An-Najah National University

Faculty of Graduate Studies

REDUCING CARBON FOOTPRINT BY USING THERMAL INSULATION MATERIALS IN PALESTENIAN BUILDING

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Dedication

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

﴿ وَقُلِ ٱعۡمَلُواْ فَسَيَرَى ٱللَّهُ عَمَلَكُمۡ وَرَسُولُهُۥ وَٱلۡمُؤۡمِنُونَۖ ﴿١٠٥﴾ ﴾ التوبة: ١٠٥

إلهي لايطيب الليل إلا بشكرك ولايطيب النهار إلى بطاعتك .. ولاتطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك

إلى من سعيت دومًا لنيل رضاهم، دونًا عن الناس، أمي وأبي الأعز على قلبي،،

إلى رفيق الدرب، وصديق الأيام جميعًا بحلوها ومرّها: زوجي الغالي،،

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Declaration

I, the undersigned, declare that I submitted the thesis entitled:

REDUCING CARBON FOOTPRINT BY USING THERMAL INSULATION MATERIALS IN PALESTINIAN BUILDINGS

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: Rafif Hanaishy

Signature:

Date: 17/4/2023

List of Contents

Dedication III

Acknowledgements IV

Declaration V

List of Contents VI

List of Tables VIII

List of Figures IX

List of Appendices X

Abstract XI

Chapter One: Introduction 1

1.1 General Background 1

1.2 Research Questions 2

1.3 Research Objectives 2

1.4 The Importance of The Study 2

1.5 Literature Review 3

Chapter Two: Methodology 13

2.1 Introduction 13

2.2 Study Area 13

2.3 Defining Criteria 16

Chapter Three: Results and Discussion 31

3.1 Climate Zone 31

3.2 CO2 Emission from Study Area 33

3.3 Percentage of Building Envelope in Study Area 40

3.4 Cost Benefit Analysis 40

Chapter Four: Conclusions 44

List of Abbreviation 46

References.. 47

Appendices.. 50

الملخص... ب

List of Tables

Table 2.1 :Specifications and % for building data in the study area 18

Table 2.1.a :U- Value calculation for clean stone wall.. 19

Table 2.2 :Specifications and % for retrofitting the building in the study area with insulation material according to IECC2021... 23

Table 2.2.a :U- value calculation for clean stone wall after adding thermal insulation material 24

Table 2.3: Insulation material in the local market with price and R- value.................... 25

Table 2.4: Average Total Consumption from Wood and charcoal, LPG, and Kerosene 29

Table 2.5: Average Total Consumption from electricity, Wood and charcoal, LPG, and Kerosene for Heating and cooling 29

Table 2.6: CO_2 Emission from different energy sources 30

Table 3.1: Different in CO_2 Emissions with thermal insulation and without thermal insulation.. 37

Table 3.2: Cost Benefit Analysis for retrofitting and new building/m².......................... 41

Table 3.3: Appendix A 1 Cost Benefit Analysis for retrofitting and new building for one building (one Flore with mean area for every governorate according to Palestinian Monetary Authority2021…………………………..………… 42

List of Figures

Figure 2.1: Study Area 14

Figure 2.2: Average Area in governorate in m² according to Palestine monetary authority

Figure 2.3: Number of hours for HDD and CDD for every governorate……………….20

Figure 2.4: Total Heat Flux from each governorate building with and without thermal insulation material as average in one year 26

Figure 2.5: Percentage of electricity Source from Israeli company 30

Figure 3.1: West Bank Climate Zone According to IECC2021 32

Figure 3.2:: Total CO2 Emission in (Giga gram) from Study Area without using thermal insulation 34

Figure 3.3: Total CO2 Emission in (Giga gram) from Study Area with using thermal insulation 35

Figure 3.4: Total CO2 Emission in (Giga gram) from Study Area without using thermal insulation with Ideal Condition 38

Figure 3.5: Total CO2 Emission in (Giga gram) from Study Area with using thermal insulation with ideal condition 39

List of Appendices

Appendix A: Tables 50

Table A. 1: Number of Completed Buildings by Region, Utilization of Building, and Type of Ownership, 2017 50

Table A.2: % of Completed Buildings* by Region, Utilization of Building, and Type of Ownership, 2017 50

Table A. 3: Average temperatures for each month separately and for each governorate separately, day and night, according to the Palestinian Meteorological Department, (long term average) 51

Table A.4: Average rainfall in the Palestinian governorates according to the Palestinian Meteorological Department, (long term average) 52

Appendix B: Figures 53

Figure B.1: Heat transfer from some construction elements (MOLG et al., 2004). .. 53

Figure B. 2: Vegetation shading (Source: American Institute of Architects (AIA) & Society of Building Science Educators (SBSE 2021) 53

Figure B.3:Vegetation shading.. 54

Figure B.4: Total electrical consumption from each governorate as average in one year for heating and cooling. 55

REDUCING CARBON FOOTPRINT BY USING THERMAL INSULATION MATERIALS IN PALESTENIAN BUILDING

By
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Abstract

Decreasing carbon dioxide emissions is a significant concern worldwide because of its connection to global warming and subsequent climate change. Buildings account for an average of 39% of emissions worldwide. Therefore, saving electricity through the use of insulating materials is a crucial step in decreasing electricity consumption and reducing carbon dioxide emissions.

A thorough survey of all buildings in the West Bank of Palestine was carried out, using the Palestinian Census Report of the year 2017 as a base to determine the quantity and condition of buildings in the various governorates of the West Bank. Additionally, annual reports from the Palestinian Engineers Association were used to calculate the number of buildings for the years 2018, 2019, 2020, and 2021. In addition to the survey, the Palestinian Monetary Authority's Residential Real Estate in Palestine 2021 report was used to determine the rate of area per building, and calculate the energy consumption for each governorate separately, using data from the Palestinian Electricity Transmission Company for the same years of study. The average energy used for heating and air conditioning was calculated, and insulating materials were applied to the buildings to measure their ability to save energy and to evaluate the impact on carbon dioxide emissions based on the source of electricity used in Palestine. Also, the approximate cost of insulating materials and the period required to recover the cost by the savings in energy consumption were calculated using the prices of materials in the Palestinian local market.

The results indicate that utilizing insulating materials can significantly decrease CO_2 emissions and decrease electricity consumption by 27.23%. The cost recovery period for retrofitted buildings is estimated to be between 4.34 to 7.2 years, and for new buildings, it is between 0.39 to 1.09 years. These estimates may vary depending on the location and the average temperature of the region.

The study recommends promoting the widespread use of insulating materials in all new construction projects and providing incentives for retrofitting already-existing structures. These initiatives will not only increase energy efficiency but also support worldwide efforts to reduce emissions and achieve sustainable development goals.

Keywords: Carbon Footprint, CO2 Emissions, Thermal Insulation Material, CDD, HDD, U- Value, R- Value, Cost Benefit Analysis.

Chapter One
Introduction

1.1 General Background

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) (Elver, 2015)

To achieve the goal of keeping the global average temperature below 2 degrees Celsius, the International Paris Agreement on Climate Change was signed on April 22, 2016, at the United Nations headquarters in New York. This agreement requires all countries to address the issue of global warming by reducing greenhouse gas emissions. Palestine has also recently joined this agreement (United nation, 2016).

