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Reducing Carbon Footprint by Using Thermal Insulation Materials in Palestinian Buildings

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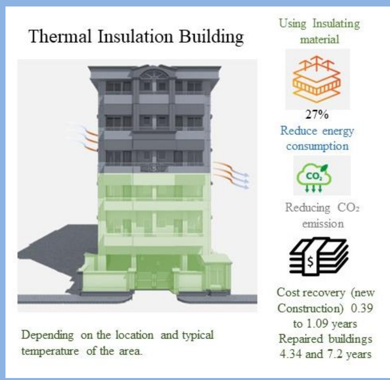
Abstract: Buildings account for 39% of emission worldwide. The study aims to clarify the effects of thermal insulation materials used in West Bank Palestinian buildings, to demonstrate their capacity to reduce emissions and saving cost. Using a variety of records from the Engineers Syndicate and the Palestinian Central Bureau of Statistics, a thorough study of buildings in the West Bank area was carried out to determine the number and area of buildings. Additionally, data from sources of energy was collected for the study years 2018–2021. Following the use of thermal insulation materials to the buildings, computations were then equipped with thermal insulation materials, and calculations to estimate the energy savings and reductions in carbon dioxide (CO_2) emissions. The results show, using insulating materials reduce energy consumption by 27.23% and CO_2 emissions significantly. It is anticipated that the cost recovery period for new construction is 0.39 to 1.09 years, and for repaired buildings it is between 4.34 and 7.2 years. Depending on the location and typical temperature of the area. The study recommends working for the widespread use of insulating materials in all new construction and for retrofitting existing structures. These initiatives will support international efforts to reduce emissions and achieve sustainable development goals in addition to improving energy efficiency.



Keywords: Carbon footprint, CO_2 Emissions, Thermal insulation material, CDD, HDD, U- Value, R- Value, Cost benefit analysis.

Introduction

The world is currently experiencing high levels of global warming as a result of human industrial activities. A major challenge for the coming years is to implement two closely related agreements: the Paris Climate Agreement and the 2030 Sustainable Development Goals (SDGs).[1]

Buildings are a significant contributor to carbon dioxide (CO_2) emissions throughout all stages of construction, operation, and demolition, accounting for approximately 39% of CO_2 emissions. According to studies in Palestine, the energy sector is the second-largest source of emissions, accounting for 30% of emissions in residential buildings, followed by 20% in industrial CO_2 emissions [2]

One of the primary uses of energy in Palestinian buildings is for heating and air conditioning [3]. The use of insulating materials in buildings can greatly reduce energy consumption by reducing the transfer of heat from the inside of the building to the outside during the winter [4], and vice versa in the summer. This can significantly contribute to the reduction of energy consumption and the decrease of CO_2 emissions.

The main goal of this research is to investigate the number and categorization of Palestinian structures in the designated study area. Furthermore, it seeks to evaluate the influence of integrating insulation materials into these buildings and assess their effectiveness in reducing carbon dioxide emissions. Additionally, the study will explore the implications of adopting insulation materials on construction costs, providing readers with a comprehensive understanding of the significance of utilizing such materials. This includes their impact on the operational expenses of the building, as well as their role in emission reduction.

A. *Climate Change and building sector:*

The State of Palestine has recently worked on preparing the first national communication report on climate change, in which Palestine affirms that it is a practical and participating member of the international community working to address the climate change phenomenon. The report includes statistics from 2011, which estimate the emissions rate (greenhouse gases in general) to be 3226 gigagrams of CO_2, with the rate from energy estimated at 1997.7 gigagrams, representing 62% of national emissions[5].

The reports issued by the State of Palestine on climate change in 2011 indicate that the energy sector has the highest percentage of emissions, representing 30% of domestic energy consumption. With an annual increase of 9.8% of emissions [5], it is expected that the emissions from the energy sector will reach 6580.42 gigagrams of greenhouse gases by 2021. According to the State of Palestine's commitment to international agreements, a 12.8% reduction must be achieved from this sector, reflecting the value of 842.3 gigagrams of greenhouse gases. [5]

B. *Energy Efficiency of Building:*

The heat transfer from the building occurs through almost all of its structural elements as shown in Figure (1). This indicates that the

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building has a high potential for heat loss, whether from the inside or outside. As a result, the building requires constant heating or air conditioning systems to maintain an ideal temperature of 25 degrees Celsius. This significantly increases the building's energy consumption[6]

