Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Towards climate resilient residential buildings: learning from traditional typologies

To cite this article: D Mohaibesh *et al* 2021 *J. Phys.: Conf. Ser.* **2042** 012146

Towards climate resilient residential buildings: learning from traditional typologies

D Mohaibesh[1], S Monna[1*], H Qadi and R Sokkar[1]

[1] Architectural Engineering Department, An-Najah National University, Nablus, Palestine

*Corresponding author: samehmona@najah.edu

Abstract. Climate-resilient buildings in Palestine can play an important role in a more sustainable residential building sector. This paper aims at evaluating the effects of adopting architectural design strategies and material technologies from vernacular architecture to create a new climate-resilient building. The paper targets single houses as these represent the majority of residential buildings in suburban and rural areas, and are similar to the vernacular architecture in size and functionality. The EDSL Tas simulation tool was used to assess the thermal performance and energy savings in the proposed model compared with traditional houses and modern typical houses, in two different climatic zones. The proposed climate-resilient house has materials and design strategies derived from vernacular architecture, in addition to the use of thermal insulation. The results show that the proposed house is more climate-resilient compared to modern houses. In cold winter and hot summer climates, the proposed model presents a total annual heating and cooling energy consumption of 59% less than typical modern houses, and 5% more than old buildings. In hot arid summer and warm winter climates, the proposed house presents a total annual heating and cooling energy consumption of 58% less than a modern typical house and 8% more than the traditional house.

1. Introduction

Energy consumption in residential buildings in Palestine is exceeds that of other buildings as well as that of industry and transportation. In 2018 households were responsible for 45% of the total energy consumption followed by transportation (38%), other building sectors (10%), industry (6%) and agriculture (1%) [1, 2]. Despite the higher percentage of energy consumption in residential buildings in Palestine, building thermal performance and energy efficiency measures are not sufficiently endorsed [3]. The housing sector is growing fast due to increased urbanization and population growth, but these rabid developments focus on issues like cost, household size, and aesthetics rather than climate-responsive and climate-resilient solutions [4]. When improving climate resilience for residential buildings, a balance needs to be found between competing approaches focusing on aspects like energy efficiency, thermal comfort, and economic operation [5]. Barakat et al. 2004 analyzed housing problems in Palestine by focusing on the obstacles to urban reconstruction in the period 1993-2000. The paper assessed the experience of the Palestinian housing council in terms of cost, thermal performance, and architectural design solutions, then provided recommendations for improving the housing sector, focusing on the function of the housing council and its operational mechanism, rather than energy efficiency and climate resilience [6].

Climate-resilient buildings have become a substantial step towards a more sustainable future. Vernacular architecture can be inspirational to close the gap for thermal performance in residential buildings, especially for single houses. Alekcis et al. 2016 reviewed various types of residential building responses to global disasters caused by climate change. The study found that exploiting the existing buildings will help to create an identity for new houses that can withstand the future climate change consequences [7]. Integrating traditional building design strategies and material properties, such as building outline, space ratio, windows, walls construction materials and thickness, roof construction detailing into current architectural practice can improve the climate resilience of residential buildings [8]. Historic houses were adapted to their local climates employing climate responsive strategies [9]. A comparison between traditional and modern houses in the sub-Saharan climate shows that 60 – 70% of inhabitants felt comfortable in traditional houses in hot and dry summers, compared to 20% of inhabitants in modern houses [10]. The courtyard space in traditional architecture can be adopted for future houses as it plays a crucial role in enhancing a house's sustainability, by providing a comfortable thermal environment, solar protection and privacy [11]. In order to create more sustainable contemporary buildings, vernacular Palestinian architectural design strategies can be introduced in the design of new buildings [12]. Alatawneh & Germana proved that earth could be a good alternative material for building envelopes that follows the sustainability dimensions, social and economic contexts, and can be used as a solution to housing problems in Palestine [13]. Studies on extracting techniques from traditional architecture are increasing in many countries around the world, as it is thought that this will drive contemporary architecture towards sustainability. Historically, the traditional architecture has met many of the needs that are no longer met today. Vernacular architecture has many features of sustainability, which is seen in the building's culture, land use, durability, construction techniques, construction waste management, air quality, and energy efficiency [14]. The design of climate-resilient buildings and the exploitation of the renewable energy sources obtainable in Palestine, especially solar energy with an average daily solar radiation of 5.4 kWh/m^2, could be the best way towards independence in the energy sector [15].

