Sustainable energy retrofitting for residential buildings in Palestine, a simulation based approach

Sameh Monna
Architectural engineering department
An Najah National University
Nablus, Palestine
samehmona@najah.edu

Adel Juaidi
Mechanical engineering department
An Najah National University
Nablus, Palestine
adel@najah.edu

Ramez Abdallah
Mechanical engineering department
An Najah National University
Nablus, Palestine
ramezkhaldi@najah.edu

Tareq Salameh
Department of Sustainable and Renewable Energy Engineering
University of Sharjah
Sharjah, United Arab Emirates
tsalameh@sharjah.ac.ae

***Abstract*— To tackle the massive drivers of global warming, which are our buildings, especially existing buildings, we need to work on making these buildings more energy efficient. Building retrofitting in Palestine can tackle the issue of energy poverty resulting from a shortage of natural resources and the dependence on imported energy. This paper aims to use energy simulation for typical existing residential buildings to assess the energy saving from a proposed retrofitting program. The most frequently used residential building types were selected for the computer simulation assessment of the energy retrofitting program. The energy use of those selected residential buildings has been identified and a base case has been established as a baseline for the energy retrofitting evaluation. Three levels of retrofitting programs were applied for the selected buildings. A Simulation model was created for the current residential building type using the DesignBuilder tool to evaluate the savings from applying the retrofit program. The simulation has been done for one climate zone in Palestine. The results show that the main energy consumption in the typical households are water heating, room heating, cooling and electric lighting. The results show that level one measures results in a 16.7% reduction in energy consumption due to reducing the heating and cooling. Level two results in a 13.3% reduction in energy consumption for heating, cooling and lighting. At level three further 28.9% reduction in the total energy consumption can be achieved for heating, cooling and water heating. The total saving from energy consumption can reach up to 58.9% of the total energy consumed in existing residential buildings by applying the three levels of the energy retrofitting plan.**

Keywords*— *Energy demand; Energy retrofitting; Building Simulation; Residential buildings; Performance simulation; Design builder

I. Introduction

Energy plays a key role in the future of green energy as an environmentally friendly source of energy [1-3]. The building sector is well known to be one of the key energy consumers in the world [4]. Final energy use in buildings increased from 118 EJ in 2010 to about 128 EJ in 2019 and CO2 emissions from buildings increased by more than 10 GtCO2 in2019, accounting for 30 % and 28 % of the global total, respectively (IEA,2020) [5]. The predominant factor for these phenomena is the increasing living standards and comfort requirements [6]. Improving the energy efficiency of buildings should also be a key factor of combating climate change and global warming [7-8]. Improving energy efficiency has become a priority for existing buildings in recent years [9]. Retrofitting approaches should be described on the basis of regulations in order to achieve cost-efficient solutions [9].

Energy retrofit of residential buildings is an approach designed to reduce global energy consumption [10]. Building energy use has become the main driver of global growth in energy consumption and CO2 emissions [10-20].

Not only does retrofitting minimize the energy used, lower the energy bills, but it also increases the quality of indoor air and eliminates external noise, increasing the market value [21]. Several factors have an impact on the implementation of energy retrofit measures, such as budget, comfort requirements and reliable economic value [22]. The energy retrofitting can be through focusing on eco-design and renovation, bioclimatic retrofitting, technological and behavioral change [23-26].

With a growing population of +2.9% per year, Palestine has the third fastest growth in the MENA region [27]. Palestine also has the highest economic growth rate, which will positively influence future investments in energy efficiency measures [27]. In the last two decades, there has been a rapid urbanization in West Bank and the Gaza strip, which has led to an increase on the demands for energy, especially in residential building sector [28]

In 2018 the households had a 45% of the final energy consumption in Palestinian territories, it consumes far more than any other sector [29]. The highest energy consumption in a typical household is water heating, followed by room heating, cooling, lighting, fridge and washing machines [27]. electricity is the type of energy that is used more than other types in residential buildings. by 2030 the Energy Consumption growth forecast showing that the energy consumption in the residential sector is going to increase by more than 30% [27]. With a share of around 9% of the Palestinian household expenditure, Palestine has the highest share Compared to other MENA countries [18]. The average emission for each kWh produced by IEC is ~ 0.700 kg / kWh [27].

Because the Construction and use of buildings is responsible for 39% of global energy-related emissions, according to the World Green Building Council, a more sustainable approach is crucial to achieve net zero carbon emissions in the future [30]. As many buildings can stay in

978-1-6654-2548-3/21/$31.00 ©2021 IEEE

use for around a century, making existing buildings more energy efficient is necessary to avoid carbon emission and to achieve a sustainable energy strategy.