Thus, there is a pressing need to develop building systems that enhance the building's efficiency, such as the use of thermal insulating materials in the building envelope, which can significantly increase energy efficiency. In addition, air conditioning systems can be optimized to reduce electricity consumption. Furthermore, the use of solar panel to heat water is a sustainable way to reduce electricity consumption. It is crucial to adopt a holistic approach to building design and construction in order to effectively address the challenges of climate change [3]

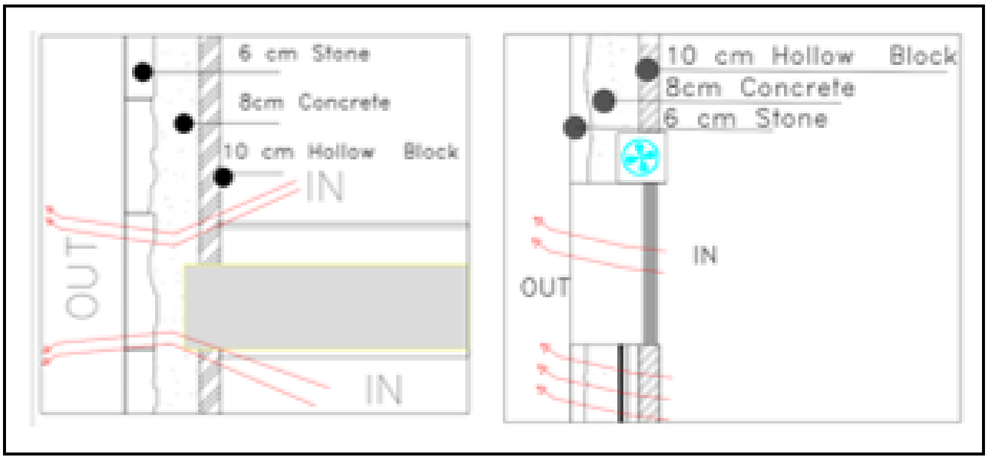

Figure (1): Heat transfer from some construction element.

Source: Your Guide to Building Envelope Retrofits for Optimizing Energy Efficiency & Thermal Comfort in Jordan Thermal Comfort in Jordan [7]

C. *Thermal insulation requirements and calculations:*

The building system relies on an integrated approach to achieve energy efficiency, which includes controlling water vapor and air filtration to prevent water vapor from being trapped by the external structure's leaks. Additionally, insulating materials protect the building from depreciation and decay [8].

Each part of the building requires a different insulation method and value depending on factors such as the type of material used and whether it is exposed to sunlight. For example, materials like glass and steel have low thermal resistance and lose heat significantly. Concrete can retain more heat, but may not be cost-effective and requires additional materials. Roofs are more vulnerable to heat loss compared to walls because heat moves vertically faster than horizontally. [9]

D. *Thermal Transmission:*

Thermal conduction, also known as thermal transmission, occurs mainly between the various layers of a building and is the primary method of heat transfer. However, while heat can be transferred through convection and radiation, most heat is transmitted primarily through conduction, with the amount of heat transferred through these other methods being relatively small [10]

To calculate the heat flow values of buildings, we need to know certain values for the materials used, and the terms for building specifications can be defined according to the International Energy Conservation Code 2021 (IECC) [11]

Thermal conductivity (k- Coefficient): The ability of the material to conduct the heat, and it submitted by the manufacturer (W/m. K)

The Thermal Resistance (R-Value) is the measure of a material's resistance to heat flow at a specific thickness. The more resistance a material has to heat flow, the higher the number.

To calculate a materials R-value, you need to divide the thickness of the material (in meters) by the Thermal conductivity (in W/mK).

$$R(m^2.\frac{K}{W}) = \frac{X}{k} \text{ --- } \mathbf{1} \text{ [11]}$$

Where:

R is the thermal resistance for the layer system in a unit (m^2.K/w)

X is the thickness of one layer(m).

k – Value is thermal conductivity (k=w/m. K).

Therefore, after calculating the thermal resistance, we can calculate the thermal transition according to the following:

Thermal Transmittance (U- Factor): The coefficient of heat transitions from layer to layer at different temperatures equals the time rate of heat flow for the unit area. (W/m^2. K)

Where:

$$Uw = \frac{1}{(Rsi+R1+R2+R3+ --\mp Rso)} \text{ -- } \mathbf{2} \text{ [10]}$$

Where:

U- Value is the thermal transmittance (U-Value= W/m^2. K)

Rsi is the thermal resistance at the inside surface (air) (m^2.K/W).

Rso is the thermal resistance at the outside surface (air) (m^2.K/W).

