements such as Courtyards, Wind Catchers and Mashrabiyyahs as part of its architectural heritage. The process of designing and building the ZEH will take 12 to 15 months. Therefore, the data which will result from building and testing the Zero Energy House shall be utilized and highlighted to support of the objective of this study.

Keywords: Sustainability, Traditional Architecture, Zero Energy House, Wind Catchers, Mashrabiyyah (Double Skin Facades).
1 Introduction

Sustainable buildings are currently emerging as a new building type which is energy efficient, environmentally friendly, and architecturally significant. The sustainability of such buildings contributes to the sustainability of the society, the cultural values, and most importantly the economy. Moreover, the pertaining technological advancements in the building industry are also expected to be influenced through providing appropriate solutions to attain sustainability measures.

On another level, the design of modern buildings which utilizes lightweight new materials to achieve structural feasibility on one hand and providing large glazed openings to allow for more interaction between inside and outside and bring in natural light, has in many ways increased the need for energy to humanize those buildings and enable them to be comfortable for their inhabitants. Accordingly, considering the rapid growth of population which leads to higher and higher impact on the grid, this forces us to look for passive sources of energy which can compensate the required amounts and to develop a design approach which helps reduce the need for energy and eventually reduce the pressure on the Grid. Such design approach is oriented towards the study and evaluation of some traditional architectural elements which are expected to provide, with some improvements, solutions for the reduction of energy consumption in buildings.

Towards that end, AURAK, which has a proven record in the research and innovation of knowledge pertaining to renewable energy, is intending to build a Zero Energy House (ZEH) taking into consideration the exploration and incorporation of traditional architectural elements in the design and to test their suitability and efficiency in reducing energy consumption inside the house.

In this paper which I consider as a DESIGN RESEARCH study preceding the design and construction of the ZEH and then testing its compatibility with the standards established for this type of buildings. In the First Part of the study, the properties of the courtyard, Wind Catchers and Mashrabiyyah and their role in traditional architecture shall be explored. The potential of using those elements in the ZEH and the suggested improvements in order to cope with the contemporary house design shall also be discussed and evaluated depending on other resources that have already conducted studies on those elements. In the Second Part, reflections on the use of such elements shall be made as well as some recommendations on how those elements can be utilized to achieve the best results in building the Zero Energy House.

2 Vision

This study is aiming to set the theoretical framework and guiding principles for the building of the Zero Energy House in UAE. It is based on utilizing the traditional concepts of the Courtyard, The Wind catcher and the Mashrabiyyah (Double Skin) as means of reducing the heat gain and eventually, the need for energy required to cool the indoor spaces of the house.

Accordingly, it can be considered as the ARCHITECTURAL CONCEPT which sets the design guidelines for building a model house which meets environmental sustainability measures of energy consumption as well as socio-cultural sustainability through identifying the architectural character of the house. Therefore, such passive design measures will be used to minimize the need for active design measures in order to guarantee efficient design and planning of the house to provide comfort for its inhabitants while keeping a net Zero Energy resultant.
3 Traditional Architecture

Traditional architecture is the outcome of how humans read their PLACE (genius Loci). It is how they respond to the place where they live in a smart way. How they utilize resources and knowledge of building in making the built environment and adapt it to their comfort (Fig. 1)

![Figure 1: Sheikh Saeed Al Maktoum house, Dubai](image)

Traditional architecture therefore introduces the most appropriate solutions that people developed through the process of trial and error to overcome the climatic conditions of their place. They adapted themselves socially and culturally to such solutions. Therefore, we can say that such harmony between humans, their socio-cultural aspects and the environment has collaborated to make the physical environment embodied in architecture and the different elements that constitute to this architectural identity.

Elements of traditional architecture that play major role in controlling the climatic conditions include: courtyards, building envelop, wind catchers, building materials, size and location of openings, and many other elements. However, for the purpose of this study, I am concentrating on three elements which are the courtyard, the mashrabiyyah and the wind catcher. They are discussed in the following:

3.1 Courtyard:

An outdoor space, piece of nature, created in the middle of the house and surrounded by the rooms of the house. It provides privacy and security for the users and it provides sun and ventilation for the rooms around it. Also the courtyard in the middle of the house enables the houses in a traditional urban neighbourhood to attach to each other representing the strong social solidarity amongst the members of the society, granting them security and safety and most importantly providing them with protection from climatic conditions represented in the strong sun and dusty wind.