Building retrofitting in Palestine can tackle the issue of energy poverty resulting from shortage of natural resources and the dependence on the imported energy. In Palestine as worldwide there are recent improvements in energy efficiency in new buildings, however existing buildings is an important sector to improve in order to meet emission reduction targets. The energy retrofitting for existing buildings can be an important step towards energy sustainability. Moreover, there is a lack of studies, evaluations and assessments for the potential saving from applying possible energy retrofitting measures.

II. METHODOLOGY

A. *Energy usage survey*

The most used existing residential building type has been selected as base case for the computer simulation to evaluate the energy retrofitting program [18]. The energy use in this selected residential building has been identified and the base case has been established as a baseline for the energy retrofitting comparison. Energy use in building survey which has been done by the Palestinian Central Bureau of Statistics in 2015 and Country report on energy efficiency and renewable energy investment climate was used as a reference for the building energy use by the household to identify the energy uses with highest consumption [31].

According to this survey, electricity consumption by household indicated that the average household consumption of electricity in Palestine for families that used electricity in 2015 was 306 kWh. This rate varies clearly between the Palestinian areas 442 kWh in the central West Bank, 294 kWh in the south of west bank, 272 kWh in the north of west bank and 265 kWh in the Gaza Strip . Survey for Gasoline consumption by household indicated that the average household consumption of gasoline in Palestine for families that used gasoline reached 95 liters in 2015. The results from the survey also showed that the rate of gasoline consumption is the highest in the central West Bank, reaching 135 liters, 114 in the north of west bank, 91 south of west bank, while this rate did not exceed 42 liters in the Gaza Strip. Survey for LPG consumption by household indicated that the average household consumption of LPG in Palestine for families that used gas in 2015 was 22 Kg, 28 kg in the south of west bank, 25 Kg in the central and north of west bank, and 14 Kg in Gaza Strip. Survey for Kerosene consumption by household showed that the average household consumption of kerosene in Palestine for families that used kerosene in 2015 was 21 liters, by 28 liters in the West Bank and 12 liters in the Gaza Strip.

B. *Energy Retrofit plan*

To improve the energy efficiency of buildings in Palestine, three levels of retrofit were applied and the impact of each level was studied separately. So that the money saved from each level covers part of the cost of the next level. So that the first level is the least expensive, followed by the second level and finally the third level is the most expensive. These levels are as follows:

Energy Modification Program: This level includes low-cost retrofit measures: Level-1, this level includes low-cost retrofit measures: (A) Lowering the set point temperature in the heating season from 20 °C to 18 °C; (B) Increasing the set point temperature in the cooling season from 23 °C to 25 °C; (C) Sealing the building to reduce leakage as much as possible by reducing the infiltration from 1 Ach to 0.25 Ach. Level-2, this level includes the medium cost retrofit measures: (A) Use of low emission transparent double glazing (Low Emissivity) (B) Hanging shade installation by using horizontal overhang above the windows 0.6 m depth (C) changing the existing lighting system (fluorescent and incandescent) with a more efficient one (using LED lighting) (D) Wall and ceiling thermal insulation by adding 5 cm of extruded polystyrene from inside, then covered by gypsum boards. Level-3, this level includes the highest capital cost measures: (A) Use of triple glazing; (B) changing the old low-efficiency HVAC system with a high-efficiency system. (C) heating the domestic hot water by the solar water heating system.

C. *Computer simulation*

A survey of residential building types based on the building's size, number of household units per floor and the number of floors have been done in order to select the most used residential type. To evaluate the retrofitting plan a simulation model for selected existing residential building types is built according to currently used construction details, materials, and systems in the considered region. This model is a typical multistory building apartment consisting of five floors and four apartments for each floor. This model is considered as a base model for the evaluations of the effectiveness of the proposed retrofit programs on total energy consumption as in figure (1) below. The simulation has been done for climate region four in Palestine, which represents the mountain region with the highest population intensity as in figure (2). The weather data file for Jerusalem has been used as it represents the selected region that includes also the cities of Hebron, Bethlehem, Ramallah and Nablus.