R1, R2, R3 ---- is the thermal resistance for each material respectively which the construction element contain. (m^2.K/W).

If the wall or the system has different layers, then U – Value is Calculated as the following equation:

$$U = \frac{(U1*A1)+(U2*A2)+(U3*A3)+----}{A1+A2+A3+--} \text{ --------------------------------- } \mathbf{3} \text{ [10]}$$

A is the area of the layer that adheres to its adjacent layer (convergence area).

Then the Heat Flow rate can calculate as the following equation:

$$Q = U * \Delta T \text{ -- 4[10]}$$

Where:

Q= Heat Flow from inside to outside (w/m^2).

ΔT= The difference in the Temperature from inside and outside (C°).

The maximum U-factor must be determined in accordance with the American Society of Heating, Refrigerating and Air-Conditioning

Engineers (ASHRAE) Standard. ASHRAE requires that the U-value must be known for each building element separately to calculate the energy flow values for walls, ceilings, windows, and doors. The energy flow from a building and the amount of energy required to maintain a building's temperature in an ideal manner are measured in heating or cooling degree hours, which are defined by international standards [6]:

Heating Degree-Day (HDD) is a measurement used to calculate the energy demand needed for a building to be comfortable, based on the number of hours that the temperature is less than 18°C [12] Conversely, Cooling Degree-Day (CDD) is a measurement used to calculate the energy demand needed for the building to be comfortable,[6] based on the number of hours that the temperature is more than 25°[13]

In this research he calculation of HDD and CDD for Ramallah as example for January according to the calculation below:

Month: January, No. of days: 31 days in one month, Sun Hours: 10 Hours, Night Hours: 14, Mean Temperature Day: 11.5 °C,Mean Temperature night: 6.9 °C.

HDD 18°C= {(18-11.5) *10*31/24} + {(18-6.9) *31*14/24)} =284.7 Hours.

CDD 25 °C=0

E. Thermal insulation Requirements:

To apply thermal insulation in a building, the floors, ceilings, and walls must be completely insulated, and the heat transfer values of the floor, walls, and ceilings must not exceed specific values which depend on the geographic area. Several factors should be considered, including [14].

1. The insulating material must cover the entire outer shell of the building within the approved standards for the region.
2. If more than one layer of insulating material is used, the layers must overlap.
3. Appliances suspended from the inside, such as lighting and air conditioning, must be installed without affecting the insulating materials.
4. The insulating material for floors should have an absorption coefficient (measurement looking at how far water can go through material before it gets absorbed) that does not exceed 0.3%, according to ASTM C272.
5. If there are suspended ceilings, the insulation should not be placed above them but on the central ceiling [6].
6. Products made from cellular plastic are durable materials. They are not susceptible to rot or insect infestation. In addition to solid panels, cellular plastic products are also available in foam form that can be sprayed onto the building envelope. Spray foam insulation is applied in liquid form using a hose and spray gun. It is a mixture of two ingredients that coalesce on contact and turn into a thick foam after a few seconds. The insulation material can be sprayed after electrical and plumbing services are performed as it will expand during curing and fill any gaps [15]
7. Good detail and technique are important for the ventilation of all types of building shell insulation. When attaching insulation to wall sockets and wires, it is important to pay attention to detail and cut patterns to attach the insulation to the wall frame [15].

Study Area

The study focuses on the 11 governorates of the West Bank-Palestine as shown in Figure (2) which displays the location of the West Bank and its governorates. Additionally, the study will examine the types of buildings in each governorate separately. Noting that traditional construction methods in the study area are still prevalent, which may involve the use of materials like stone, concrete, and clay bricks. These materials often have poor insulation properties compared to modern construction materials like insulated concrete forms, insulated panels, or energy-efficient windows commonly used in other countries.

To determine the size of new buildings, data from the Palestinian Central Bureau of Statistics (PCBs) up until 2017 will be used, along with annual reports from the Palestinian Engineers Association up until 2021.