From a climatic point of view, courtyards provide shade, ventilation and most importantly, air movement creating a draft of cold air coming downwards to the courtyard at night and hot air moving upwards at day time. (Fig. 2)
With a proper orientation of the courtyard as well as the openings of the rooms surrounding the courtyard, one can say that it will have a positive effect on the temperature inside the house. Also, the provision of arcades in the courtyard will provide more shade on the facades which again, contributes to reducing the heating effect on the walls. (Fig. 3)

Courtyard house as a building type that existed in many regions of hot and humid climates is a passive solar solution. The performance of the courtyard with respect to thermal and ventilation aspects has been tested using Computation Fluid Dynamics (CFD) simulation and proved that a courtyard improves remarkably the thermal performance of the house and eventually reduces the needed energy to cool down the internal spaces (Almhafdy 2014). (Fig. 4)

The use of the courtyard in the design is not limited to traditional houses only. It is used also in modern architecture in different ways. Le Corbusier created a courtyard in the first floor of Villa Savoye and also he created a roof garden (Fig. 5: (a)). Those two elements were used, from the designer’s view, to bring nature inside the villa and utilize the sun as
much as possible taking into consideration the cold weather in the place of the villa. Also, he wanted to compensate for the area of the garden which was occupied by the structure of the villa (Fig. 5: (b)). The roof garden was created to complete the natural balance of the place. This contributes to the environmental sustainability of the Villa.

3.2 Mashrabiya (Double Skin Façade DSF):
Traditionally, Mashrabiya served many purposes (Fig. 7):

1- Reduce the heat coming inside the house,
2- Reduce the glare of the outside sunlight,
3- Provide privacy,
4- Aesthetic expression for the interior as well as for the exterior,
5- Noise control.

Hence, building envelope is the most important factor in keeping the inside environment insulated from the outside. It prevents heat from transferring both ways from outside to inside and vice a versa. (Fig. 8)
In traditional buildings, the envelop or the external wall was thick and massive since it was a load bearing wall on one hand, and made of natural materials mostly earth and stone and sometimes wood on the other hand. Therefore, by the virtue of its size and materials, the external wall will provide the required heat insulation by keeping heat from transferring within it.

Another aspect for this traditional external wall (envelop) is the use of small openings. Although structural need could be behind having thick walls with small openings which are usually vertically proportioned, but as a result of that it helped in achieving privacy on one hand and in reducing the chances of heat penetration to the internal spaces on the other hand.

Building technology now a days provided solutions for the structural requirements of buildings so that thick walls are not needed any more. With regards to thermal performance which the traditional wall used to do, we need to treat the building envelop as follows:

1- It reflects sun rays and not absorb it (Color and Texture),
2- It has thermal insulation that prevents heat from reaching inside (Material),
3- It circulates the hot air on the skin of the building by creating air draft between two skins (Double Skin).

Figure 9: Solar Decathlon 2013

The first and second points are concerned mainly with the selection of insulation materials, texture of the external surfaces and their color. While, the third point is about installing a second skin in front of the original or what is called call the structural envelop of the building to provide the following benefits:

1- Shade resulting from the outer skin on the inner skin and on internal spaces of the building, (Fig. 9)
2- Filtering and improving the quality of natural light and glare coming to the inside of the building, (Fig. 10)
3- Creating an air draft between the two skins to reduce the effect of heat conduction between air and the inner skin of the building. (Fig. 11)

It has been emphasised in many studies that double skin facades reduce 19%-40% of the energy consumption depending on the materials (Hamza 2005). The air flow between the inner and outer skins provide natural ventilation. Additionally, it provides an architectural opportunities to create transparent facades which are not achievable with the conventional curtain wall or masonry facades.

The application of the Mashrabiyyah or the Double Skin Façade could also be achieved by using traditional materials that are locally produced and traditionally used, namely Al-Arish (Palm Leafs). (Fig. 12)
Al-Arish, which is made of the Palm Leafs is available locally and could be developed to serve the purpose of building Double Skin technique provides protection from sun and, beside its function in front of facades, it could be used to build shading pergolas, partitions, screens and even roofs which blend buildings with its local environment and contribute to emphasising its local identity. Additionally, as a local material, it is the best sustainable solution to be used in solving problems of shade, heat and privacy (Piesik 2012). (Fig. 13)

Moreover, another dimension to the use of locally manufactured elements such as Al-Arish would contribute to the survival of local traditional crafts and even push it to new limits. This will definitely enhances the social as well as economic sustainability of the communities which are making their living out of this industry.

