Low Carbon Residential Building for Climate Change Adaptation: The Case of a Village House in the Delta Region, Egypt

Mohsen Aboulnaga*[1], Ayman Wanas[2], Mohamed Elkhayat[3] and Amr Elwan[4]
[1] Faculty of Engineering, Cairo University, Egypt; [2] Arab Academy of Science, Technology and Maritime Transport (AASTMT), Egypt; [3] New and Renewable Energy Authority (NREA), Ministry of Electricity and Renewable Energy, Egypt; [4] Technical Military Institute, Egypt
mohsen_aboulnaga@yahoo.com, awanas@aast.edu, mohamed.elkhayat@yahoo.com, amr_elwan_07@yahoo.com
E-mail of corresponding autor: mohsen_aboulnaga@yahoo.com

1.0 INTRODUCTION AND BACKGROUND

Rapid development of cities including buildings, energy supply and demands, transport and waste generation increase the risk of climate change, especially in the MENA region [1]. The IEA 2015 report highlights the state of energy performance in buildings and the role energy efficiency and low-carbon pathway in saving more than 50 exajoules of energy yearly worldwide - saving is equivalent to the current combined building energy use of China, France, Germany, Russia, UK and US [2]. The IPCCC report on CC stated that Egypt is considered one of the countries that will be heavily influenced by CC risks despite its low CO_2 emission of 1% of the World's GHG emissions (CO_2/population = 2.25 tCO_2/capita) [3, 4]. Green Economy is a vital tool in realizing Sustainable Development Goals, specifically SGS 7, 11 and 12 [5]. Residential buildings in Egypt consumed 43% of the total electrical energy generated (149 TWh) in 2012/2013 resulting of 184.3Mt CO_2 emissions and around 70% in 2015 [2, 6-8]. This highlights a vital question on the future sustainability of cities in terms of energy supply and how retrofitting of buildings to be low-carbon can make a great difference in reducing the demands on energy, yet meeting global carbon emissions reduction targets.

2.0 SCOPE AND OBJECTIVES

This research project comprises of three main tasks: i) retrofit of rural residential building to be low-carbon; ii) innovative sustainable model of an existing Egyptian village prototype; and iii) climate change responsive scenarios 2030, 2050, and 2080. This paper focus on the 2nd task and the scope of this research work is to assess the energy performance of a selected residential village house in the Delta region, North of Egypt, which witnessed major floods during winter of 2016. The objective is mainly to retrofit the village building by applying efficiency measures to make it low carbon. Studies of retrofitting buildings in Cairo, Egypt can be found in [9, 10].

3.0 METHODS AND MATERIALS

The method encompasses filed visits, energy audit assessments and measurements of a village prototype residential house. Low-tech technologies (ThermalShield paint - thermal insulation and green roof) and high-tech technologies (on-grid Solar PV array (6 kWp - generating clean electricity from renewable energy, and double efficient glass widows with a shading coefficient less than 0.30) were applied. A Red FLIR type-e6 compact thermal imaging camera was used to understand the heat gain and energy performance in August 2015 and June 2016.

Table 1: Elements of the retrofitted in low-carbon village prototype

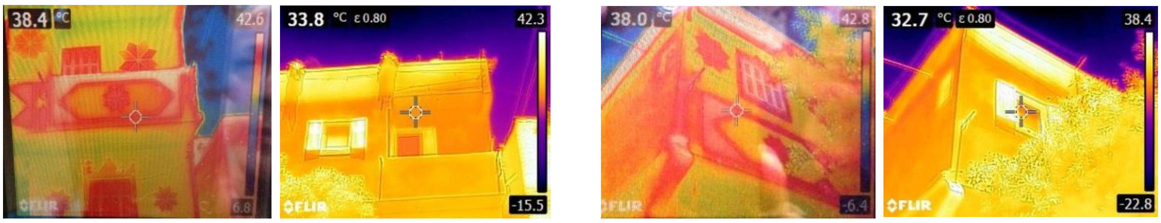
Item	Description
Efficient glass	g-value = 0.29 (solar control) with reflection of 34%
PV Array	16 -26 PV panel with output 265 Watts
Output Power	6.00 kWp (IEC standards 61215 and 61730 (ensuring quality of the PV array)
Efficiency	16% - with the green roof, it will be 19%
Roof and Walls SRI	77% & 78% at h_c = 12 and 30 W/ m^2 K and improved to 94%

Fig.1. Facades after installing efficient glass to reduce energy consumption and 3D of the PV array

Before applying the JotaShield Extreme paint with high Solar Reflective Index (SRI) of 94% was applied the building external walls, temperatures were measured using an IR e6-type to find out how much heat and energy have been reduced (Figure 1, 3). Existing glass windows (U-value 5.70 W/m^2°K) were replaced by double glazing windows using Reflecta-Sol TS450 with SC 0.37, but it was improved further changing it from SGG COOL-LITE ST 450 to SGG REFLECTASOL GREEN (Table 1). A solar PV array (6 kWp) has been calculated and integrated with a green roof on top of the L shape roof (Figure 3) to improve its efficiency due to the lower air temperature resulting from the green roof near the PV array (insulation capacity of the soil of 15.00-16.00m^2 using two systems (Soil mix Farming and Hydroponic Farming), and water insulation and root blocker (Sikapla-12-G).

4.0 RESULTS AND DISCUSSIONS

Measurements of the residential house were conducted to determine the energy performance and suggest the best solutions. This was carried out before and after installations. Figure 2 and 3 show the results before and after improvements. It was found that the improvement in the TSR and the corresponding improvement in the SRI are in the range of 35% to 40% and 25% to 30% respectively. Also the measurements show that the application of JotaShield and efficient glass with SC of 0.29 have led to a reduction in the North-west façade's surface temperature by 4.6°K (from 38.4°C to 33.8°C) and in the North-east façade by 5.3°K (from 38.0°C to 32.7°C) as shown in Figure 2. The green roof has help in reducing roof surface temperature by 6°K, hence will increases the efficiency of the solar PV array.



a) North-west façade before and after improvements b) North–east façade before and after improvements

Fig.2. Thermal imaging the building's façades before and after installing the efficient smart glass

a) Green roof with herbs and vegetables b) Thermal image after installing the green roof

Fig.3. Installed green roof on a high reflective solar index (SRI) with JotaShield cool green painted roof

5.0 CONCLUSION

The application of low-tech and high-tech low carbon technologies has led to a reduction in the building's surfaces' temperatures by almost 5°K from the baseline reference. The on-grid connected Solar 26 PV array (6 kWp) calculations resulted in decreasing the electrical energy demands of the residential village house (4500 kWh/yearly) to almost 87%, making the building low carbon and near Zero Energy Building (nZEB), hence adapte to climate change. The next publication will highlight the results of integrating renewable energy application of the On-grid connected 26 Solar PV panels array. The climate change assessments, using ENVI-MET and EECOTECT to predict the impact of introducing the prototype retrofitted residential house improvement in the various sescenario (2030, 2050 and 2080) will be carried out.

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