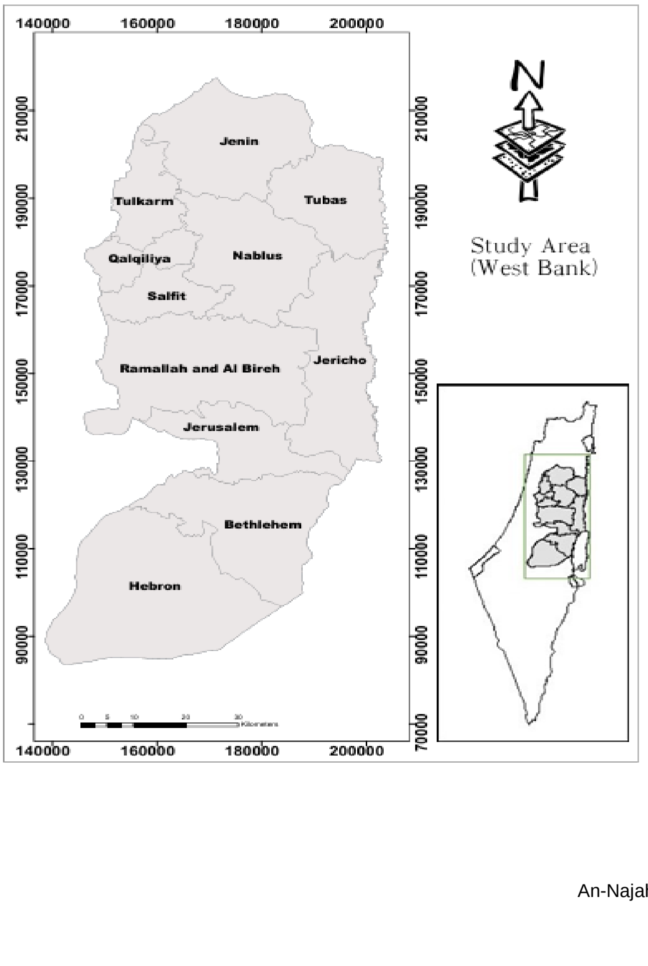

Figure (2): Study Area**.**

Methodology

The research methodology as shown in figure 3 is based on analyzing Palestinian buildings in the West Bank region, categorized by construction type and area, and evaluating the energy consumption rate for each governorate separately. Additionally, the study will analyze electricity usage between 2019, 2020, and 2021, as well as the types and quantities of heating used during the winter season. This will involve assessing the quantities of energy used for heating and air conditioning from electricity sources and other heating sources, such as gas or coal. The emissions generated by these energy sources will be calculated and compared, taking into account the impact of building insulation. Finally, the study will evaluate the potential emissions reduction if buildings were properly insulated, in line with global agreements signed by the Palestinian government.

A. *Building Type:*

The types of buildings in the West Bank governorates vary according to reports issued by the PCBs. They include clean stone buildings, which have an external covering made entirely of stone, as well as buildings made of a combination of stone and cement, reinforced concrete, cement bricks, clay bricks, and old stone buildings, The calculation of the number of buildings and floors in each governorate was based on the specific building types approved by the PCBc of Statistics report. This data allowed for an accurate assessment of the building in each governorate.

B. *Temperatures with heating degree day (HDD) and cooling degree day (CDD):*

The study utilized data from the Palestinian Meteorological Department to determine the average daytime and night time temperatures for each month across the Palestinian governorates. This information was then used to calculate the number of hours per month that require either heating or air conditioning. The results of the study are as follows:

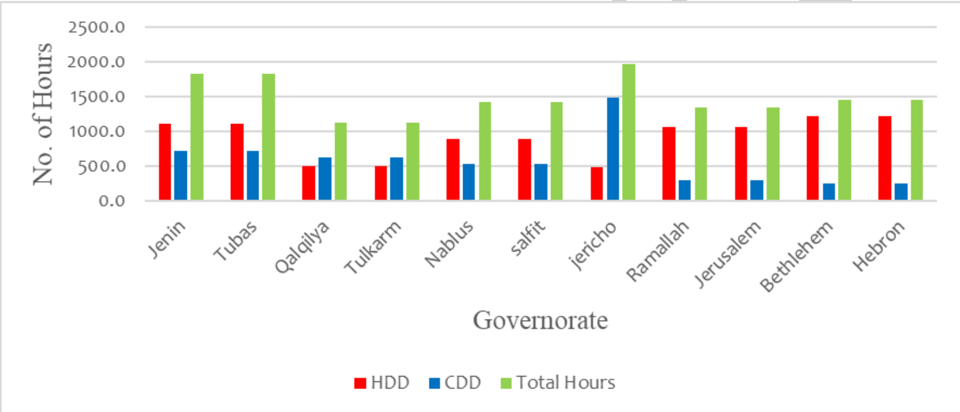

Figure 3: Number of hours for HDD and CDD for every governorate.

Source: Palestine metrological department.