The Sustainable Development Goals (SDGs) are 17 objectives that aim to align national strategies with societal development and economic growth. These goals include improving education, eliminating poverty, promoting health, protecting social and ethnic groups, increasing youth employment opportunities, empowering marginalized women, addressing climate change, protecting water and natural resources, and preserving the environment, (United nations, 2022)Therefore, it is crucial for all participating countries to take all necessary actions to achieve these goals through all available means.

Buildings are a significant contributor to carbon dioxide emissions throughout all stages of construction, operation, and demolition, accounting for approximately 39% of carbon dioxide emissions. According to studies in Palestine, energy sectors are the second-largest source of emissions at 30% of residential buildings and followed by 20% industries CO2 emissions (ENVIRONMENTAL QUALITY AUTHORITY, 2017).

One of the primaries uses of energy in Palestinian buildings is for heating and air conditioning. 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, and vice versa in the summer. This can greatly contribute to the reduction of energy consumption and the decrease of the carbon dioxide emissions.

Therefore, the use of insulating materials plays a significant role in reducing heat transfer and decreasing electricity consumption, which in turn helps to decrease carbon dioxide emissions. This will be the focus of the research.

1.2 Research Questions

- What percentage of buildings must be isolated and retrofitted to achieve CO2 emissions reduction goal in Palestine?
- What specifications must be adopted to achieve insulation in the best way to maintain the building's heat, whether in cold or hot weather?
- What insulation materials are used in Palestine and available in the local markets, and how they are affecting the capital cost for the building?
- What is the thermal insulation's effect on the building's running cost expenses and energy savings?

1.3 Research Objectives

- Determine the study area's thermal insulation requirements for construction elements.
- Define thermal insulation design, overall thermal transmittance (U-value) or the overall coefficient of heat transfer (U-factor), Overall thermal resistance (RT), thermal resistance (R) of a material, and thermal conductivity (K).
- Determining the amount of CO2 emission that may be reduced due to the use of thermal insulators if thermal insulating materials are used for insulation specific percentages of the existing buildings, and the embodied Energy can be reduced consumption.

1.4 The Importance of The Study

- This study aims to analyze the status of buildings in Palestine and reflect on the impact of insulating materials on reducing emissions and energy consumption in existing buildings on the national level. Which will help in understanding the potential of the construction sector in meeting the emission reduction goals of the State of Palestine to comply with international treaties on climate change.

- In addition, this study highlights the importance of thermal insulation in reducing the energy consumption on the household level. This is particularly important in Palestine due to high energy prices since almost all of the energy is imported.

1.5 Literature Review

1.5.1 Introduction

Climate change is a major worldwide concern, Due to its profound influence on all facets of life and possible repercussions on future generations.

The temperature has been rising at a rate of 0.14 degrees Fahrenheit (0.08 degrees Celsius) every decade since 1880. The pace of temperature increase, however, has doubled since 1981 to 0.32 Fahrenheit (0.18 C) each decade (National Centers for Environmental Information, 2021).

The melting of ice caps, increased precipitation, increasing sea levels, and changes in the populations of animals and vegetation are just a few of the devastating effects that this temperature increase has had on the world. (National Centers for Environmental Information, 2021).

On land, however, the temperature rise is larger than it is in most oceanic regions. Infectious illness patterns alter as a result of climate change (Lindsey, 2022).

Human actions like burning fossil fuels, which results in an increase in greenhouse gases in the atmosphere, are the main causes of the rapid temperature increase. It is crucial to remember that the current warming is happening considerably more quickly than any previous warming that was brought on by natural forces unconnected to human activities. These effects were still present in the past, but their impact was much smaller compared to the current warming (Riebeek, 2010).

Forecasts predict that the surface temperature will increase between 2-6 degrees Celsius by the end of the 21st century. Even if emissions are reduced, the earth will continue to experience warming as it has not fully adapted to the environmental changes caused by human activity (Riebeek, 2010).

The four main greenhouse gases: carbon dioxide, methane, nitrous oxide, and halocarbons or CFCs (gases containing fluorine with chlorine and bromine) can remain in the atmosphere for varying periods, ranging from months to thousands of years. These gases can affect the climate on different time scales, depending on their lifetime in the atmosphere (The Guardian, 2011).

Due to numerous factors that remove carbon dioxide from the atmosphere, it is difficult to determine the lifetime of carbon dioxide in the air, primarily from burning fossil fuels (which are responsible for approximately 75% of human emissions on global warming). Between 65 and 80 percent of the carbon dioxide released into the air dissolves in the ocean over 20 to 200 years, the rest is removed through slower processes that take hundreds to thousands of years, including chemical weathering and rock formation. Its influence is thousands of years old, as for methane, the primary source of it is livestock and rice fields. It is responsible for 14% of the greenhouse effect, which is removed through chemical reactions and lasts about 12 years, a relatively short period, nitrogen dioxide is responsible for about 8% of the global warming effect, and its primary sources are nitrogen-enriched soil and livestock waste. It is destroyed in the stratosphere and removed from the atmosphere more slowly than methane and persists for about 114 years, chlorofluorocarbons (CFCs, HCFCs, HFCs, and PFCs) constitute only 1% of the global warming effect. They are mainly sourced from industrial processes containing many different chemical species. Each of them can persist in the atmosphere for a limited period ranging from less than a year to several thousand years, water vapor is a very effective absorber of heat energy in the air, but it accumulates in the atmosphere in the same way that other greenhouse gases accumulate, and this is due to its concise life in the atmosphere from hours to days, as the amount of water vapor that can be saved in the atmosphere increases as its Temperature rises, it is, therefore, part of a feedback loop rather than a direct cause of climate change (The Guardian, 2011).

1.5.2 Climate Change and Building Sector

According to international reports, buildings are considered one of the most influential sectors in increasing the proportion of carbon in the atmosphere. Carbon is a significant problem for construction in all stages of the building's life(Xi & Cao, 2022). Buildings are considered one of the highest sectors in energy consumption in general, as the percentage of Energy in 2019 reached 36 %, with a value of 37 % of the emissions value, according to the World Building Report 2021(Hamilton, 2021).