Figure-1: the representative building type selected for the application of the retrofitting plan

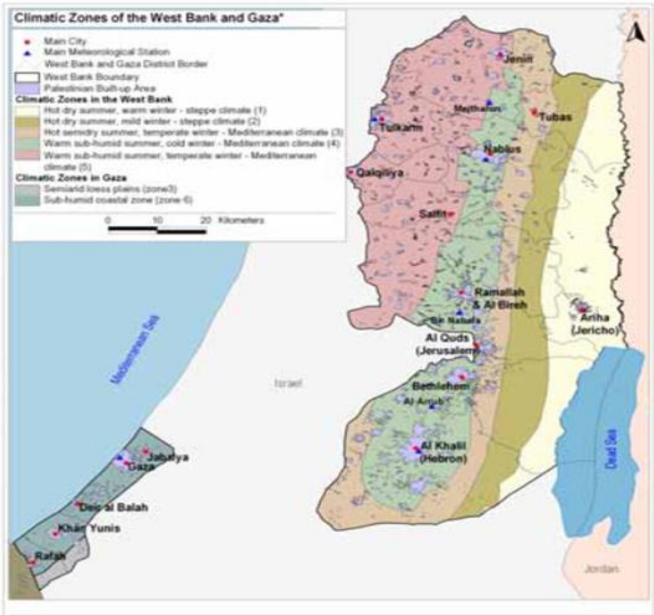

Figure 2: climatic zones shows climate zone 4 with highest population intensity [32]

III. RESULTS AND DISCUSSION

Saving in annual electricity consumption has been estimated using computer simulation tools (Design Builder). The results from applying the retrofitting plan have resulted in a considerable reduction in energy consumption for lighting, heating, cooling and domestic hot water. The results for the base case scenario, where the typical selected building responds to the majority of buildings with the inefficient energy performance, show that energy consumption for heating, cooling, lighting and domestic hot water are the main consumption of this type of buildings. The total energy consumption was 87.2 kWh/m² per year as can be seen in Table 1. by applying the first level of the retrofitting plan which included changing the set point temperatures and reducing the infiltration resulted in a decrease in energy consumption for heating and cooling to 72.6 kWh/m² per year which represents a decrease of 16.7%.

By applying the combination of level 1 mentioned above and level 2 which includes replacing the glazing, add shading, replace the lighting and install thermal insulation from the inside resulted in a decrease in energy consumption for heating, cooling and lighting to 61 kWh/m² per year. This is a 13.3% reduction in energy consumption from applying level 2 and a total 30% reduction from applying levels 1 and in figure 3, compared with the base case scenario.

Finally, applying the combination of level 1 and 2 mentioned above and level 3 which includes an efficient HVAC system, triple glazing type and solar water heating resulted in a reduction in energy consumption for heating, cooling and water heating to 35.8 kWh/m² per year. This is a 28.9% reduction in energy consumption from applying level 3 and a total 58.9% reduction from applying levels 1,2 and 3, compared with the base case scenario as it can be seen in table 1 and figure 3.

Table 1: The applied actions at the three retrofitting levels, and the results for energy consumption (kWh/m²)

Action/retrofit level	**Lighting**	**Heating**	**Cooling**	**Domestic hot Water**	**Total Energy**
Base case	*14.5*	*29.3*	*21.4*	*22.0*	*87.2*
Reduce infiltration, level-1	*14.5*	*22.0*	*22.9*	*22.0*	*81.4*
Set point Temperatures-level-1	*14.5*	*19.4*	*16.8*	*22.0*	*72.6*
Insulation, shading, glazing, lighting- level-2	*9.2*	*16.7*	*13.0*	*22.0*	*61.0*
HVAC, level-3	*9.2*	*16.4*	*6.6*	*22.0*	*54.2*
Triple glazing and water heating, level-3	*9.2*	*15.9*	*5.1*	*5.5*	*35.8*