C. *Building Type and Total Area*

Information about the kind and number of buildings in Palestine was obtained from the PCBS according to the last building report in 2017 [6]. From 2018 to 2021, population growth for building was calculated according to the annual reports for the Engineering Association, and an additional percentage of 30% (assumed) was added for buildings built in Area C. The area for each building governorate was calculated according to Palestine Monetary Authority 2021[16], The data has been transformed as total external celling and floor areas, considering that each building has one floor and ceiling area. Additionally, the wall areas have been calculated based on the number of floors for each building. In this analysis, the U-Value for each construction element has also been provided to explain the thermal conductivity and insulation properties of these components as show in table (1) (U- Value with and without thermal insulation material). This comprehensive approach allows for a detailed assessment of the building stock, taking into account the specific dimensions and thermal characteristics of the different construction elements.

Every type of building has a U-value that differs from another, which will be clarified in the table below with and without insulation material submitted according to climate zone. In this study's estimates, the researcher made the following assumptions about the wall area: 55% walls, 8% doors, and 37% glass.

Table (1): %of building type (No. and area)[17] [16] and U- value [7]without and with insulation material.

Item	% of Building	U- Value (W/m². k)	U- Value (with insulation) (W/m². k)
Slab on Grade	100%	1.22	1.17
Clean Stone	34%	2.54	0.58
Stone and Concrete	8%	2.59	0.55
Concrete	8%	2.64	0.59
Cement Block	41%	1.35	0.47
Adobe Clay	0.3%	2.03	0.56
Old Stone	8%	1.35	0.52
Solid Slab	15%	1.10	0.51
Rib Slab	85%	1.20	0.38

Source: Guidelines for green buildings in Palestine [4]

To achieved the U-value for construction element, For the floors, it was assumed that polyethylene membrane was utilized as the insulating material. Additionally, existing buildings were retrofitted with a 5 cm polystyrene board, and 10 cm hollow cement block to enhance wall insulation. As for the ceilings, the approved method involved creating plane concrete structure, thermoseal 200 and water proofing bitumen roll from outside, Furthermore, the ceiling insulation included from indoor celling 5cm polystyrene boards and 5cm gypsum boards.

F. Energy Use:

Based on the information provided, the energy consumption for each governorate in the West Bank was calculated separately using data on electricity, gas, kerosene, and firewood. It is important to note that the electricity supply in the West Bank is sourced from the Israeli side, and is comprised of 26% coal, 4% renewable energy, and 70% natural gas[18]. Using this information, the amount of energy consumed and the corresponding emissions for each energy source were determined.

Calculating the average electricity consumption for each governorate separately for the years 2019, 2020 and 2021 by adopting the difference between the average lowest month consumption and the average consumption of the months as the amount of consumption whether for heating or air conditioning, according to the data of the Palestinian Electricity Transmission Company.

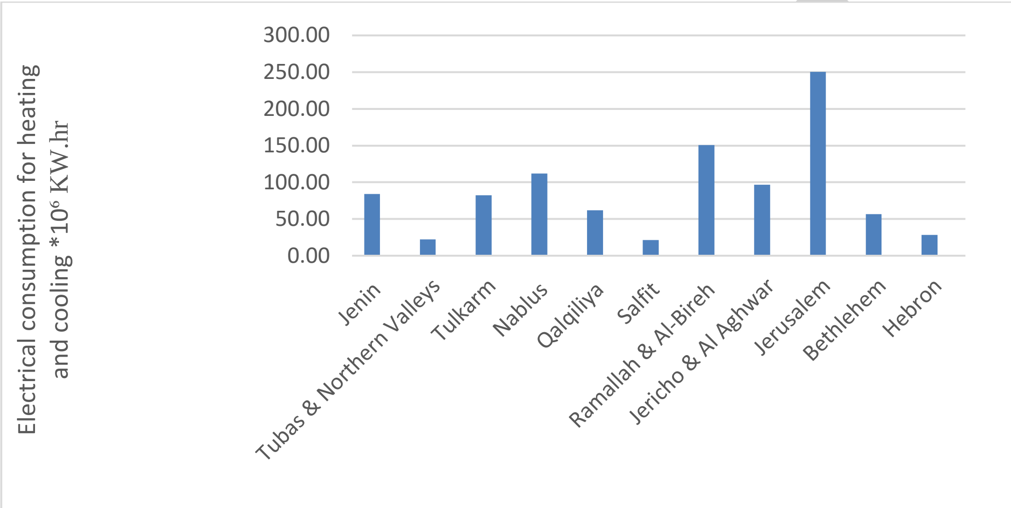

Figure (4): Total electrical consumption from each governorate as average in one year for heating and cooling.