The State of Palestine has recently worked on preparing the first national communication report on climate change(Environmental Quality Authority, 2016), in which Palestine affirms that it is a practical, participating member of the international community to address the climate change phenomenon by reports and statistics that were made in 2011, the reports indicating that the estimation of the emissions rate (greenhouse gases in general) is 3226 Giga grams of carbon dioxide, of which the rate is 1997.7 from Energy, which is estimated at 62% of national emissions. It is divided at the rate of (59%) into 1900.2 Giga grams of carbon dioxide CO_2, 802.6 Giga grams of methane CH_4(25%), and 523.5 Giga grams of nitrous oxide N_2O (16%). The transportation sector was at the forefront, accounting for 47%, followed by the household sector, with 30% of the total emissions. Accordingly, if the independence scenario, which represents the end of the Israeli occupation, is adopted, the State of Palestine will increase its emissions for the years 2020, 2030, and 2040 to 5200, 6860, and 9130 Giga grams of carbon dioxide equivalent, respectively. On the other hand, if the current situation scenario, which represents the continuation of the Israeli occupation, is adopted, it is anticipated that greenhouse gas emissions will reach 5960 Giga grams, i.e., a reduction of 12.8% (Environmental Quality Authority, 2016),Therefore, according to the agreements signed by the State of Palestine, it is among its strategic plans to reduce emissions to reduce climate change, where two scenarios have been adopted to mitigate emissions, as follows:

1. The independence scenario (represented by the end of the Israeli occupation) aims to reduce emissions by 24.4% by 2040.
2. The current situation scenario (reflecting the continuation of the Israeli occupation) aims to reduce emissions to 12.8% by 2040 (Environmental Quality Authority, 2017).

Accordingly, among the measures that target buildings to reduce emissions and within the strategic plans of the State of Palestine, improving thermal efficiency standards in buildings and developing existing systems are among the basics to reduce emissions and achieve emissions reduction as required (Environmental Quality Authority, 2017).

The reports of the State of Palestine on climate change, which were issued in 2011, indicate that the energy sector has the highest percentage of emissions, from which it occupies 30% of domestic energy consumption and with an annual increase of 9.8% of emissions, it is expected that during 2021 the value of emissions from the energy sector will reach Domestic Energy amounts to 6580.42 Giga grams of greenhouse gases, and according to the State of Palestine's commitment to international agreements, a 12.8% reduction must be achieved from the sector, and this reflects the value of 842.3 Giga of greenhouse gases(Environmental Quality Authority, 2017).

1.5.3 Energy Efficiency of Building

The share of electricity constitutes 9% of the expenditures of the Palestinian family and is the highest in the Middle East (World Bank Group, 2016).

According to the survey carried out by the Palestinian Center Bureau of Statistics in 2015 (PCBS), which shows the number of devices and the use of electricity, air conditioners, electric room heaters, water heating, refrigerators, and lighting are the top consumers in the home(World Bank Group, 2016).

The heat transfer from the building almost from all the construction elements which shows in Figure no (B-1), that mean the building which indicates the high ability of the construction elements to leak heat, whether from the inside or outside of the building, which leads to the building's permanent need for heating or air conditioning systems to reach the ideal temperature of 25 degrees Celsius, and this leads to the building becoming energy consuming significantly.

Accordingly, there was a need to develop building systems by enhancing the building's efficiency, building envelope by using (thermal insulating materials), which increase building's energy efficiency, and air conditioning to reduce electricity consumption. In addition, use of solar panels to heat water reduces 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 (World Bank Group, 2016).

By implementing these strategies, buildings can not only reduce their carbon footprint, but also decrease their operating costs and improve the overall comfort of the building for its inhabitants. Additionally, using sustainable building materials and incorporating green spaces can also contribute to the overall environmental performance of a building. Overall, it is important for all countries to take action in reducing the carbon emissions of their buildings in order to meet the goals of green building code (Green Building Education Services, 2014.).

1.5.4 Definitions and Types of Thermal Insulating Materials

Thermal insulation is a construction material used to reduce heat transfer from one body to another, as some materials can reduce thermal Energy through heat conduction and radiation (Prajapati et al., 2018), With low thermal conductivity, often less than 0.1W/m.K (UN CTCN, 2015).

By using insulating materials with a low thermal conductivity value, the building's heat loss or gain can be reduced. This can lead to a decrease in energy consumption for heating and cooling, resulting in cost savings and a reduction in carbon dioxide emissions. Additionally, every material has a thermal transfer coefficient (thermal conductivity) and is approved by the manufacturer.

Insulating materials are classified into several types:

1. Inorganic insulation materials: These are derived from non-renewable natural minerals such as glass, rock wool (fibrous materials), perlite, and calcium silicate (as cellular materials), which are melted at high temperatures (UN CTCN, 2015).
2. Organic insulating materials: are typically produced through chemical processing of fossil fuels or natural materials. Fibrous materials like cellulose, cotton, wood pulp, cane, and synthetic fibers are commonly used, as are cellular materials such as cork, polystyrene(MOLG et al., 2004) (polystyrene is a synthetic polymer made from the monomer styrene, which is derived from petroleum and other organic chemicals. While it is synthetic and not derived from a natural source, polystyrene is still considered organic because it is made from carbon-based compounds)(American Chemistry Council, 2021), polyethylene, polyurethane, and other polymers. Additionally, reflective or cooling coatings, like elastomeric or acrylic coatings, can also be considered organic insulation materials.
3. Materials for composite insulation: such as thermal plasters or lightweight concrete.
4. Insulation materials based on gas have a lower thermal conductivity than air and consist of two gas-filled panels (Pacheco, 2015).

1.5.5 Thermal Insulation Requirements and Calculations

In an integrated approach to sustainable development, renewable energy sources like solar, wind, and geothermal power are utilized to operate a building's systems and minimize its dependence on fossil fuels. In addition, energy-efficient appliances, lighting, and HVAC systems are employed to significantly reduce the building's energy consumption and carbon emissions. Ultimately, the implementation of energy-efficient building systems and practices is paramount in addressing climate change and achieving sustainable development.

The building system relies on an integrated approach in terms of energy efficiency used in addition to controlling water vapor and air filtration to keep water vapor from being isolated from leakage of the external construction elements and insulating materials to protect it from depreciation and decay (Allen, 2011).

The condensation of water vapor is a factor that can impact the temperature of a building, as well as the lifespan of its interior coating and overall structural integrity. Therefore, ventilation of the building must be maintained permanently, especially in places with a lot of condensation, such as cooking places and the bathroom (UN CTCN, 2015).

Each part of the building depends on a different insulation method and value. The type of material used and whether it is exposed to sunlight. For example, glass and steel have low thermal resistance and lose significant heat. Concrete saves more heat but is not necessarily cost-effective and requires additional materials. Roofs are more susceptible to heat loss than walls because heat moves faster vertically than horizontally (Allen & Thallon, 2011).

Several factors influence heat gain and flow from buildings; The building must have a value of thermal resistance and thermal conductivity appropriate for the building's external environment. A higher thermal resistance value, measured in (m^2.K/W) or (ft^2.h/BTU) in British thermal unit calculation, prevents heat flow and considers the amount of heat flow, the temperature difference, the kind of materials used, and their capacity to transfer heat in addition to the solar heat gain coefficient (Allen & Thallon, 2011).

1.5.6 Thermal Transmission

Thermal conduction, also known as thermal transmission, typically occurs in parallel between the various building layers and is the method by which energy in the form of heat is transmitted from buildings. However, most heat is transmitted primarily through conduction, and the amount of heat transferred through convection and radiation is very small (Saudi Energy Efficiency Center, 2021).

