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BIOMIMICRY APPROACH DESIGN OF PETROL STATIONS WITH INTEGRATING RENEWABLE ENERGY IN THE UAE

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ABSTRACT

Highway petrol stations are located outside the main cities in the UAE. Connecting these remote petrol stations to power plants requires trenching for poles or underground cables as well as countless hours of work. The integration of PV solar panels and smart materials such as chromogenic glazing into the design and structure reduces the cost and the environmental impact. Even though solar energy is one of the cheapest sources of energy worldwide, it is challenging to achieve a design that reflects the identity of the city. Modern technology makes it difficult for designers and architects to balance themes such as sustainability, formation, and identity. The goal of the research is to explore the potential of using smart technologies to improve performance and to demonstrate, simultaneously, the most suitable design for optimizing energy for highway petrol stations in the UAE. As an example, the national Ghaf tree of the UAE is a cultural and historical symbol of stability and peace that can withstand harsh environment. This study introduces a reference design for the petrol station. A three-dimensional model using Autodesk Revit and an energy model using the Autodesk Insight program is built for the reference case. Several designs for the petrol station with different surface areas, shape, orientation, and window-to-wall ratio are studied to optimize the energy consumption. Variables such as the location of the oasis, its area, and its services will remain constant. The study concludes that the dynamic characteristics of smart glazing materials can combine not only one objective sustainable design quality, but more than one, including energy efficiency requirements to harmoniously integrate with the surrounding environment

Keywords: energy efficiency; optimized energy; building orientation, UAE.

1 INTRODUCTION

The harsh climate in the UAE causes high cooling demand throughout the year. Huge energy waste due to the use of low-efficiency appliances, high living standards, government subsidies, and the energy-intensive lifestyle have boosted the energy consumption in UAE [1]. A report by management consultancy Strategy &, formerly Booz Company, confirmed that electricity consumption alone over the past 10 years has more than doubled [2]. Therefore, energy-efficient buildings are a growing challenge, due to population growth, and high consumption rates that are unsustainable in the long term [3]. Proper design of the envelope components not only can save the required energy for the building but also can improve the thermal comfort of its occupants [4].

However, sustainable movement is growing to maintain a healthy lifestyle and overcome the rate of energy consumption that is growing rapidly in the UAE. In this context, Dubai Municipality issued buildings and glazing regulations supported by the law in 2003 and Abu Dhabi established ESTIDAMA Pearl building rating system in 2010. The building regulations implemented on newly constructed buildings will sustain the country with its rapid growth [5]. With the expo of 2020 UAE, there is a huge focus on introducing and maintaining the flow of the city with a sustainable approach by providing strategies of development to make UAE on the map of sustainability. In the cities of UAE, there had to be

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a modern approach to sustainability in the building sector which architecture forms. This will help in fulfilling the needs of the present without compromising the ability of future generations to meet their own needs [6].

Typically, a petrol station building includes production auxiliary rooms, service occupancy, office occupancy, and other facilities. The major source of energy consumption in petroleum stations is air-conditioning, lighting and electrical equipment. Petrol stations have a number of negative effects on the environment despite their importance. To reduce the environmental impacts of petrol stations, several researchers suggested sustainable designs of petrol stations [7]–[11]. Researchers in Europe, such as Pasi [7], Morales-Terrés et al. [8] and Ohlrogge and Wind [9], have focused on assessing the environmental impact of petrol stations rather than concerns regarding their energy use. Jovanović et al. [10] studied the topic of energy efficiency of petrol stations and the use of renewable energy for covering their energy demands. Abdullahi and Adedayo [11] investigated reducing the petrol station resources including raw materials, water, and energy for a petrol station in Nigeria.

This paper brings architecture as a new perspective to achieve sustainability in buildings and tests whether a building can be energy efficient by its architectural form. The paper presents a petrol station design as a future model for a highway petrol stations across the country. The importance of research lies in developing a design that reduces the energy consumption of the petrol station, which reduces material expenses and makes the station more sustainable through finding an ideal architectural form which contributes more to the environment and wastes less.

The work includes studying and analyzing of energy levels of a standard model. This will be followed by developing designs that improve the energy performance of highway petrol stations to reach the optimal form that reduces energy consumption in highways petrol stations across the UAE. The work aims at achieving a sustainable design that reflects the identity of the city.

