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Article

Development of a Solar Home in Middle East: A Review

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***Abstract*— The exponential growth of the population and development comes in hand with excessive use of natural resources which leads to the depletion of the non-renewable material. The main goal of this Solar Decathlon Solar Home competition is to select the best home, which can be assembled within 10 days in the desert climate. The solution of four issues with capacities and technologies are strategized to implement the benefit of the inhabitants of the Middle East region such as sobriety, innovation and mobility. The main objectives of this study are to describe the design philosophy, highlight the exclusive experimental analysis on thermal and sensor which embed the energy efficient and sustainability. The added value of Islamic perspective of 'Mizan' and 'Sakinah' which mean balanced home and tranquillity are emphasizing the application of balance need for human and nature. The results showed the conductivity of plant waste material known as oil palm trunk is a medium of a heat transport and thermal insulator during high temperature while the innovative sobriety solution is achieved through wind and sandstorm sensor. A conclusion was drawn that the engineering of green product is performed the optimum human comfort in the dwelling of desert area, while from a social aspect, the principle of privacy protection is essential through the planning of a space in the solar home.**

***Keywords*— Solar Home; Insulation; Solar Decathlon; 'Mizan' and Sakinah'; Sandstorm Sensor.**

I. INTRODUCTION

The worldwide growth in the renewable energy industry has been positive for the past two decades. The energy consumption in Dubai, UAE has led to the previous launch of Concentrated Solar Power (CSP) project with an expected capacity of 1,000MW by 2030 [1]. The purpose of this future investment in renewable energy is also to achieve the Dubai Integrated Energy Strategy 2030 action plan, which aims to reduce energy demand by 30% by 2030. The residential building sector has shown that more than 50% delivered energy consumption is for the use of air conditioning for cooling. The measures such as using thermal insulation, using energy-efficient equipment for air conditioning for instance, and using solar water heaters are the captured criteria to achieve green building certified in Dubai. In 2016, the Solar Decathlon Middle East (SDME) 2018 was created through an agreement signed between Dubai Electricity and Water Authority (DEWA) and the Department of Energy of the United States of America, in June 2015, to organize a sustainable solar houses competition in Dubai, UAE in 2018 [2].

The solution for houses in this competition is judged based on ten contests which are architecture, engineering and construction, energy management, energy efficiency, comfort condition, sustainable transportation, house functioning, sustainability, communication and innovation [2]. This paper describes the key features of solar home which also known as Mizan Home, the proposed design that address the following four principles: Middle East climate, innovation, sobriety and a dwelling with 'Sakinah' value with bioclimatic respond and mobility consideration.

II. 'MIZAN AND 'SAKINAH' HOME DESIGN PHILOSOPHY

Team USIM-UTM regards the competition as a challenging solution to adapt the designs to the heat, dust and high humidity experienced in the Middle East. Mizan is an Arabic word means balance. This design attempts to integrate the 'Mizan' concept in solar home which will balance the human need and sustainability. The balanced in sustainability will lead to 'Sakinah' that is also from Arabic words which defines the peace, tranquillity and serenity [3]. Sakinah is bridging the Syariah and practicality in the perspective of the Islamic view (Fiqh Al-Maskan) [4] and the application of sustainability highlights a home as a precious place to merge the balance in livelihood. The sustainability is addressed through its practicality in the function of space, innovative technology in building a house in order to achieve the spirit of 'Sakinah'. This will be a

house showcase with green product and sustainability impact. The aim of the development of this house concept can be seen in Figure 1.

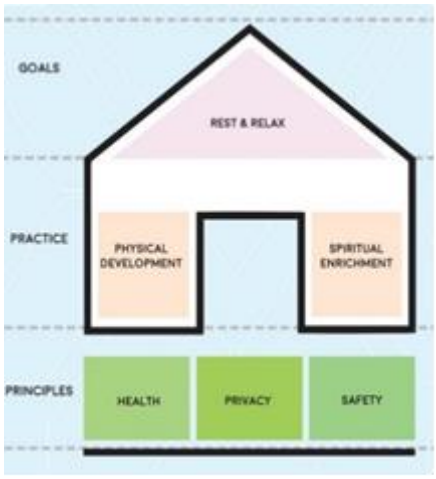

Fig. 1 The goals, practice and principles of Mizan Home

The main design approach is on sustainability, providing energy-efficient solutions, as well as, raising awareness on promoting the responsible use of energy via the production of waste plant as insulation for thermal comfort and solar technologies. The tranquillity from Mizan Home emphasizes on two aspects. The first aspect is an encounter with the human comfort and energy consumption which highlights the use of green product such as agricultural waste material as heat insulation. Figure 2 depicts the floor plan of the Mizan Home with the Dubai UAE sun path. The floor plan is developed using the Autodesk Revit software.