Accordingly, to calculate the heat flow values of buildings, we need to know some values for the materials used, and the terms for building specifications according to the International Energy Conservation Code 2021 can be defined as follows:(International Code Council, 2021)

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

Thermal Resistance (R-Value): The inverse time ratio for thermal flow from one surface to another for a unit area. (m^2.K/W).

$$R(m^2.\frac{K}{W}) = \frac{X}{K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

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 transition from layer to layer at different temperatures equals the time rate of heat flow for the unit area. (W/m2. k) (MOLG et al., 2004)

Where:

$$Uw = \frac{1}{(\mathrm{Rsi+R1+R2+R3+} --\mp\mathrm{Rso}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

U- Value is the thermal transmittance (U-Value= W/m². K)

Rsi is the thermal resistance at the inside surface (air) (m2.K/W).

Rso is the thermal resistance at the outside surface (air) (m2.K/W).

R1, R2, R3 ---- is the thermal resistance for each material respectively which the construction element contain. (m2.K/W).

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

$$U = \frac{(U1*A1)+(U2*A2)+(U3*A3)+----}{A1+A2+A3+--} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

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:

$$Q = U * \Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

Q= Heat Flow from inside to outside (w/m²).

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

Maximum U- Factor shall be determined according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard.

According to ASHRAE, the U-Value must be known for each element separately to calculate the energy values flowing from buildings—walls, ceilings, windows, and doors. The Energy flowing from a building and the amount of Energy required by a building in order to maintain its Temperature in an ideal manner is also known as the hours a building requires for heating or cooling, which are defined under international standards as follows:

Heating Degree – Day (HDD): It is a measurement to calculate the energy demand needed for the building to be comfortable(ASHRAE, 2019), which calculate by all hours having a temperature less than 18 C (Monna et al., 2021).

Cooling Degree-Day (CDD): It is a measurement to calculate the energy demand needed for the building to be comfortable(ASHRAE, 2019), which calculate by all hours having a temperature of more than 25 C (Monna et al., 2021).

1.5.7 Solar Heat Gain Coefficient (Shgc)

Glass windows are an essential component of buildings. Therefore, windows affect the building's heat as the glass absorbs and redirects heat to the interior in three ways: convection, conduction, and radiation(Bhatia, 2019).

The solar heat gain coefficient is defined as the criterion for estimating the solar radiation that passes through the glass, where the characteristics of the Glass and its technical specifications will affect the absorption and transmittance coefficient. The value of SHGC ranges between 0-1; a lower value means less transmission of solar heat and its increased capacity for shading. For example, if the SHGC is equal to (.8) The Glass allows 80% of the sun's rays to pass into the building (Bhatia, 2019).

The heat values gained from Glass depend on three central values: the U-Value coefficient, the SHGC coefficient, and the Visual Light Transmission (VLT coefficient), which is the percentage of light passing through the Glass (ASHRAE, 2019).

The maximum permissible values for each building approved by ASHRAE are determined by the area's geographical location and the system's approved standards (ASHRAE, 2019).

The upper limit of the U-Value and SHGC must be considered when designing and constructing the building to maintain its efficiency. The U-Value of the building is used to determine the acceptable amount of heat that can leak into it through convection, radiation, and conduction, whether gained or lost from the building (Jourdan Green Building Council (GBC), 2018).

SHGC only shows the value of heat gained from sunlight by radiation only. In both cases, U - value, and SHGC must be the lowest possible to achieve the most energy conservation (ASHRAE, 2019).

The SHGC value can be reduced by several traditional methods, including shading from the building horizontally or vertically, and using opaque Glass, and as figure (B-2) in appendix (B) planting trees and plants (Jourdan Green Building Council (GBC), 2018).

To apply thermal insulation in a building, floors, ceilings, and walls must be completely insulated, and the heat transfer values of floor walls and ceilings must not exceed specific values which depend on the geographic area. Several factors should be considered, including (Pacheco, 2015):

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 not to 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 (ASHRAE, 2019).
6. Products made from cellular plastic are durable materials. The produce is not susceptible to rot or insect infestation. In addition to solid panels cellular plastic products are also available in foam form that is 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. Insulation material can be sprayed after electrical and plumbing services are performed as it will expand during curing and fill any gaps(UN CTCN, 2015).
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 (UN CTCN, 2015).

Chapter Two

Methodology

2.1 Introduction

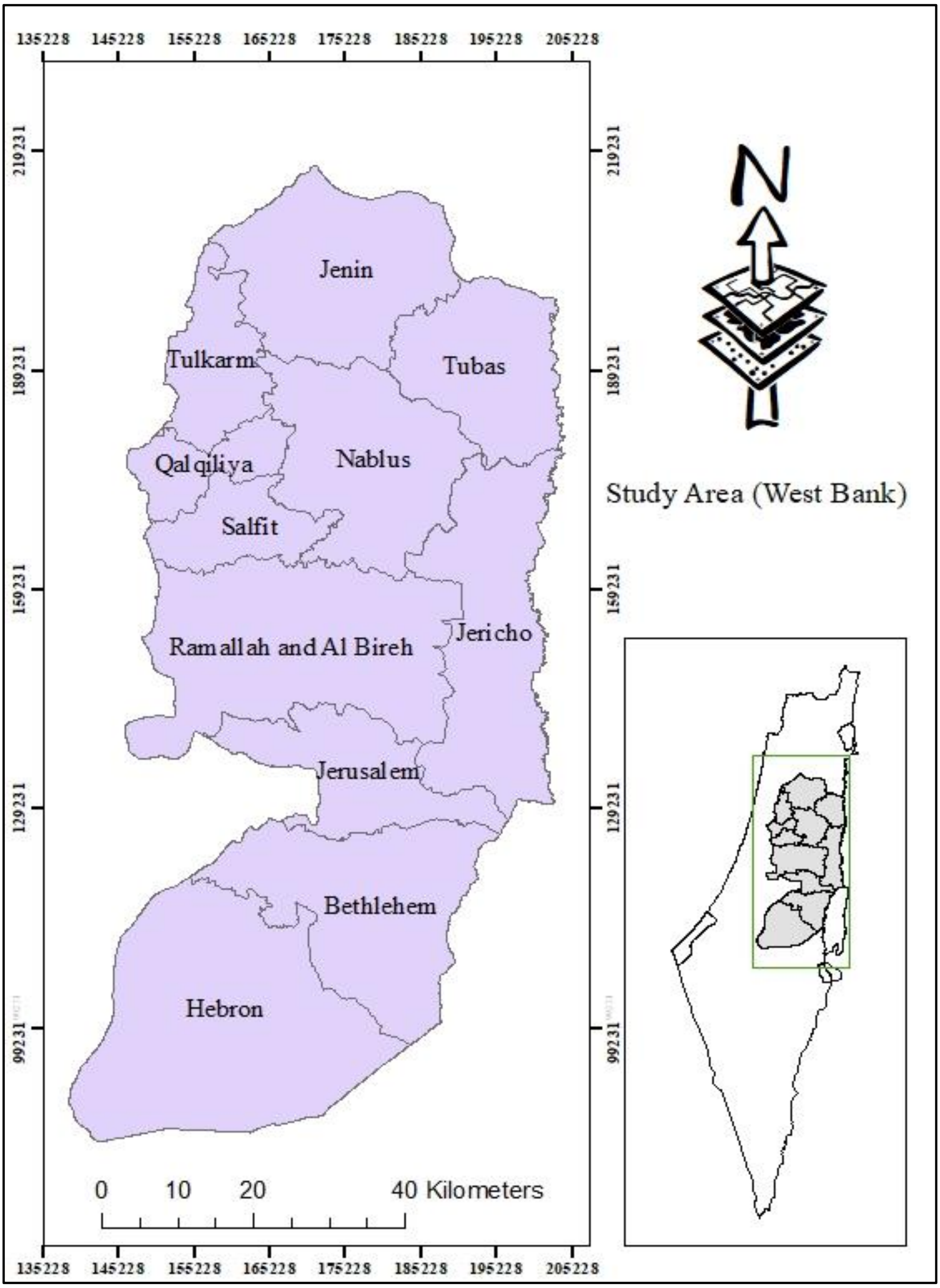
The research methodology is based on analyzing Palestinian residential buildings in the West Bank region by type of construction, areas, and the energy consumption rate for each governorate separately. In addition to making an analysis of the use of electricity throughout the year and the types and quantities of heating in the winter season, analyzing the quantities used for heating and air conditioning from electricity sources and other heating sources from gas or coal, and converting them to the number of emissions issued and comparing them if the buildings are thermally protect, how much emissions will be saved in response to the global agreements signed by the Palestinian side to reduce emissions, the overall methodology is shown in the flow chart in Figure (B-3) in appendix (B).