2 METHODOLOGY

This paper compares three models; a standard model and two energy-efficient models (Design 1 and Design 2). Autodesk Revit will be used to generate the three-dimensional models. Autodesk insight will be used to study the energy performance of the three models considering different surface areas and shapes, orientation, surface area to volume ratio and glazing. Variables such as the location of the petrol station, its area, and its services will remain constant. A building's external envelope affects its thermal performance since it is directly exposed to the outdoor environment. Consequently, climate data including design external air temperature, average monthly external air temperature, wind speed and solar radiation will be fixed for all three scenarios. The distribution, the ratio and direction of the openings will change, which will be reflected on the energy performance of each design. Even cost and aesthetics are influenced by the building form. Undeniably, the selection of an optimum form, orientation, and envelope configuration can reduce energy consumption by 40% [12] because there is a high correlation between the shape of a building and its energy consumption [13].

3 STUDY AND ANALYSIS

The site is located in Dubai which is heading to the future by expo 2020. There is a movement in improving the technology and the infrastructure of the city to boost the economy and tourism. In addition, the urban aesthetic moving towards the future, through the metro station and the high-tech towers. The suggested location for the petrol station is in Ras Al Khor area which is accessed directly from Ras Al Khor Road. The site is surrounded by the industrial

area from the south while the residential area is located to the east of the site. The site encounters the prevailing winds from the northeast with a speed of 14–18 km/h. The temperature can reach 41°C in summer, and it can drop to 18°C in winter.

The first design is driven by the futuristic image of the UAE. The aim is to create a new image or rebrand the petrol stations in Dubai. The design goal is to blend with urban aesthetic of Dubai, achieving a fast base metropolitan city. The assumption of a spaceship landing on sites of petrol stations is the fantasy that draws the shape of the petrol station Oasis. The colour choices are to make the oasis an eye-catcher on the highway and easy to notice also it pays tribute to the 1960s and 1970s futuristic aesthetic petrol stations in the USA (Norms, LA, California). The second design took a classical approach from the landscapes of UAE which is the desert. To achieve a variety in design proposals for the sake of the research a curved form had to be given. The dunes of the desert were the source of inspiration from which the first curves of the form were taken. A concept had to be added to the project to be familiar with the local taste in architecture with a contemporary look to serve as a new look for petrol station.

To study the energy performance of each design, a Revit model was generated. The energy simulation was conducted using Autodesk Insight with the assumption mentioned in Table 1. The three designs shown in Fig. 1 have the same floor area. The surface area of the reference design is 666.27 m^2 with area to volume ratio of 0.463 while the first design has surface area to volume of 0.492 and a surface area of 743.3 m^2. The second design has a 582.5 m^2 surface area with area to volume of 0.572 as presented in Table 2.

Table 1: Petrol station location and properties.

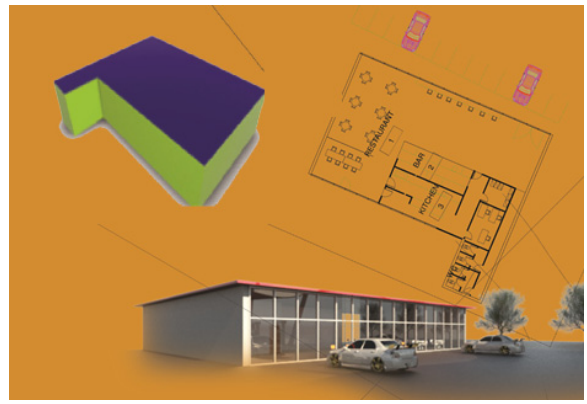
Location	Dubai, United Arab Emirates Latitude: 25.269510269165 Longitude: 55.3088417053223
Building envelop: Reference case	Exterior wall, U = 4.8794 W/(m^2 K) Roof, U = 0.602 W/(m^2 K)
Building envelop: Design 1 and Design 2 (exterior walls and roof)	U = 0.29 W/(m^2 K)
Glazing: Reference case	Single pane clear – no coating, U = 6.7069 W/(m^2 K)
Glazing: Design 1 and Design 2	Double low E, U = 1.26 W/(m^2 K)

Table 2: Petrol station design parameters.