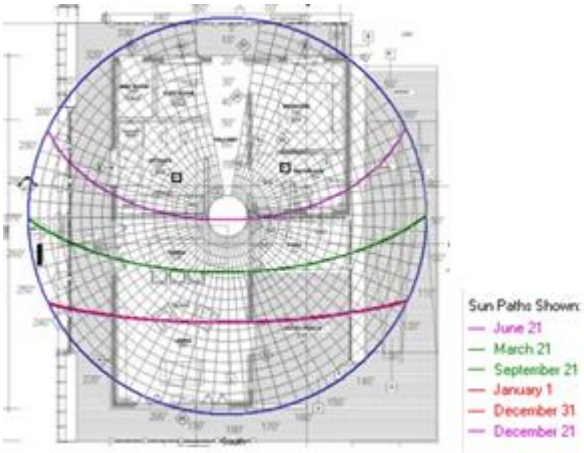

Fig. 2 Floor plan and sun path of Mizan Home using Autodesk Revit

The second part is dealing with the social aspect of design found in study carried out in [8]. There are seven principle designs found and this study will focus on "privacy protection" as design principle that will relate to social point of view. We are discussing this principle because it is one of the most essential criteria in designing a home.

III. MIDDLE EAST CLIMATE

A. Solar Decathlon in Dubai

The solar home competition will take place in Dubai. Focusing on energy consumption pattern, this proposal is designed to solve the issues to reduce heat gain during summer by implementing the selective thermal insulation based on bio-waste in the wall. The heat insulation from biomass fiber (the results are shown in Figure 5) that will be introduced in Mizan Home can improve the zero-energy waste policy from the abundant agriculture waste which also offers healthy thermal insulation to reduce heat in a building. Figure 3 shows the simulation through Integrated Environment Solution Virtual Environment (IES-Ve) software which emphasis on temperature in indoor. The temperature is increasing to 44 ºC at the beginning of the summer season in which the thermal comfort needs to be ranged for thermal comfort from 22 ºC to 24 ºC.

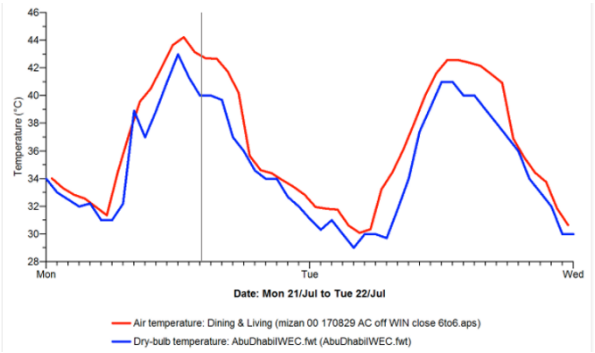

Fig. 3 Temperature variations in July

Furthermore, the reported wind speed in the Middle East region indicates that there is a good potential to harness the wind energy in the region [3]. The average wind speed in UAE is reported at 4.5 m/s especially in May [5]. During the summer season, the wind power density is high and it is found that the average usage by residential in Dubai is 0.0545 $/kWh per unit charge [3]. The daylight availability in this region achieves the maximum illuminance lux in July. According to theoretical analysis data of Middle East region, the recommended temperature.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	31 (88)	31 (88)	41 (106)	41 (106)	45 (113)	45 (113)	47 (117)	48 (118)	43 (109)	40 (104)	41 (106)	31 (88)	48 (118)
Average high °C (°F)	24.0 (75.2)	25.4 (77.7)	28.2 (82.8)	32.8 (91.2)	37.6 (99.7)	39.5 (103.1)	40.8 (105.4)	41.3 (106.3)	38.9 (102)	33.4 (92.1)	30.5 (86.9)	26.2 (79.2)	33.4 (92.1)
Daily mean °C (°F)	19 (66)	20 (68)	22.5 (72.5)	26 (79)	30.5 (86.9)	33 (91)	34.5 (94.1)	35.5 (95.9)	32.5 (90.5)	29 (84)	24.5 (76.1)	21 (70)	27.5 (81.5)
Average low °C (°F)	14.3 (57.7)	15.4 (59.7)	17.6 (63.7)	20.8 (69.4)	24.6 (76.3)	27.2 (81)	29.0 (83.8)	30.2 (86.4)	27.5 (81.5)	23.9 (75)	19.9 (67.8)	16.3 (61.3)	22.3 (72.1)
Record low °C (°F)	8 (46)	7 (45)	11 (52)	8 (46)	17 (63)	22 (72)	25 (77)	25 (77)	22 (72)	16 (61)	13 (55)	10 (50)	7 (45)
Precipitation mm (inches)	15.6 (0.614)	25.0 (0.984)	21.0 (0.827)	7.0 (0.276)	0.4 (0.016)	0.0 (0)	0.8 (0.031)	0.0 (0)	0.0 (0)	1.2 (0.047)	2.7 (0.106)	14.9 (0.587)	88.6 (3.488)
Avg. precipitation days	5	7	6	3	0	0	1	0	0	0	1	5	28