2.2 Study Area

The West Bank's 11 governorates—Jenin, Tubas, Qalqilya, Tulkarem, Nablus, Salfit, Jericho, Ramallah, Jerusalem, Bethlehem, and Hebron—are the subject of the study. The location of the West Bank and its governorates are shown in Figure (2-1). In addition, the types of buildings in each governorate will be separately examined using data from the Central Statistics Authority up until 2017, in conjunction with annual reports from the Palestinian Engineers Association up until 2021, to determine the size of the new buildings.

Figure 2.1

Study Area



According to the reports issued by the Palestinian Central Statistics, the types of buildings in the West Bank governorates vary between clean stone buildings (which mean that all external cover of the building is stone only), stone and cement, reinforced concrete, cement bricks, clay bricks, and old stone buildings, which are divided as table (No. A-1, No. A-2) in appendix (A) (PCBS, 2017).

The tables presented above illustrate variations in the construction styles of buildings across different governorates. Notably, the prevalence of cleaned stone buildings appears to be more significant in the central and southern regions, while cement block buildings seem to be more common in the northern regions.

The thickness and composition of building walls can significantly impact the rate of heat leakage from a structure. Specifically, when comparing stone and cement block walls with the same thickness, stone walls tend to leak heat at a higher rate than cement block walls composed of two layers. This difference in heat leakage can have a notable effect on a building's energy consumption rate, which, in turn, can contribute to varying emissions rates across different governorates.

2.2.1 Temperatures

The maximum and minimum temperatures of the West Bank governorates vary. According to the information issued by the Meteorological Department, the average temperatures of the governorates throughout the year are as table (A-3) below in appendix (A).

2. Provide values close to reality as possible; percentages of buildings that are (not depicted and others) have been added per percentages of buildings for each governorate separately.

Note: Due to the lack of monitoring stations in all governorates, the temperatures of Tubas were adopted as identical to Jenin and for Qalqilya, such as Tulkarm, Salfit, such as Nablus, Jerusalem, such as Ramallah, Bethlehem, such as Hebron.

Through the average temperature table, we can calculate the hours that need heating (HDD) and cooling (CDD) according to international standards

2.2.2 Precipitation

The percentage of rainfall varies from governorate to governorate with an average of 213 mm to 877 mm as shown in table (A-4) below in appendix (A).

Thus, based on the climatic readings of each governorate in the geographical area of the West Bank and according to the American Heating, Refrigeration and Air Conditioning Engineer (ASHRAE International Code), appropriate thermal insulation will be studied for each governorate to reduce emissions. And the amount of emissions that will be saved as a result of the use of insulating materials, and methods of properly isolating the building, whether retrofitting the existing building or isolating new buildings.

2.3 Defining Criteria

The impact of using thermal insulating materials in the governorates of the West Bank-Palestine, on reducing energy consumption and the amount of carbon dioxide saving as a result of their use in Palestinian buildings, during the comparison of energy consumption in years 2019, 2020, and 2021.

2.3.1 Building Type and Total Area

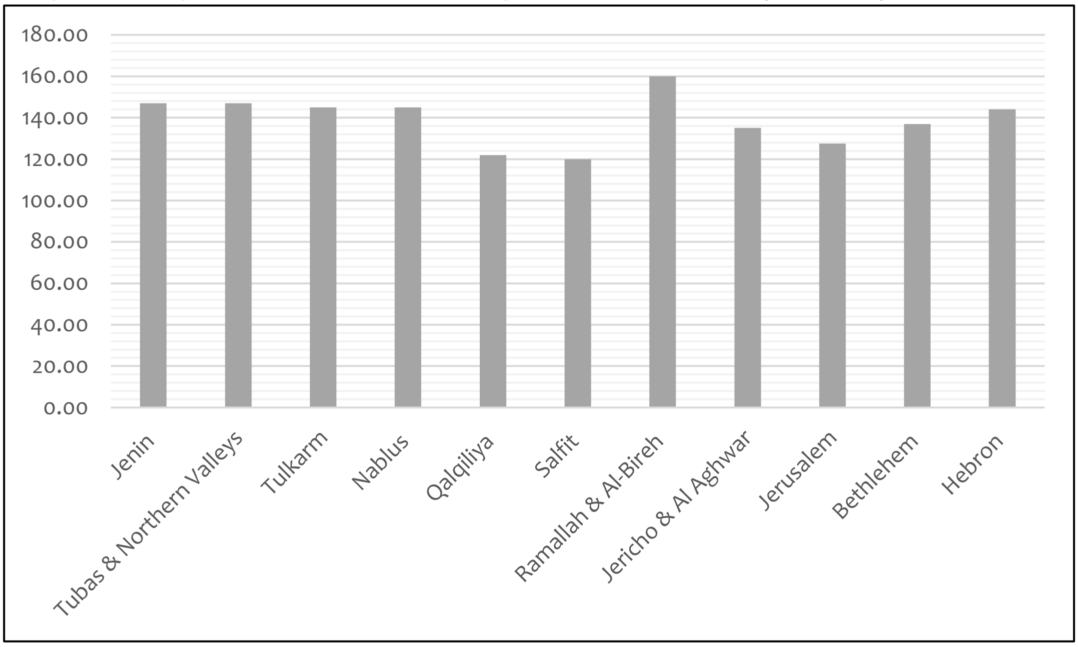
Information about the kind and number of buildings in Palestine was obtained from the PCBs according to the last building report in 2017(PCBS, 2017); every type of building has U- Value different from another.

From 2018 – 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, which didn't have any license, otherwise area rate for buildings different form each governorate, this is according to the annual report of the Palestinian Monetary Authority as shown in figure (2-2) (PALESTINE MONETARY AUTHORITY, 2021).