Note: The total electrical consumption reported for the Hebron governorate appears to be illogical, and the researcher has reservations about its accuracy. However, it is important to note that this data was obtained directly from official authorities.

Table No. 2 show the total wood and charcoal, Liquified Petroleum Gas (LPG), and kerosene used for heating, The average consumption for April to October was taken. Then the difference between the average for the previous months and the total consumption rate for the months from November to March was taken, beside the electrical consumption which calculated as figure no. 5.

Table (2): Total energy consumption in study area.

Energy	Unit	Total Energy used for heating and cooling
Total Energy for heating and cooling- electrical	Kw.hr	966,781,300.03
Wood and charcoal	Ton	1,447.00
LPG	Ton	41,158.00
Kerosene	Thousand Litter	1,588.14

Source: Palestinian electricity transmission LTD, Jerusalem district electricity Co. ltd, Average 2019,2020,2021, Palestinian Central Bureau of Statistics, 2020

G*: Emission from Energy:*

Carbon footprint values vary depending on the type of Energy used. Likewise, the scientific literature on emission values varies widely as there is no definitive data on emission values for different energy sources. Therefore, CO_2 studies have been adopted according to the table below and the attached information.

Table (3): Rate of emissions from energy source.

No.	Energy type	CO_2 (gCO_2-eq./MJ)	g CO_2/Ton[19]
1.	Coal	900	
2.	Natural Gas	400	
3.	Renewable Energy	0	
4.	Wood and charcoal/ Ton	145	606680.00
5.	LPG (Ton)	80	334720.00
6.	Kerosene (Thousand Liter)-m³	91	380744.00

Source: Greenhouse gas emissions from fossil fuel fired power generation system[20]

To determine the energy savings resulting from the use of insulation materials in buildings under current conditions, we employed a method based on calculating the energy required for cooling degree days (CDD) and heating degree days (HDD) in ideal conditions, considering the hours of heating and cooling necessary for uninsulated buildings. Then calculated the potential energy savings from applying insulation materials to all buildings in the study area by 100%, and converted this to a rate applicable to the current situation. Finally, we determined the corresponding reduction in emissions resulting from the use of thermal insulation.

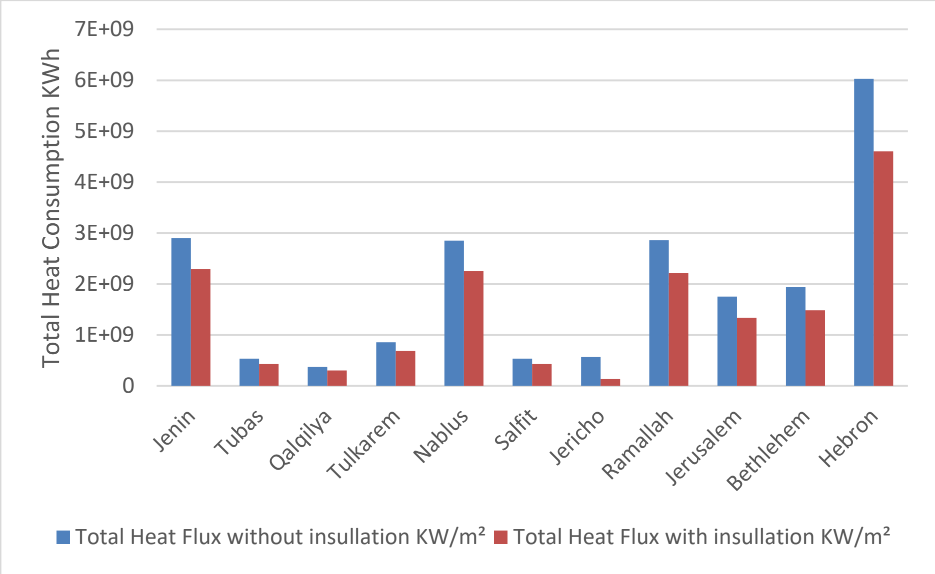

Figure (5): Total Heat Flux KW/m² from each governorate building with and without thermal insulation material as average in one year.

Results and Discussion

The study analyzed the energy consumption of buildings for heating and air conditioning, with and without insulation materials. The study looked at the temperatures, number, and type of buildings in each governorate, and found that the use of insulating materials led to a reduction in emissions by 18.88%-23.66 %, except for Jericho, the insulation material led to reduction in emissions by 76.48%, this is because of the high use of electrical energy to air-condition buildings, which is mainly due to high temperatures. By reducing electricity consumption, the emissions were also reduced, the total emissions show as table (4) the different between four scenarios which studied.