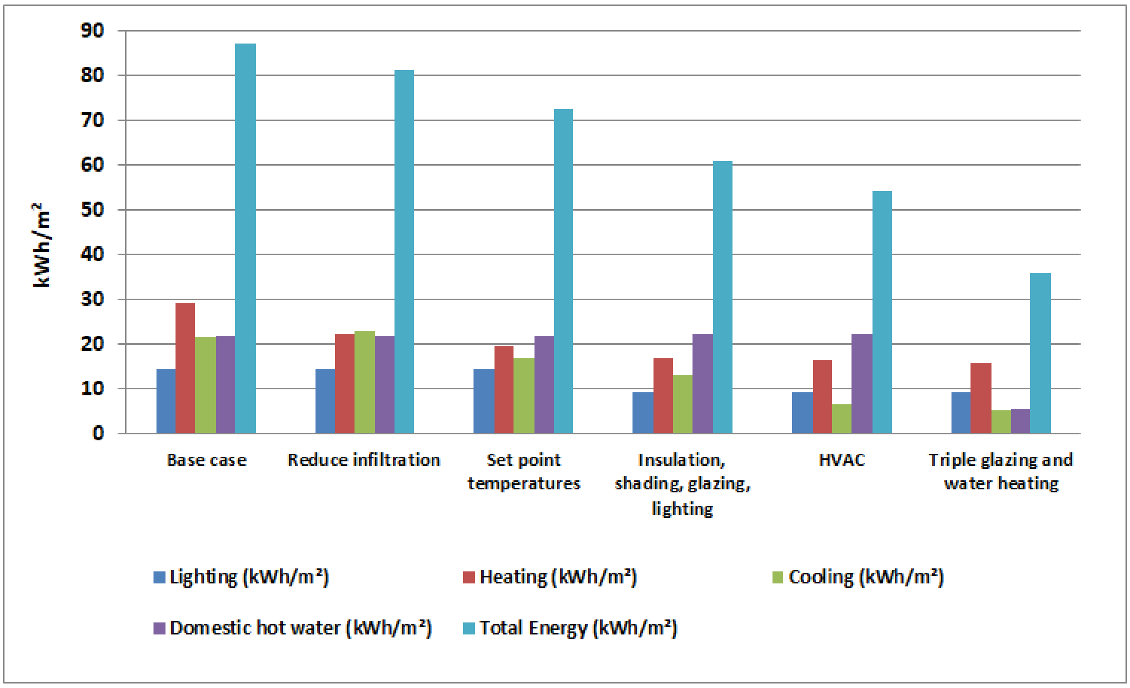

Figure 3: Reduction in Energy consumption for lighting, heating, cooling and domestic hot water and the total reduction from applying the retrofit plan compared to the base case

IV. Conclusion

A Simulation model was created for the current residential building type using the Design Builder tool to evaluate the savings by applying the retrofit program. The results show that at level one of the suggested plan, the energy consumption for heating and cooling can be reduced by 16.7 %. At level two the energy consumption for heating, cooling and lighting can be reduced by a further 13.3 % by adapting the building envelope optimization (using thermal insulation, glazing optimization, shading and efficient lighting). At level three the energy consumption for heating, cooling, lighting and equipment can be reduced by a further 28.9 % of the total energy consumption. The total energy reduction can reach up to 59 % of the total energy consumed in residential buildings by applying the three levels of the energy retrofitting plan. The retrofit plan can be extended for other climatic regions in Palestine and can include other residential building types. As a result, reducing the GHG emissions, for residential buildings and open new perspectives of the energy savings sector in different climates.

References

[1] Abdallah, R., Juaidi, A., Abdel-Fattah, S., & Manzano-Agugliaro, F. (2020). Estimating the optimum tilt angles for south-facing surfaces in Palestine. Energies, 13(3), 623.

[2] Abdallah, R., Juaidi, A., Assad, M., Salameh, T., & Manzano-Agugliaro, F. (2020). Energy recovery from waste tires using pyrolysis: Palestine as case of study. Energies, 13(7), 1817.

[3] Manzano-Agugliaro, F., Taher, M., Zapata-Sierra, A., Juaidi, A., & Montoya, F. G. (2017). An overview of research and energy evolution for small hydropower in Europe. Renewable and Sustainable Energy Reviews, 75, 476-489.

[4] Pombo, O., Allacker, K., Rivela, B., & Neila, J. (2016). Sustainability assessment of energy saving measures: A multi-criteria approach for residential buildings retrofitting—A case study of the Spanish housing stock. Energy and Buildings, 116, 384-394.

[5] IEA, 2020. Tracking Buildings 2020. IEA, Paris. https://www.iea.org/reports/ tracking-buildings-2020.

[6] Al-Saadi, S. N., Al-Hajri, J., & Sayari, M. A. (2017). Energy-efficient retrofitting strategies for residential buildings in hot climate of Oman. Energy Procedia, 142, 2009-2014.

[7] International Energy Agency, 2006. World Energy Outlook. International Energy Agency. OCED/IEA, Paris.

[8] Li, J., Colombier, M., 2009. Managing carbon emissions in China through building energy efficiency. J. Environ. Manag. 90 (8), 2436–2447. https://doi.org/10.1016/j. jenvman.2008.12.015.

[9] Tang, F., Chen, J., Li, J., & Rodriguez, D. (2020). Energy saving actions toward NZEBs with multiple-criteria optimization in current residential buildings. Energy Reports, 6, 3008-3022.

[10] Jia, L., Qian, Q. K., Meijer, F., & Visscher, H. (2021). Exploring Key Risks of Energy Retrofit of Residential Buildings in China with Transaction Cost Considerations. Journal of Cleaner Production, 126099.