In this study's estimates, the researcher made the following assumptions about the wall area: 55% walls, 8% doors, and 37% glass.

Figure 2.2 AUTHORITY, 2021)

Average Area in governorate in m² according to Palestine monetary authority

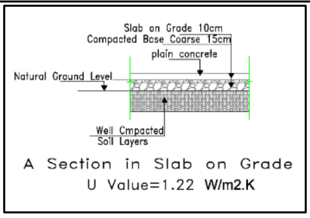
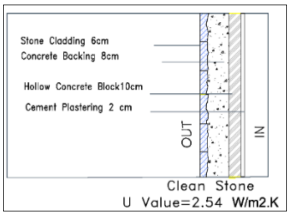
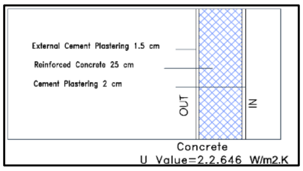
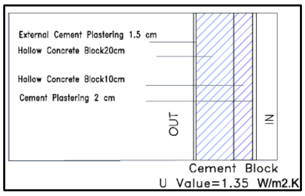
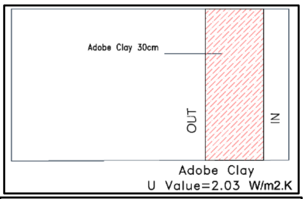
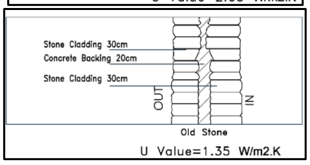
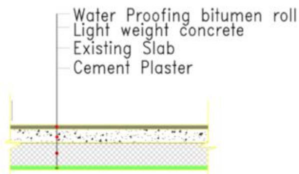
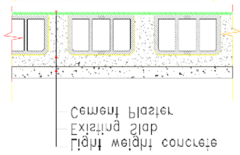


Note: (PALESTINE MONETARY AUTHORITY, 2021)

The type of construction differs in the buildings in the study area, and accordingly the proportions of the buildings were clarified according to the table (2-1) in addition to calculating U- Value for every construction element.

Table 2.1

Specifications and % for building data in the study area

No.	Item	%. Of Building	Section	U- Value (W/m². k)
1.	Slab on Grade	%100		1.22
2.	Clean Stone	34.46%		2.54
3.	Stone and Concrete	8.18%	Assumed 50% area clean stone and 50% concrete	2.59
4.	Concrete	8%		2.64
5.	Cement Block	40.96%		1.35
6.	Adobe Clay	.34%		2.03
7.	Old Stone	8.06%		1.35
8.	Solid Slab	15%		1.1
9.	Rib Slab	85%		1.2

The table no. (2-1-a) below show an example to how calculate the U- Value:

Table 2.1.a

U- Value calculation for clean stone wall

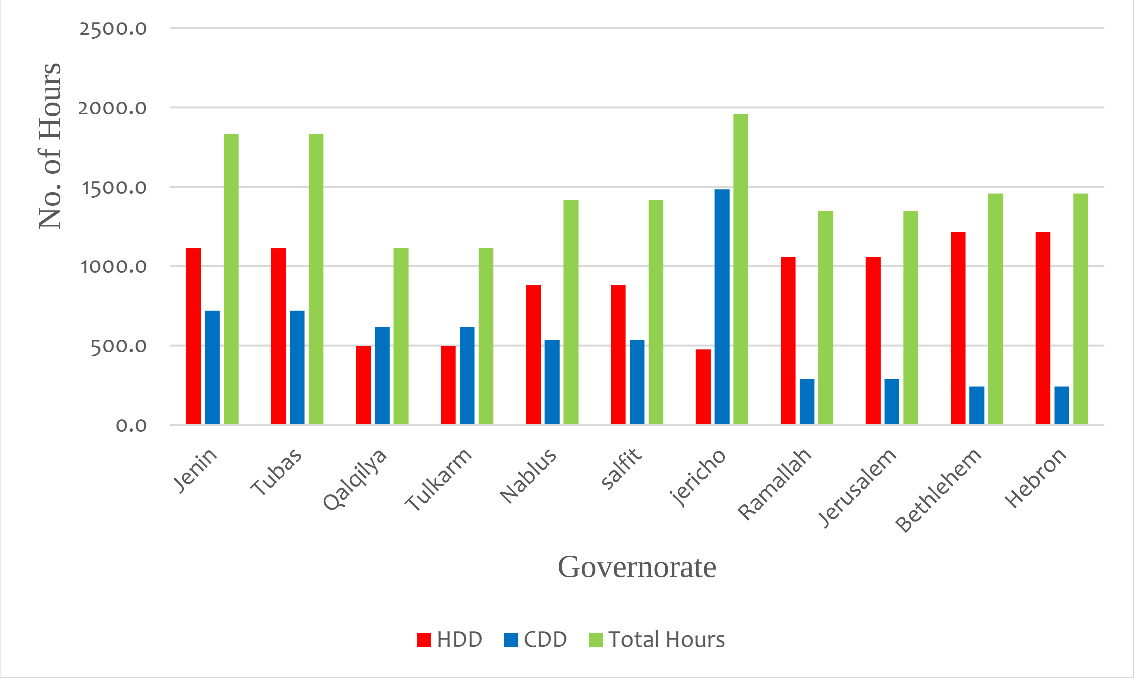
Layer	Thickness	Density	K - Value	R- Value
	cm	(Kg/m3)	K(W/m.k)	(m2.K/W)
External Surface Resistance	0	0	0.00	0.040
Stone	6	2250	2.27	0.026
Cast in Site Concrete	8	825	1.17	0.068
Hollow Concrete Block	10	1280	1.00	0.100
Cement Plastering	2	1500	0.72	0.028
Internal Surface Resistance	0			0.130
	Total R – Value			
	U – Value			2.547

2.3.2 Temperature

Information showing the maximum and minimum temperatures for each governorate separately for every month of the year for years (2019, 2020, and 2021) was collected from Ideal temperature is 25 °C the Palestinian Meteorological Department as shown in figure (2-3). The general average was taken, and accordingly, the number of hours that need HDD and CDD throughout general (ASHRAE, 2019).

Figure 2.3

Number of hours for HDD and CDD for every governorate



The 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

Figure 2-3 show that Nablus, Salfit, Ramallah, Jerusalem, Bethlehem, and Jerusalem in nearly needs the same hours to cooling and heating, which conforming with Palestinian climate zone, also Jenin, tubas, Qalqilya, and Tulkaram nearly needs the same hours to cooling and heating, which also conforming with Palestinian climate zone, and Jericho in different climate zone.

2.3.3 Climate Zone

The Climate Division of Palestine aimed to create and implement codes for constructing energy-efficient buildings in Palestine, which were based on several factors including the average annual precipitation, and temperature of the West Bank. The ultimate goal was to promote building practices that were more adaptive to the local climate and could reduce energy consumption and associated costs.

The requirements of the International Energy Code 2021 (IECC2021) must be calculated in order to determine the criteria of thermal insulation material in the study area. The first requirement relates to the mean participation in each zone, and the second to the total HDD and CDD. The equation about participation is:

$$Pcm < (2.0 * (TC + 7) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where:

P cm: (Annual precipitation in cm).