This paper aims at comparing the thermal performance of modern and traditional single houses. Building outline, building height, windows shape, construction materials, and the use of thermal insulation are the main assessed parameters. Then, a proposed house will be introduced based on this comparison, to improve building thermal performance towards climate-resilient residential buildings.

2. Methodology

The methodology used a comparative approach of the thermal performance between a typical modern construction and traditional old houses. A survey for the old and modern houses' typologies was carried out. Then, representative models for the most used building types, with similar floor area were established, as can be seen in Figure 1. Field measurements for the indoor air temperatures were carried out during two representative weeks in summer and in winter to compare the traditional and modern single houses' thermal performance in the Nablus region. The measurements were carried out for rooms with a similar orientation, size, and use in the absence of heating and cooling. The study targets the single houses as it represents the majority of buildings in the rural and suburban areas in Palestine.

The building envelope material's physical properties, building outline, window shape, and building height for both new and old buildings were identified as evaluation parameters. These parameters were evaluated as the main differences between traditional and modern houses. The base case (typical modern house) has high infiltration (0.8 ach), no thermal insulation, double clear glazing, typical wall and roof construction, typical outline with no internal courtyard, horizontal window shape (1.6 m width*1.2 m height), and a building interior height of 2.7 m. The traditional model, on the other hand, has high infiltration (0.8 ach), no thermal insulation, single clear glazing, traditional wall and roof construction materials and thickness, traditional building outline with an open courtyard, vertical window shape (1 m width*1.6 m height), and a building interior height of 3.7 m. The Proposed model has low infiltration (0.3 ach), double glazing, wall and roof construction materials and thickness. The proposed model was established to benefit from the traditional plans by adding the courtyard, a vertical window shape (1 m width* 1.6 m height) was used instead of a horizontal one, then space height was raised from 2.7m in modern buildings to 3.3m, after that wall, ceiling, and roof materials were changed; 7cm thick perlite block was used instead of concrete hollow block, 7cm expanded polystyrene thermal insulation was added to external walls, concrete was used for flooring instead of ceramic tiles and 5cm thick thermal insulation was added to the roof. Envelope construction materials for the three models are explained in Table 1, and the proposed model floor plan is shown in Figure 2. All three models have occupancy of 5 persons per household, which is the average family size in Palestine. The range of indoor temperatures was set between 18°C and 24°C. During the summer cooling period, the windows were gradually opened to reach 50% opening when the outdoor temperature was below 25°C, whereas the windows were closed during the heating period. The shading was considered only by self-shading of the building through open courtyard, window shape, and building outline, as overhangs and external shatters are not widely used in Palestine.