Fig. 4 Dubai Temperature Data

IV. MIDDLE ROUGH WIND AND SANDSTORM SENSOR

In the Middle East, the sandstorm is considered as a phenomenal catastrophe. The latest sandstorm struck Jeddah, Makkah in April 2017, in which the wind speed reached at the 55km / hour, resulting in least visibility for less than one kilometer for people outdoors. The unexpected disaster caused many people, especially children suffering from the airborne sand [5]. To solve the sobriety solution, the Mizan

Home will be equipped with reliable and sandstorm sensor in which this sensor can measure the wind speed and detect the sandstorm before it attacks the Mizan Home. We will be alerted about the danger ahead, whether we are in the house or outside of it.

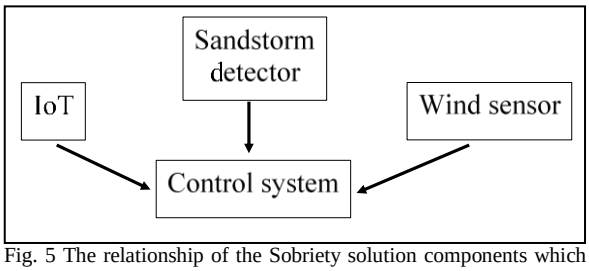

Fig. 5 The relationship of the Sobriety solution components which involve Sandstorm detector, wind sensor and IoT temperature data of Dubai

Basically, the design consists of anemometer which can measure wind speeds, a control system to manage the connected devices, battery/supplied power from the electric grid, DC motor to automatically close the window/door, wind sensor and sandstorm detector. The detector/sensor is solid and provides no abrasion by sand. Two or three sensors will be placed near the house, then, all wind direction angles can be covered and connected to the control system. Here, Internet of Things (IoT) will be applied in which all devices, software and even the house can share the data networking and connectivity. We would be able to know the updated wind speed through anemometer and we will be alarmed when the wind speed exceeds the limited value so that early precautions for any unexpected consequences could be taken. The wind speed detection system would be able to give reliable measurements even at very low wind speed as it works without inertia. Through IoT, we can be alerted even when we are not at home. The sandstorm will detect the incoming sand and close any open windows or doors. The sensors/detectors work based on thermal measuring principle which gives a solid and robust construction to ensure the devices adapt to extreme conditions. The sand particle detector works based on acoustic particle detection and it is not only sensitive but also immune against abrasion. The components of the Sobriety solution are shown in Figure 5.

V. RESULTS AND DISCUSSIONS

A. *Thermal Conductivity*

The comparison of the k-value for building thermal insulation shows the plant waste from the oil palm fiber is sufficient to be considered as green product with 0.04-0.048 W/mK.(Table I) based on the linear regression (see Figure 6). The usage of EFB fiber from oil palm, which also can replace the rock wool insulation material, is extracted from the empty fruit bunches. This fiber is proven as a good raw material for bio composites. The cellulose content of OPF as reported in [9] is in the range of 43%–65% and lignin content are in the range of 13%–25%.

TABLE I
THERMAL CONDUCTIVITY (SOURCE: AHMAD MARZUKI, 2016)

Material	Value (W/mK)
Hemp	0.038-0.040
EFB palm fibre	0.04
Coconut fibre	0.048
Wood fibre	0.04
Kenaf	0.061-0.065
Glasswool	0.036-0.038
Structural softwood or plywood	0.115

The strong correlation of the variable EFB fiber shows the thermal density conductivity is achieved, the range from 70 to 746 kg/m3. This shows the fiber is an efficient thermal insulator and thermal conductivity.