3.3 Wind Catchers:
Wind Catchers are traditional architectural elements that are used in hot and humid regions like the Gulf, Egypt and Iran. It is a 5-8 meters high tower that is hollow from inside and sits on top of houses to collect air from high points and bring it down to the internal spaces of the house. In most cases in a house it is only one tower over the living or sitting room. In large houses they can be more than one. (Fig. 14)

The main function of this Wind Catcher is to provide natural ventilation for the house and to improve the thermal performance. A testing was conducted on a reduced scale model for a wind catcher in Yazd in Iran by using a Computational Fluid Dynamics CFD software concluded that the Wind Catcher was effective in lowering the temperature by 17% to 26% during the warmest hours of the day (Hedayat 2015). The mass of the tower could also store the night cold air temperature which can be used in the next day (Hedayat 2015).
Some issues with the Wind Catchers need to be developed in order to use it practically. Of such issues is the dust and humidity carried by the wind to the inside of the house directly. Some studies have been conducted to overcome such issues, however, mainly they were at the commercial level and lack the sensitivity in dealing with the traditional form of the Wind Catcher as a cultural icon. One practical proposal which could be tried is to utilize the air collected by the Wind Catchers and feed it as FRESH AIR to HVAC equipment. The reduced temperature of this fresh air by the effect of the Wind Catcher will reduce the pressure on the AC equipment and eventually reduces its energy consumption.

Another aspect of the Wind Catcher that could be utilized is by making it a Solar Chimney. By installing a thermal conductive surface (Metal Plate) in the highest point of the Wind Catcher it will be heated up by the sun and accordingly it will heat the surrounding air. The hot air will ascend in the Wind Catcher and will create a negative pressure which, automatically, drag colder air to move in the house (Fig. 15). If a water feature is installed in the main spaces the house or in a courtyard, air will be cooled while moving towards the Wind Catcher. This feature also improves the thermal comfort and ultimately, reduces the energy consumption on the air conditioning and ventilation of the house.

4 Design of the Zero Energy House

Through the demonstration of traditional elements discussed above, and taking the results of this study as well as others which are referred to here, it looks that utilizing the three elements and even more, can easily reduce the required energy in this house. And since the basic methodology for this study is to follow a Design Research approach, thus, each of the abovementioned elements including other elements to be included in the project shall be subjected to thorough investigation and evaluation in order to guarantee the best performance with regards to the reduction of energy consumption. The design, on the other hand, shall not compromise the aesthetic and functional values associated to the culture and to the place.

The main aspects that the ZEH shall take into consideration are grouped in the following:
- **Design**: decisions shall concentrate on Building orientation, floor layouts (courtyards), building mass, use of shading elements (mashrabiyyah), traditional wind catchers and solar chimneys, size of openings, Landscaping.
- **Building technology**: Thermal insulation in roof and walls, building details, building tightness (doors and windows), roof gardens, environmental friendly materials (Arish).
- **Renewable energy sources**: Use of PV panels to generate needed power. The use of solar energy shall be the main source of renewable energy that will be used in the building of this house.
After building the ZEH, it will be tested against the many issues of sustainability especially those related to comfort of the internal environment such as temperature and ventilation.

5 Conclusion

The increasing demand on energy to meet the needs of modern houses will reach to a point where renewable energy sources alone are not sufficient. The design of the house should be sensitively done in a way that takes into consideration reducing the amounts of required energy through passive solutions. Courtyards, Wind Catchers and Double Skin Facades as well as the use of local materials such as Arish are not the only means by which we can bring down the energy consumption down. Orientation of the building, location and type of windows, tightness of the building, and method of insulation of the external envelop and the quality and source of the materials used in construction are also important factors that contribute to the reduction of energy consumption.

The matter will be much more feasible if we use efficient equipment which consumes less energy such as Inverter AC compressors, LED lighting and green products that increases the level of sustainability and reflects positively on other aspects such as socio-cultural sustainability and economic sustainability.

With regards to the Zero Energy House which will be built on the premises of this study, the architectural concept shall reinterpret the traditional elements studied here by utilizing their properties in a contemporary way while keeping its authentic meaning and function.

Other aspects of the house shall take into considerations the state of the art technological advancements in the fields of renewable energy pertaining to solar power. A team of specialized faculty members and researchers at AURAK will work in parallel to equip the house with the most feasible PV systems and power storage devices which can generate and store the sufficient energy needed for the house.

References