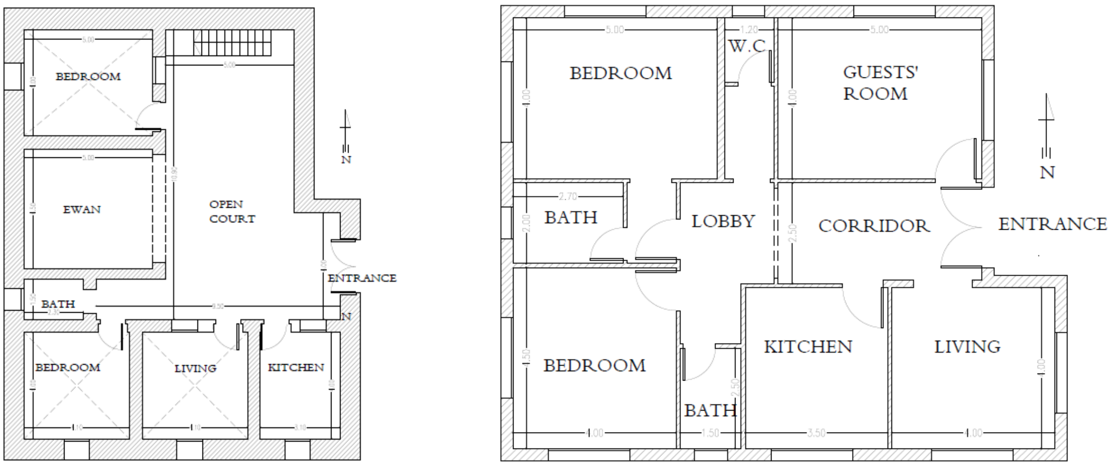
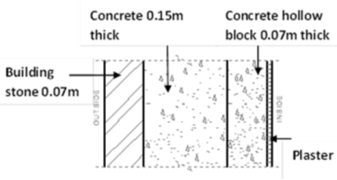
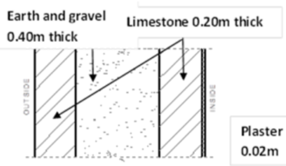
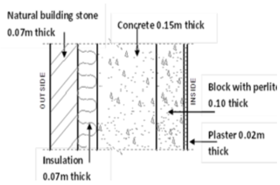
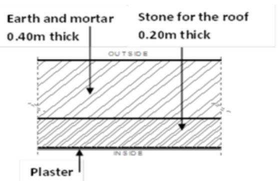
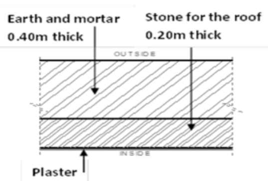
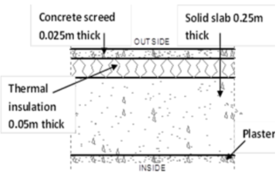


Figure 1. The most used traditional house of 147m^2 (left) and the modern house of 140m^2 (right)

Computer simulation models for as-built modern and old houses with similar built-up areas were constructed using the theEDSL Tas simulation tool to evaluate the indoor thermal environment and the potential energy consumption for heating and cooling [16]. The simulations were also performed for a proposed single house resulting from using a building outline, building height, window shape, and construction materials derived from old typologies, in addition to the use of thermal insulation. Then, the heating and cooling energy consumption for the proposed model was evaluated in comparison with a typical modern house and a traditional house, in order to assess its climate resilience.

Table 1. Envelope construction materials for the three types of buildings

Buildings type	Base case (typical house model)	Old model	Proposed model
External Wall			
Roof			

The weather data were used for two different climatic zones in Palestine: Zone (4) the mountains climate zone; as it represents the highest population density, it has a heating dominated climate, with cold winters and relatively humid summers, and is represented by the city of Nablus. And Zone (1), which has a hot and dry summer and warm winter climate; it has a cooling dominated climate, and is represented by the city of Jericho, as can be seen in Figure 3.