Table (4): Different in CO_2 Emissions with thermal insulation and without thermal insulation. (Ideal condition mean keeping the everyday temperature between 20 and 25 degrees Celsius).

Gov.	Current Condition		Ideal Condition	
	With or without using thermal insulation			
	Without	With	Without	With
	Ton CO_2* 10^³	Ton CO_2* 10^³	Ton CO_2* 10^³	Ton CO_2* 10^³
Jenin	44.92	35.53	1491.45	1179.64
Tubas	11.77	9.44	276.42	221.66
Qalqilya	32.45	26.32	192.84	156.43
Tulkarem	43.22	34.68	441.58	354.35
Nablus	59.59	47.09	1467.55	1159.63
Salfit	11.47	9.22	274.84	220.96
Jericho	49.88	11.73	290.09	68.24
Ramallah	79.21	61.44	1469.31	1139.60
Jerusalem	130.91	100.03	900.60	688.17
Bethlehem	30.35	23.20	999.41	763.96
Hebron	18.41	14.06	3099.13	2365.81
Total	512.18	372.74	10903.20	8318.44
Different in CO_2 saving emission in Giga gram	139.44		2584.79	
% of reduce emission	27.23%		23.71%	

The previous table show the different of emission for each governorate, for instance, the Jenin governorate exhibits an average savings rate of 20.91%, while Tubas shows a savings rate of 19.81%. It is worth noting that although Jenin and Tubas are located within the same climate zone according to the Palestinian code[8], differences in population, the number of buildings, and their characteristics contribute to the slight variations in emissions rates observed.

Based on the previous findings, it is evident that achieving complete insulation in all buildings can lead to a significant reduction in emissions. Specifically, the emissions rate can decrease by approximately 27.23%, equivalent to approximately 139.44 Giga gram. This reduction surpasses the target set by international agreements signed by the State of Palestine in climate change. In 2020, the estimated emissions were expected to reach 5200 Giga gram, with previous studies indicating that 30% of emissions originate from residential buildings. Consequently, the estimated emissions from all building-related sources, including heating, air conditioning, lighting, and water heating, amount to approximately 199.68 Giga gram. Achieving 100% building insulation can contribute to a remarkable reduction in energy consumption for heating and air conditioning, resulting in a 70.76% decrease in emissions compared to the expected value.

The study assessed the cost recovery percentage for using thermal insulation in buildings, based on calculations for a one-floor building with a specific area, as reported by the Palestinian Monetary Authority. The results showed that using thermal insulation for retrofitting would result in a cost recovery period of between 4.34-7.2 years, while using thermal insulation materials during the construction phase would result in a cost recovery period of between .39-1.04 years.

Note: thermal insulation price depends on the Palestinian local market, retrofitting price calculation contained thermal insulation and construction work.

Conclusions

In this study, the impact of insulating materials on West Bank buildings was extensively examined, utilizing statistical information from the Palestinian Central Bureau of Statistics (PCBS). Actual energy consumption data for the years 2019, 2020, and 2021, specifically focusing on heating and air conditioning, were analyzed to calculate the effects of insulating materials.

In conclusion, the utilization of insulating materials plays a pivotal role in reducing energy consumption and carbon emissions in buildings. Through the implementation of insulating materials, energy consumption for heating and air conditioning can be effectively reduced by 27.23%. This reduction is of particular significance in the context of the West Bank, where energy consumption is high, and emissions remain a pressing concern. It is crucial for the Palestinian government to take proactive measures, aligning with international agreements, to promote the use of insulating materials in both new construction projects and retrofitting existing buildings. This concerted effort will enhance energy efficiency, minimize emissions, and contribute to global sustainability goals.

Furthermore, the adoption of insulating materials must align with international standards, considering guidelines set forth by organizations such as ASHRAE, while also accounting for locally available materials. Adhering to these standards and utilizing appropriate materials from the local market can yield higher energy savings and cost efficiency.

In addition to employing insulating materials, there are other complementary strategies to further mitigate emissions and enhance energy efficiency in buildings. These include incorporating energy-efficient appliances and lighting, implementing intelligent building management systems, harnessing renewable energy sources, and promoting sustainable transportation options. It is crucial to adopt a holistic and integrated approach, encompassing all these measures, to maximize their effectiveness. Engaging stakeholders such as building owners, architects, engineers, and policymakers is vital to ensure the feasibility, cost-effectiveness, and widespread adoption of these solutions.