	Floor area (m^2)	Surface area (m^2)	Volume (m^3)	Surface area to volume ratio
Reference case	360	666.27	1440	0.463
Design 1	360	743.3	1510.17	0.492
Design 2	360	582.505	1017.564	0.572

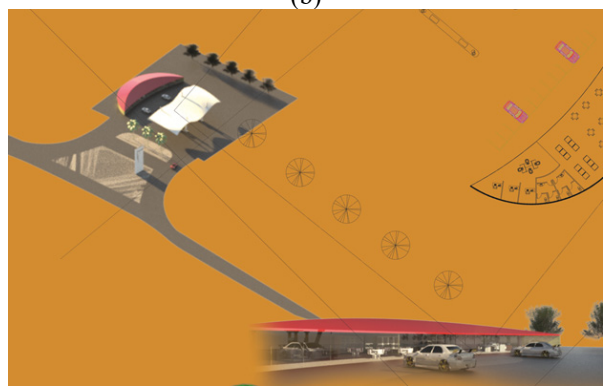
4 RESULTS AND DISCUSSION

The energy consumption for the three designs is presented in Fig. 2. The Reference design showed high energy consumption compared with the other two designs noting that the reference design does not follow the green building regulations in UAE while the alternative designs are implementing Dubai's green building code.



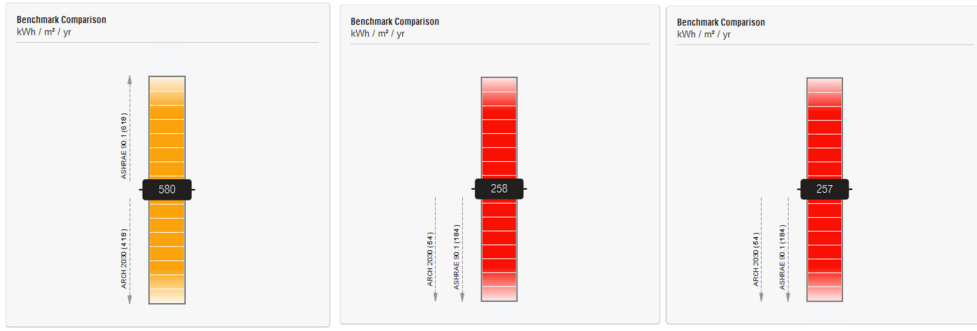
(a)

(b)



(c)

Figure 1: Design alternatives. (a) Reference design; (b) Design 1; and (c) Design 2.



(a) (b) (c)

Figure 2: Energy consumption. (a) Reference design; (b) Design 1; and (c) Design 2.

Calculations indicate that the first and second design alternatives have the same energy consumption. The thermal gain is not the only consumer of energy. Factors such as thermal lighting and the proportions of openings in each direction play a big role in the rates of energy consumed. The energy consumption per year is 257 kWh per m^2 compared with 258 and 580 kWh per m^2 with Design 2 and the reference design respectively. The ratio of the surface area to volume of the first design is smaller than the ratio of Design 2. This reduces the heat transfer rate for the first design compared to Design 2 to minimize the thermal transfer across the building's exterior, the building should be as compact as possible, tilted toward the cubic shape. But to reach the optimum shape the three factors, temperature, wind speed and direction and the building orientation should be taken into consideration. To reduce the environmental impact of using traditional energy sources, solar panels will be integrated into the energy-efficient design. Nowadays, there is a wide range of developed and innovative solar systems that can be integrated into buildings and not just added to the roof. These products are varied in technologies, performance and form. Advanced products become not just additive elements, but part of the main envelope components.

It is important to consider the glazing system to reduce energy consumption and achieve a good indoor thermal environment. Heat transfer through windows is high because they are usually the weakest parts of the building membrane for heat transfer. Glass is considered a weak separator between the outdoor and indoor environment. The window-to-wall ratio has a clear effect on cooling energy. Windows orientation also has a major effect on heat transfer. In general, windows should occupy the minimum wall area in each direction in hot climates. In this context, Design 1 and Design 2 are further investigated to study the effect of orientation and glazing. As shown in Fig. 3, the effect of both glazing and orientation is minimal for Design 1. Only 3% difference in energy consumption between the best and the worst cases. Design 2 is more sensitive to glazing and orientation. The difference in energy consumption between the worst and the best case is in the range of 13%.