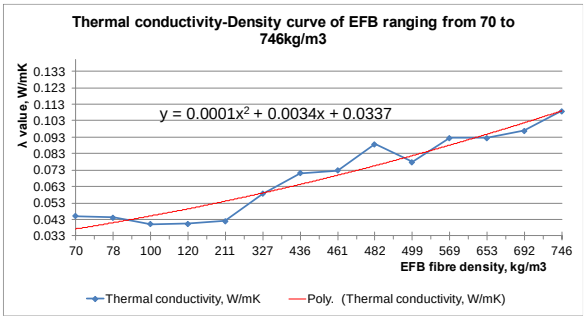

Fig. 6 Thermal conductivity density curve of Empty Fruit Bunch (EFB)

Figure 7 depicts he result of the u-value comparison of wall profiles, where the fiber from plant waste material has achieved the lowest u-value as an insulator.

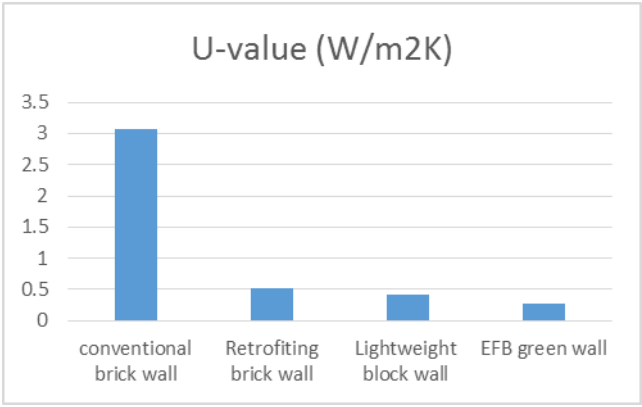

Fig. 7 U-Value comparison of wall profiles

B. *Daylighting*

The daylight illuminance is calculated based on Dubai UAE CIE Standard clear sky condition at 10am, 12pm and 2 pm around the equinox and the summer solstice in the room condition without artificial lighting. Figure 8 depicts the daylight availability in Mizan Home. The results show that the daylight availability is insufficient in kitchen area, master bedroom and toilet. Illuminance level in these rooms yields less than 100 lux. This is due to the room having less

opening such as window as to avoid thermal transfer from outside of the house into the inside of the house which one of the most challenging factors to achieve indoor comfort condition in Dubai, UAE. The standard required illuminance level for housing is between 150 lux. Based on modelling result from IESVE, the strategy of daylighting transmission to indoor is proposed to manufacture the pipeline of two meters with a transmission factor of 0.25 to be act as a light well, while light diffuser is installed on the ceiling under the light well. This passive strategy creates daylight harvesting and increase the daylight quantity of the mention spaces.

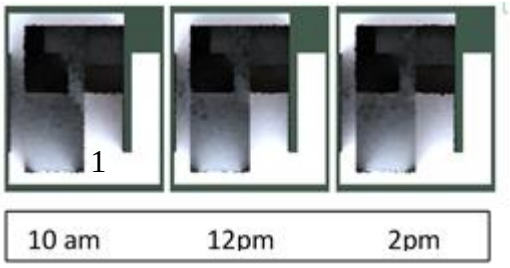

Fig.8 Daylight availability in Mizan home

C. Social Aspect: Privacy Protection as Design Principle

From the social aspect point of view, "privacy protection" is one of the important design principals in housing. Two components are associated with the design principle mentioned above, namely, (i) entrance and forecourt/ compound (ii) bedroom. The in-depth interview with the designer of Mizan Home is to gain data to be analyzed descriptively. The house is designed via two entrances to capture a cross ventilation in a modular space. The other entrance is known as secondary entrance, which normally use by the relative of the resident (see Figure 9).