T= Annual mean temperature in °C

This equation demonstrates that all governorates are in climate zone (A), except Jericho which is in climate zone (B), meet the requirements in table C301.3.

The second requirement is about HDD and CDD, as the following equation:

$$CDD\ 10\ °C \leq 2500\ and\ HDD\ 18°C \leq 3000 \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The criteria in table C301.3(2) show that the study area in the zone (4A) and Jericho in the zone (4B), which mean the thermal transmission and thermal conductivity must meet the criteria in ASHRAE for thermal insulation and energy code in climate zone 4A and 4B(International Code Council, 2021b).

The U-value for climate zone 4A and 4B according to IECC is as following:

U-value for walls: Should not exceed 0.57 W/m²·K.

U-value for ceilings: Should not exceed 0.32 W/m²·K

Palestinian Green Building Guidelines:

U-value for walls: Should not exceed 0.6 W/m²·K.

U-value for ceilings: Should not exceed 0.32 W/m²·K (babaa et al., 2013).

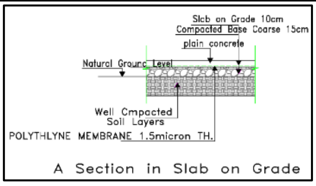
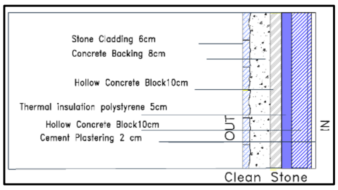
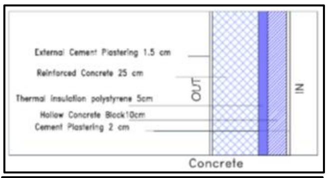
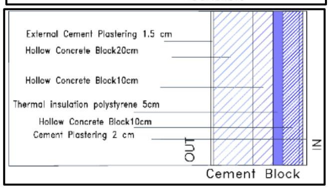
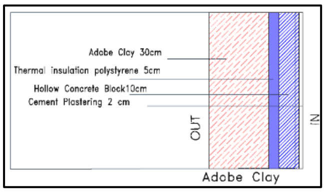
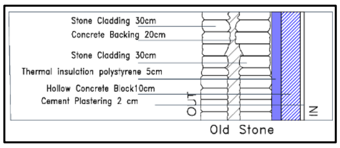
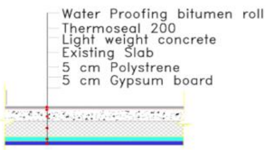
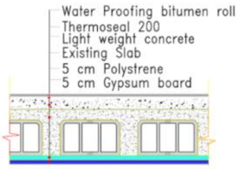
By treating the external walls and ceilings to match these standards, the goal is to ensure that the building elements have sufficient insulation to minimize heat transfer and enhance energy efficiency.

The study conducted a thorough review of relevant standards and diligently followed them while implementing insulation materials in buildings. To accurately assess the energy-saving potential, various insulation methods were employed and their associated savings were calculated. Moreover, external ceilings were enhanced with an insulation layer and tiles, with the specific details provided in table No. (2-2).

The table No. (2-2) shown Specifications and % for retrofitting the building in the study area with insulation material according to IECC 2021.

Table 2.2

Specifications and % for retrofitting the building in the study area with insulation material according to IECC2021

No.	Item	%. Of Building	Section	U- Value (W/m². k)
1.	Slab on Grade	%100		1.17
2.	Clean Stone	34.46%		58.
3.	Stone and Concrete	8.18%	Assumed 50% area clean stone and 50% concrete	55.
4.	Concrete	8%		59.
5.	Cement Block	40.96%		47.
6.	Adobe Clay	.34%		56.
7.	Old Stone	8.06%		52.
8.	Solid Slab	15%		51.
9.	Rib Slab	85%		38.

Note: Thermal insulation specifications K- Value, and R-Value are determined from the datasheet in the local market.

Table no. (2-2-a) show that the U-Value decrease after applying thermal insulation material, which decrease heat leakage from the walls.

Table 2.2.a

U- value calculation for clean stone wall after adding thermal insulation material

Layer	Thickness	Density	K - Value	R- Value
	Cm	(Kg/m3)	K(W/m.k)	(m2.K/W)
External Surface Resistance	0	0	0.00	0.040
Stone	6	2250	2.27	0.026
Cast in Site Concrete	8	825	1.17	0.068
polystyrene	5			1.33
Hollow Concrete Block	10	1280	1.00	0.100
Cement Plastering	2	1500	0.72	0.028
Internal Surface Resistance	0			0.130
Total R – Value				1.723
U – Value				.581

2.3.4 Insulation Material in Palestine

After surveying according to the prices of the Palestinian local market based on one of the main suppliers, the insulation material and their prices founded according table (2-3):

Table 2.3

Insulation material in the local market with price and R- value

No.	Item	Picture	Price $/m²	R-value
1.	Glass wool 5 cm		1.97	1.25
2.	Expanded polystyrene 5cm		4.7	1.33
3.	Expanded polystyrene 3cm		3.11	.8
4.	Expanded polystyrene 2cm		1.89	.53
5.	Thermocoat 3 cm		7.73	.06

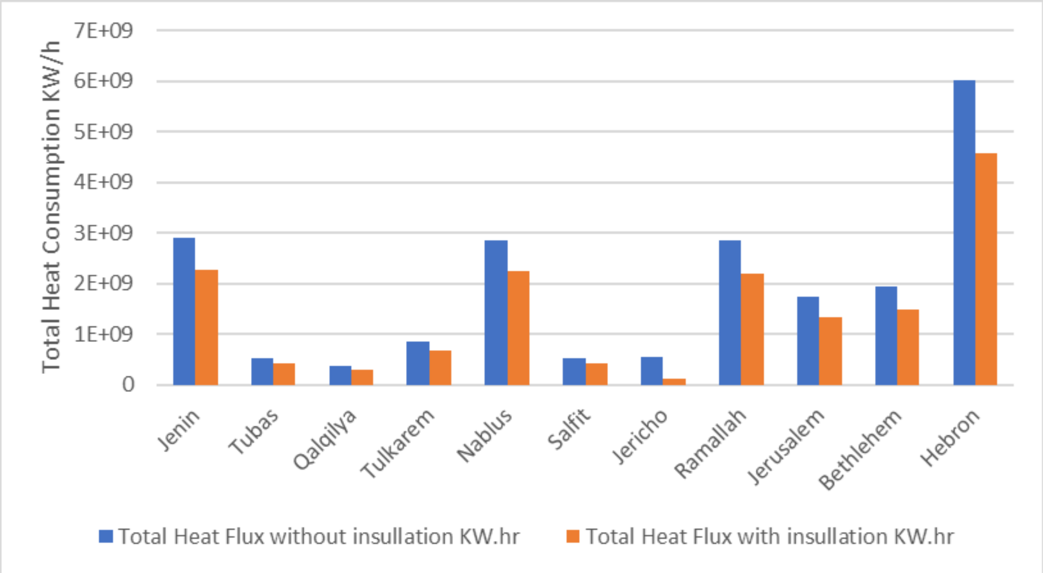
In the research calculation to have the acceptable U- Value for the floor, wall, and roof to retrofit the building, the best choice, according to U- value and price, was to use expanded polystyrene 5cm, which complies with the international standard.