5 CONCLUSION

Petroleum stations play a key role in the development of the transportation sector. To achieve a green, low-carbon transportation system, petrol stations need to reduce their energy consumption. This study introduces a reference design for the highway petrol stations in UAE. The suggested designs integrate energy-efficient buildings with architectural concepts drawn from the classical approach of UAE which is the desert or the futuristic image of UAE.

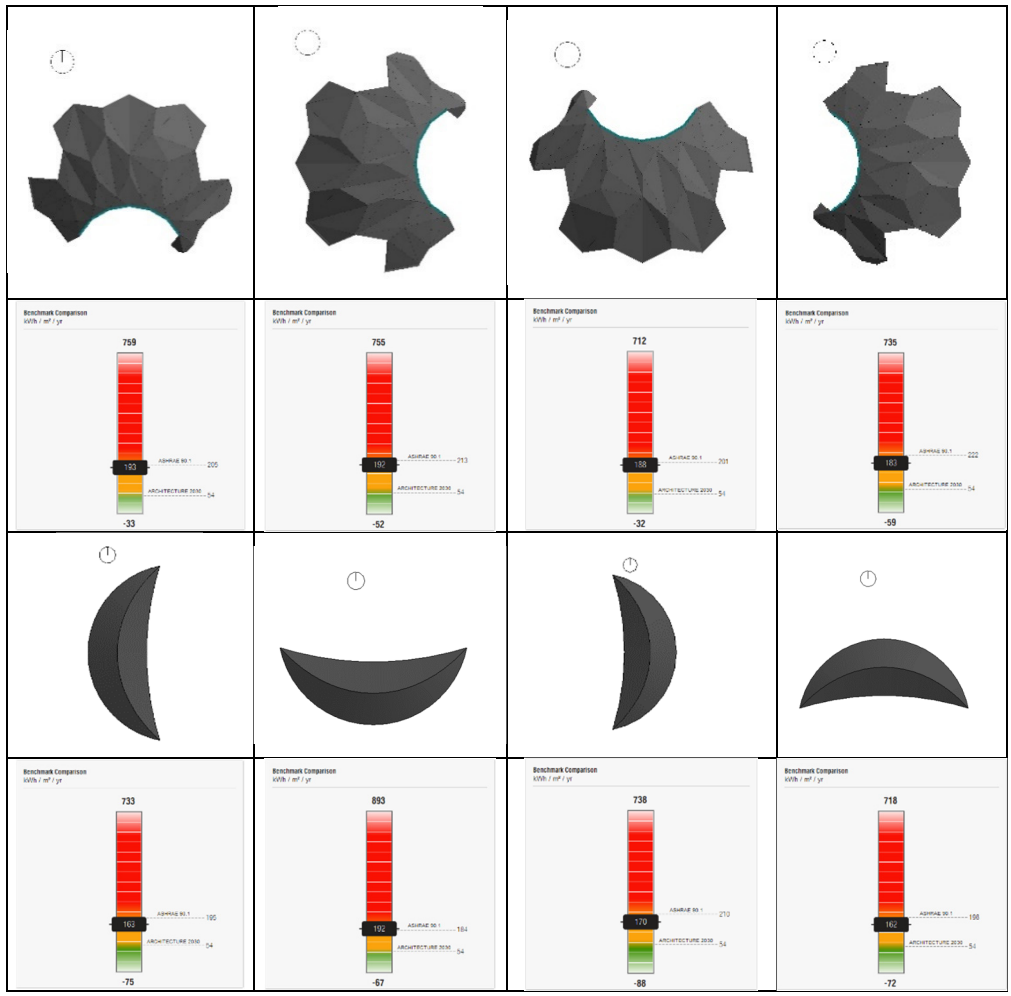


Figure 3: Effect of orientation and glazing.

The suggested designs were analyzed to study the reduction in energy consumption when implementing Dubai's green building code. The work revealed that adapting efficient energy measures in designing petrol stations in UAE can reduce energy consumption per m^2 from 580 kWh to 257 kWh per year. Furthermore, the effect of glazing and orientation on energy consumption was also studied. It was found a reduction of 13% in energy consumption can be achieved through orientation and glazing.

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