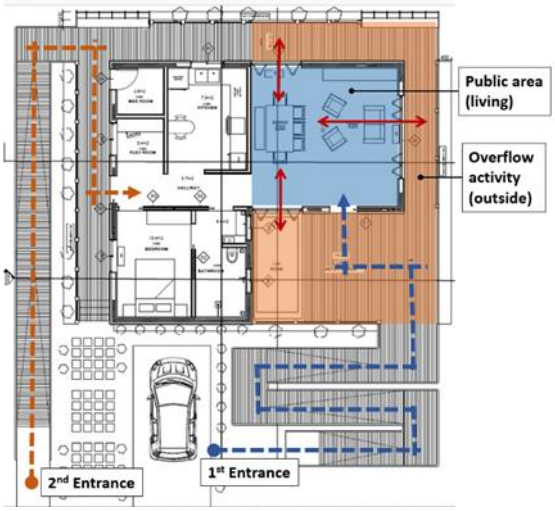

Fig. 9 The Mizan Home Internal Layout

D. Sandstorm Sensor

With the placement of the sensors and connection through IoT and networks, the proposed Mizan Home adapts to the basic concept of 'Sakinah'. This concept allows a peaceful environment that is automated during storm or windy situations. In a case where the situation gone worse, the network could also be connected to the landline telephone to send an emergency signal to the authorities. Simultaneously, since it is connected the authorities could be able to read the transmitted wind speed and the storm conditions at the preferred places. Figure 10 shows the sandstorm and wind sensor devices in the Mizan Home concept.

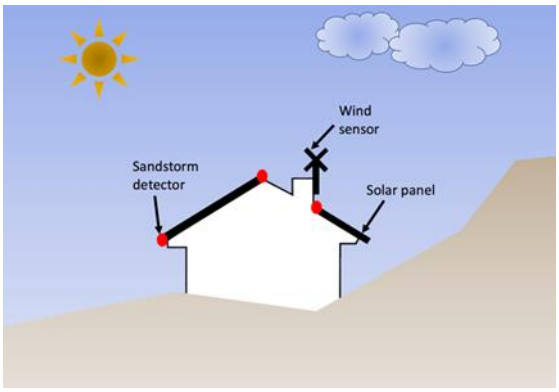

Fig. 10 Sandstorm and wind sensor devices in the Mizan Home concept

VI. CONCLUSIONS

Based on the results of the study, the development of a new product from natural resources shall introduce the green product to industry such as fibre from oil palm tree. This high-performance of engineering product influence the thermal conductivity which contributes to the higher thermal comfort and reduce heat gain. The Mizan Home is a balanced dwelling with an engineering green material where it becomes a solution for heat reduction. While the sandstorm sensor is significant to this home to comply the environment locally. The enhancement of the social part is measured through the design parameters with peaceful (Sakinah) and balance in living.

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REFERENCES

[1] R. L.Hirsch, R. M. Bezdek and R. M. Wendling. (2005). Peaking of world oil production: impacts, mitigation, & risk management (No. DOE/NETL-IR-2005-093; NETL-TPR-2319). National Energy Technology Laboratory (NETL), Pittsburgh, PA, Morgantown, WV, and Albany, OR.Sdme 2018 rules and building code_v3.0).

[2] M. M. Rahman, "MENTAL HEALTH: ISLAMIC PERSPECTIVE. QIJIS (Qudus International Journal of Islamic Studies)", vol. 3, no. 1, pp. 54-71, 2010. O. Spahic, "Conceptualizing Islamic Architecture", *Al-Shajarah*, vol. 15, no. 2, pp. 199-228, 2015.

[3] M.J. Shawon,, L. El Chaar, L. A. Lamont, "Overview of wind energy and its cost in the Middle East", *In Sustainable Energy Technologies and Assessments*, vol. 2, pp. 1-11, 2013.

[4] N. Hameed, "School closures announced as sandstorms expected to continue till Thusrda", *Arab New*, 2017.

[5] Y. Sekine and N. Shinohara, "Disasters and Their Impacts on Air Quality in the Human Living Environment", *In Rethinking Resilience, Adaptation and Transformation in a Time of Change*, Springer International Publishing, pp. 65-71, 2017.

[6] K. Alkhaja, M. Sulayem, M. and B. Abu-Hijleh, “Evaluation of indoor environmental quality conditions in elementary schools' classrooms in the United Arab Emirates Moshood Olawale Fadeyin”, *Frontiers of Architectural Research*, vol. 3, pp. 166–177, 2014.

[7] Othman Nor Hafiza (2014). Rumah Tiang Dua Belas Kelantan: Satu Kajian Ruang Rumah Tradisional Melayu. Unpublish Master of Literature, Universiti Malaysia Kelantan.

[8] Muhsin Fakriah (2013). House design of Malaysia Medium-Cost Terrace Houses Based On Islamic Design Principles. Unpublish Master of Architecture, Universiti Teknologi Malaysia.

[9] S. Shinoj, R. Visvanathan, S. Panigrahi, S. and M. Kochubabu, “Oil palm fiber (OPF) and its composites: A review”, *Industrial Crops and Products*, vol. 33, no. 1, pp. 7-22, 2011.