By prioritizing the implementation of insulating materials and complementary energy-saving measures, the West Bank can make significant progress in reducing energy consumption, lowering carbon emissions, and contributing to a sustainable future by less CO_2 emission. The findings of this study provide valuable insights for policymakers, industry professionals, and stakeholders involved in building construction and energy management.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.

Author's contribution

The authors confirm contribution to the paper as follows: study conception and design: Rafeef hanaishy, theoretical calculations and modeling: Rafeef Hanaishy; data analysis and validation, Abdelhalem Khader. draft manuscript preparation: Rafeef hanaishy, Abdelhalem khader. All authors reviewed the results and approved the final version of the manuscript.

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Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article

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List of Abbreviation:

No.	Abbreviation	Meaning
1.	ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
2.	ASTM C272	Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions
3.	CDD	Cooling Degree- Day
4.	CFCs	Chlorofluorocarbons
5.	CO_2	Carbon Dioxide
6.	GBC	Green Building Council
7.	HDD	Heating Degree-Day
8.	HVAC	Heating, Ventilation and air conditioning
9.	IECC2021	International Energy Code 2021
10.	K- Coefficient	Thermal Conductivity
11.	LPG	Liquefied Petroleum Gas
12.	M.T. D	Mean Temperature Day
13.	MTN	Mean Temperature Nighty
14.	PCBs	Palestinian Center Bureau of statices
15.	R- Value	Thermal Resistance
16.	RT- Value	Overall Thermal Resistance
17.	SHGC	Solar Heat Gain Coefficient
18.	U- Factor	Thermal Transmittance
19.	VLT Coefficient	Visual Light Transmission

References

1] Elver. implementing-the-paris-climate-agreement-and-the-2030-sustainable-development-goals, Compassion in world farming. 2015;

2] Environmental Quality Authority. Initial National Communication Report to the United Nations Framework Convention on Climate Change (UNFCC). Ramallah, Palestine; 2016.

3] World Bank Group. Energy Efficiency Action Plan 2020-2030. Ramallah, Palestine; 2016 Jun.

4] babaa, seder, mona, hijawi. Guide for green buildings - State of Palestine, Engineering association – Palestine higher green building Council. palestine; 2013.

5] Environmental Quality Authority. Report on nationally determined contributions in climate change. Ramallah, Palestine; 2017 Aug.

6] ASHRAE. Energy Standard for Buildings Except Low-Rise Residential Buildings. lluminating Engineering Society ANS institute, editor. American: ASHRAE; 2019.

7] Jourdan Green Building Council (GBC). Your Guide to Building Envelope Retrofits for Optimising Energy Efficiency & Thermal Comfort in Jordan Thermal Comfort in Jordan. 2018.

8] M.Haj-Hussain. A sustainable strategy for the future housing buildings in Palestine. Amman; 2010 Jul.

9] Allen T. Fundamentals of Residential construction. 3rd eddition. Canada: John Wiley & Sons; 2011.

10] Saudi Energy Efficiency Center SA. Guide of thermal insulation materials and systems according to Saudi building code requirements. 2021.

11] International Code Council. International Building CODE (IBC). Second Edition. USA: International Code Council (ICC); 2021.

12] International Code Council I. International Energy Conservation Code (IECC). USA; 2021.

13] Monna, Juaidi, Abdallah. Towards Sustainable Energy Retrofitting, a Simulation for Potential Energy Use Reduction in Residential Buildings in Palestine. MDPI. 2021 Jun 28;

14] Pacheco G. Cost-Effective Energy Efficient Building Retrofitting. Fernando Pacheco-Torgal, Claes-Göran Granqvist, Claes-Göran Granqvist, editors. 2015.

15] Hausladen G& SM d (Author) LP (Author) SM de (Author) HG (Author). Climate Design: Solutions for Buildings that Can Do More with Less Technology. CTCN. Munich; 2005.

16] Palestine Monetary Authority. Annual report of Palestine real estate in residential [Internet]. 2021. Available from: www.pma.ps

17] PCBS. State of Palestine Central Bureau of Statistics Final Results Report as of July, 1028 [Internet]. 2017. Available from: http://www.pcbs.gov.ps

18] Jolien N. Organisation for Economic Cooperation and Development (OECD), Israel, Progress in the net zero transition. Paris, France; 2021.

19] EPA. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references. 2022.

20] M. STEEN. Greenhouse gas emissions from fossil fuel fired power generation system. Joint Research Center European Commission; 2000.