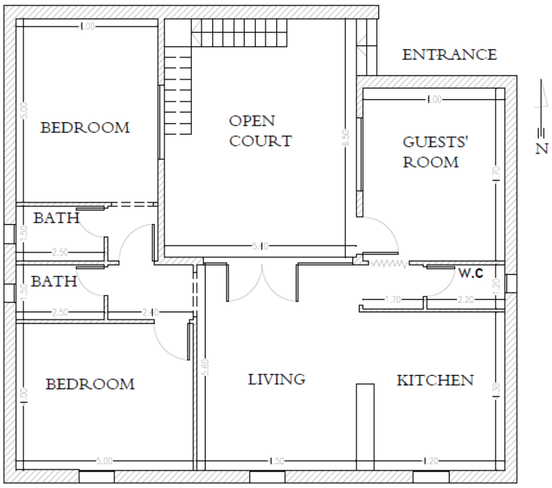


Figure 2. The proposed model for a climate-resilient single house

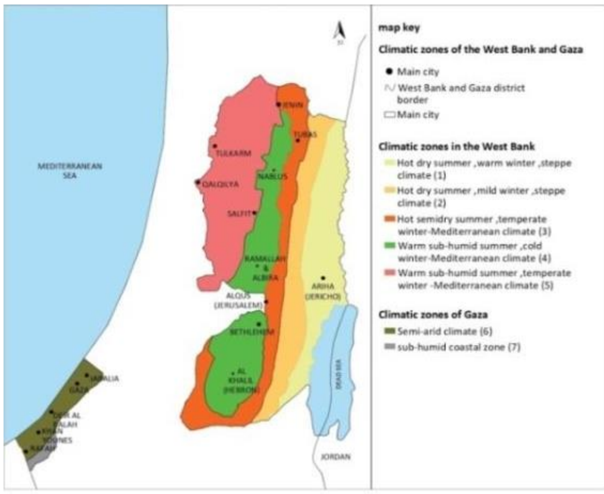


Figure 3. Climatic zones in the Palestinian Territories, the map was produced based on the data provided by ARIJ) [17]

3. Results and Discussion

The results from the field measurement for two weeks in winter show that the traditional house was performing better than the modern house most of the time; however, the indoor air temperature remained below 16°C for both buildings, due to the high infiltration and the absence of thermal insulation. The indoor air temperature difference between traditional and modern single houses was in the range of 1 to 5°C, as can be seen in Figure 4. For the summer period, the results show that the traditional house performed better than the modern house all the time, with an indoor air temperature in the range of 28 to 30°C, compared with the range of 29 to 33°C for the modern house. The indoor air temperature difference between traditional and modern single houses was in the range of 1 to 3°C, as can be seen in Figure 4.

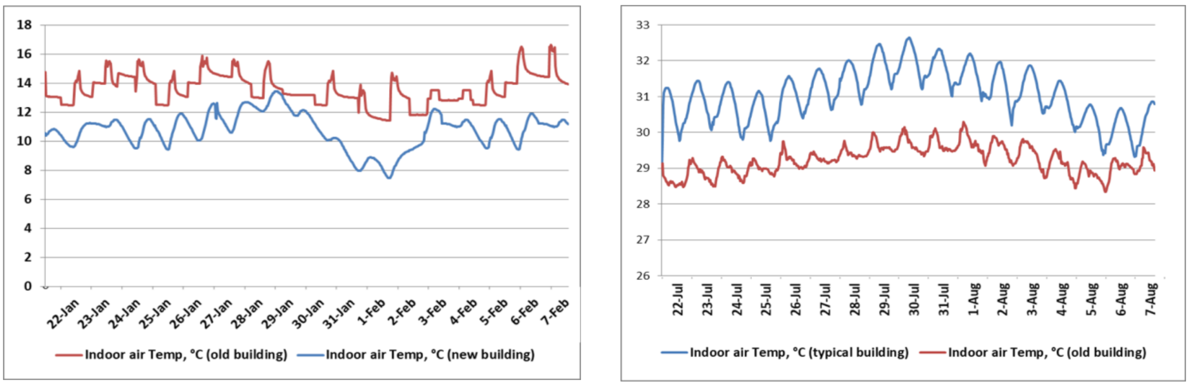


Figure 4. The indoor air temperature for two weeks in winter (left) and two weeks in summer (right)