[11] Lizana, J., Molina-Huelva, M., & Chacartegui, R. (2016). Multi-criteria assessment for the effective decision management in residential energy retrofitting. Energy and Buildings, 129, 284-307.

[12] AlFaris, F., Juaidi, A., & Manzano-Agugliaro, F. (2016). Energy retrofit strategies for the housing sector in the arid climate. Energy and Buildings, 131, 158-171.

[13] AlFaris, F., Juaidi, A., & Manzano-Agugliaro, F. (2016). Improvement of efficiency through an energy management program as a sustainable practice in schools. Journal of Cleaner Production, 135, 794-805.

[14] Juaidi, A., AlFaris, F., Saeed, F., Salmeron-Manzano, E., & Manzano-Agugliaro, F. (2019). Urban design to achieve the sustainable energy of residential neighbourhoods in arid climate. Journal of Cleaner Production, 228, 135-152.

[15] Juaidi, A., Montoya, F. G., Gázquez, J. A., & Manzano-Agugliaro, F. (2016). An overview of energy balance compared to sustainable energy in the United Arab Emirates. Renewable and Sustainable Energy Reviews, 55, 1195-1209.

[16] Juaidi, A., Montoya, F. G., Ibrik, I. H., & Manzano-Agugliaro, F. (2016). An overview of renewable energy potential in Palestine. Renewable and Sustainable Energy Reviews, 65, 943-960.

[17] AlFaris, F., Juaidi, A., & Manzano-Agugliaro, F. (2017). Intelligent homes' technologies to optimize the energy performance for the net zero energy home. Energy and Buildings, 153, 262-274.

[18] Monna, S., Juaidi, A., Abdallah, R., & Itma, M. (2020). A Comparative Assessment for the Potential Energy Production from

PV Installation on Residential Buildings. Sustainability, 12(24), 10344.

[19] Juaidi, A., AlFaris, F., Montoya, F. G., & Manzano-Agugliaro, F. (2016). Energy benchmarking for shopping centers in the Gulf Coast region. Energy Policy, 91, 247-255.

[20] Abdallah, R., Natsheh, E., Juaidi, A., Samara, S. and Manzano-Agugliaro, F., 2020. A Multi-Level World Comprehensive Neural Network Model for Maximum Annual Solar Irradiation on a Flat Surface. Energies, 13(23), p.6422.

[21] Galante, A., & Pasetti, G. (2012). A methodology for evaluating the potential energy savings of retrofitting residential building stocks. Sustainable Cities and Society, 4, 12-21.

[22] Mejjaouli, S., & Alzahrani, M. (2020). Decision-making model for optimum energy retrofitting strategies in residential buildings. Sustainable Production and Consumption, 24, 211-218.

[23] Richard Hyde, Nathan Groenhout, Francis Barram, Ken Yeang, 2013. Sustainable Retrofitting of Commercial Buildings in Warm Climates. Routledge, London

[24] Salameh T, Assad MEH, Tawalbeh M, Ghenai C, Merabet A, Öztop HF. Analysis of cooling load on commercial building in UAE climate using building integrated photovoltaic façade system. Solar Energy. 2020;199:617-29.

[25] Abdelsalam Aldawoud , Tareq Salameh, Young Ki Kim, Double skin façade: energy performance in the United Arab Emirates, Energy Sources, Part B: Economics, Planning, and Policy, 08 Sep 2020.

[26] Abdelsalam Aldawoud;Tareq Salameh, Natural Ventilation to Improve the Thermal Performance of Schools in UAE, 2020 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates, 2020.

[27] West Bank & Gaza energy efficiency action plan 2020-2030. Final Report. 2016. World bank

[28] Sameh Monna, Silvia Coccolo, Jérôme Kämpf, Dasaraden Mauree, Jean-Louis Scartezzini, 2016. Energy Demand Analysis for Building Envelope Optimization for Hot Climate: A Case Study at An Najah National University. Proceeding from PLEA 2016 Los Angeles - 36th International Conference on Passive and Low Energy Architecture.

[29] Cecilia Camporeale and Roberto Del Ciello, 2020. Country report on energy efficiency and renewable energy investment climate - palestinian territories. meetMED, European Union.

[30] IEA (2019), Global Status Report for Buildings and Construction 2019, IEA, Paris https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019

[31] Palestinian Central Bureau of Statistics. Household Energy Survey: (2015) Main Results . Ramallah, Palestine

[32] Applied Research Institute – Jerusalem (ARIJ), 2003. Climatic Zoning for Energy Efficient Buildings in the Palestinian Territories (the West Bank and Gaza) Technical Report, Jerusalem, Palestine