The results from computer simulation for the three studied models, i.e. the modern typical single house, the traditional old house, and the proposed climate-resilient house in Climate Zone (4), show that the annual potential heating loads for the three models are 113kWh/m^2, 53.3kWh/m^2 and 48.2kWh/m^2 respectively. The proposed house has 57% less energy for heating compared to modern typical buildings and 10% less than traditional old buildings. The results also show that the annual potential cooling loads for the three models are 70.9kWh/m^2, 17.1kWh/m^2, and 26.3kWh/m^2 respectively. The proposed model uses 63% less energy for cooling compared to typical modern houses and 35% more than traditional old buildings as seen in Figure 5. The simulation results for the three models in Climate Zone (1), show that the annual potential heating loads are 37.1kWh/m^2, 10.2.5kWh/m^2, and 8.8kWh/m^2 respectively. The proposed model uses 76% less energy for heating compared to typical modern houses and 14% less than traditional old buildings. The results also show that the annual potential cooling loads are 131.4kWh/m^2, 47.2kWh/m^2, and 60.4kWh/m^2 respectively. The proposed model has 54% less energy for cooling compared to modern typical buildings and 22% more than traditional old buildings seen in Figure 5.

The simulation results confirm the field measurements results that the old buildings perform better than the modern buildings for both heating and cooling with 53% less energy for heating and 76% less energy for cooling for Zone (4), and 72% less energy for heating and 64% less energy for cooling for Zone (1). The proposed building is performing better than the modern and traditional buildings in winter, and performing better than the modern buildings in summer, but less well than the old buildings. This can be justified by the effect of a huge thermal mass in old construction.

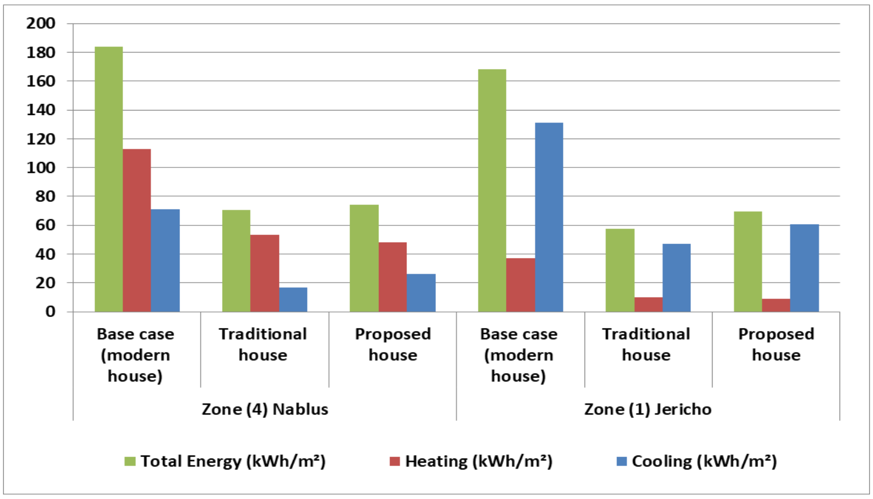


Figure 5. The heating and cooling loads for the three buildings types (modern typical single house, traditional house, and proposed climate-resilient house)

4. Conclusions

Old traditional architecture in Palestine has proven to be more climate-responsive and adaptive to climatic conditions. The field measurements for indoor air temperature for modern typical buildings and old traditional buildings confirm that old buildings present a better thermal performance. The single house characteristics of old houses such as building outline, window shapes, building envelope thermal properties, and building's height in addition to the use of thermal insulation have been adapted in a proposed single house planned to be climate-resilient. The computer thermal simulations for this proposed model in comparison to old and modern typical houses show that the proposed house has total annual heating and cooling consumption of 74.5kWh/m^2, which is 59% less than the modern typical house (183.9kWh/m^2), and 5% more than the old house (70.4kWh/m^2) for cold winter and hot summer regions in Palestine. For a hot and dry summer and warm winter climate, the proposed house presents a total annual heating and cooling consumption of 69.8 kWh/m^2 which is 58% less than the modern typical house (168.4kWh/m^2), and 8% more than the old house (57.4 kWh/m^2).

Based on these results a new residential form, which benefitted from the climate resilience of traditional forms and materials and the use of thermal insulation, has proven to be more energy-efficient than typical modern houses. This model will be more adaptable to climate change which has recently been causing heat waves and extreme temperatures in the Middle East. When comparing this proposed house with a traditional old house, it remains slightly less energy efficient. Further research to improve this climate-resilient house can assess enhancing thermal insulation in cold winter regions. For hot dry summer regions, future research can assess enhancing solar protection and evaporative cooling through a water fountain in the open courtyard.

References

[1] Cecilia Camporeale and Roberto Del Ciello. 2020. Country report on energy efficiency and renewable energy investment climate - Palestinian territories. European Union.
[2] Monna, Sameh & Juaidi, Adel & Khaldi, Ramez & Itma, Mohammed. 2020. A Comparative Assessment for the Potential Energy Production from PV Installation on Residential Buildings. Sustainability. Volume 12. 10.3390/su122410344.
[3] Monna, Sameh & Barlet, Aline & haj Hussein, Muhannad & Bruneau, Denis & Baba, Mutasim. 2019. Human thermal comfort for residential buildings in hot summer and cold winter regions, a user based approach. Journal of Physics: Conference Series. 1343.
[4] Coccolo, Silvia & Monna, Sameh & Kämpf, Jérôme & Mauree, Dasaraden & Scartezzini, Jean-Louis. (2016). Energy demand and urban microclimate of old and new residential districts in a hot arid climate. PLEA Conference on Passive and Low Energy Architecture.
[5] Fei Tang, Jie Chen, Jing Li, Dragan Rodriguez. 2020. Energy saving actions toward NZEBs with multiple-criteria optimization in current residential buildings. Energy Reports, Vol. 6
[6] Barakat, Sultan & Elkahlout, Ghasan & Jacoby, Tim. 2004. The Reconstruction of Housing in Palestine 1993–2000: A Case Study from the Gaza Strip. Housing Studies, 19:2, 175-192.
[7] Julija Aleksić, Saja Kosanović, Dušan Tomanović, Mirko Grbić, Vera Murgul. 2016, Housing and Climate Change-related Disasters: A Study on Architectural Typology and Practice, Procedia Engineering, Volume 165, Pages 869-875, ISSN 1877-7058,
[8] Vissilia Anna-Maria. 2009. Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics, Building and Environment, Vol. 44
[9] Rubio-Bellido, C.; Pulido-Arcas, J.A.; Cabeza-Lainez, J.M. 2015. Adaptation Strategies and Resilience to Climate Change of Historic Dwellings. Sustainability, 7, 3695-3713.
[10] Barbara Widera. 2021. Comparative analysis of user comfort and thermal performance of six types of vernacular dwellings as the first step towards climate resilient, sustainable and bioclimatic architecture in western sub-Saharan Africa, Renewable and Sustainable Energy Reviews, Volume 140, 110736, ISSN 1364-0321,
[11] Haj Hussein, Muhannad & Barlet, Aline & Semidor, Catherine. 2010. Socio-Environmental Dimensions of Private Outdoor Spaces in Contemporary Palestinian Housing. Open housing international. 35. 67 - 76. 10.1108/OHI-02-2010-B0009.
[12] Tawayha, Fajr & Bragança, Luís & Mateus, Ricardo. 2019. Contribution of the Vernacular Architecture to Sustainability: A Comparative Study between the Contemporary Areas and the Old Quarter of a Mediterranean City. Sustainability. 11. 896. 10.3390/su11030896.
[13] Al Atawneh, B & Germana, M.L. 2015. Earth for social housing in Palestine: an alternative for a sustainable refurbishment of building's envelopes. CIAT2015.
[14] Salgın, Burcu & Bayram, Ömer & Akgün, Atacan & Agyekum, Kofi. 2017. Sustainable Features of Vernacular Architecture: Housing of Eastern Black Sea Region as a Case Study. MDPI, Switzerland. Arts; DOI: 10.3390/arts6030011.
[15] Said, Nour & Alsamamra, Husain. 2019. An Overview of Green Buildings Potential in Palestine. International Journal of Sustainable and Green Energy. Vol. 8, No. 2
[16] Environmental Design Solutions Limited (EDSL), USA, Inc. https://www.edsltas.com/
[17] 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.