2.3.5 Heat Transfer from Building

The heat flow from the buildings was calculated according to the existing status of the Palestinian buildings in the study area. The heat flow of the buildings as shown in figure (2-4) was calculated in the case of retrofitting buildings by using insulating materials, according to the temperatures in each governorate separately, and finding the difference in heat flow according to the attached table:

Figure 2.4

Total Heat Flux from each governorate building with and without thermal insulation material as average in one year



To arrive at this figure, the researcher relies on the total heat flux without thermal insulation. To calculate this, we multiply the total number of HDD needed in one year by the difference between the ideal temperature of 20.5°C and the minimum winter temperature, and then multiply that result by the U- value, of each construction element. This gives us the total heat flux in winter. Similarly, we calculate the total heat flux in summer using the same method, but with the total number of CDD and the ideal temperature of 25°C for summer.

As Example for heat flux in Ramallah calculated as the following:

Governorate: Ramallah.

HDD: 1057 hr.

CDD: 290.1 hr.

U- Value: 2.54 W/m². k for clean stone wall.

Maximum temperature: 28.7 °C.

Minimum temperature: 6.9 °C.

Total Area for clean stone wall in Ramallah: 9552867.5 m2 (As previously mentioned, the governorate's total number of buildings, number of floors, and average floor area were all taken into consideration).

Total Heat flux for 1m² = U*ΔT

$$= 2.54*(28.7-25) + 2.54*(20.5-6.9) = 43.94 \text{ W/m}^2.$$

For all area (clean stone wall) in one year =

$$\{\{(2.54*(28.7-25)*290.1\} + \{2.54*(20.5-6.9)*1057\}\} *9552867.5=37.484*10^{6} \text{ KW.hr}$$

This calculation repeated for every construction element (floor, wall, roof) for every type of building in each governorate.

To calculate the total heat flux with insulation material, the researcher repeats the same method as before but with one key difference: adjusted the thermal transmission for each construction element based on the insulation material used.

The difference in heat flux between without and with thermal insulation is primarily due to the U-Value of the construction element. For example, a stone wall without insulation material has a U-Value of 2.54 (W/m². K). However, by using thermal insulation, the U-Value decreases to 0.51, resulting in a reduction of about 77% in the heat flux from the stone wall. It's worth noting that the extent of heat flux reduction varies across governorates due to differences in building types, as per data from PCBs.

2.3.6 Cost-Benefit Analysis

The heat flow was adopted according to the temperature difference for each governorate, the number of hours that need heating or air conditioning separately, and the type of walls in the buildings.

The unit price per kilowatt hour is (0.164 $ ~ 0.56 NIS)(PCBs, 2020); insulating materials for walls and their ability to reduce heat flux from the building, including the extent of saving energy cost compared to the price of the insulating materials used and the building's ability to recover the cost of insulating materials during a specific period.

The total heat flux calculated by the total hours need for HDD and CDD for one year by 1 m² for every element and reflect that to price for KW. hu with the price for thermal insulation.

The cost calculation for thermal insulation takes into account both existing buildings and those yet to be constructed, with the additional cost of retrofitting existing buildings. This includes the cost of building blocks, plastering, and painting, as well as the thermal insulation material. To effectively install electrical conductors and ensure the insulation layer remains intact, a block or gypsum is installed after the insulating material. The chosen thermal insulation material is 5cm of expanded polystyrene, which is both efficient and cost-effective. For new buildings, the price solely includes the cost of the insulation material.

2.3.7 Energy Use

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 as shown in figure (B-4) in appendix (B), in addition to the amount of fuel consumption during the previous years of gas, coal and kerosene (PCBs, 2020).

The data reveals that the Jerusalem governorate has a notably high percentage of electricity consumption for heating and air conditioning, followed by the Ramallah governorate. These consumption patterns vary across governorates, dependent on factors such as population size, temperature fluctuations, and the number of hours requiring heating or cooling. Moreover, the presence of commercial activities and official institutions in a region can contribute to an increased demand for private electric energy for heating and air conditioning.

The average consumption for April to October was taken for Wood and charcoal, Liquified Petroleum Gas (LPG), and kerosene. Then the difference between the average for the previous months and the total consumption rate for the months from November to March was taken as shown on table (2-4), and table (2-5) shown the average total consumption from electricity, wood and charcoal, LPG, and kerosene for Heating and cooling

Table 2.4

Average Total Consumption from Wood and charcoal, LPG, and Kerosene

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep.	Oct	Nov	Dec
Wood and charcoal/ Ton	484	511	386	314	370	516	538	479	461	397	427	332
LPG (Ton)	24590	22028	22768	9345	15410	14387	14359	13686	14854	13194	18190	21607
Kerosene (Thousand Liter)	638	428	132	29	16	10	47	54	56	93	341	267

Table 2.5

Average Total Consumption from electricity, Wood and charcoal, LPG, and Kerosene for Heating and cooling

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

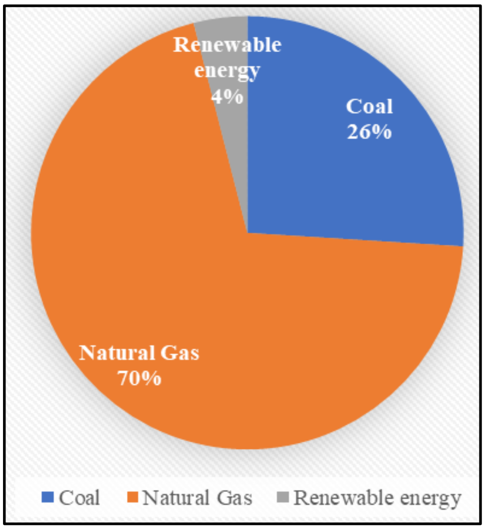
2.3.8 Energy Source

The primary source of electricity in Palestine, in general, and the West Bank in particular, comes from the Israeli side. The Israeli side relies on several sources for energy production, including coal with a percentage of (26%), natural gas with a percentage of (70%) and renewable Energy in general with a percentage of (4%) as shown in figure (2-5) (noting that data were adopted in 2018)JOLIEN, 2021, beside that according to PCBs. the renewable energy in total energy consumption is 10.9% (PCBS, 2020).

Israeli electricity companies have adopted a plan to reduce electricity production from coal and increase the percentage of renewable Energy until 2030 to become (20%), each of which has an amount of carbon dioxide emissions, which affects the climate mainly.

Figure 2.5

Percentage of electricity Source from Israeli company



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, carbon dioxide studies should be carried out according to the table (2-6) and the attached information.

Table 2.6

CO2 Emission from different energy sources

No.	Energy type	CO2 (gCO2/Kw.hr)	g Co2/Ton(EPA, 2022)
1.	Coal	900	
2.	Natural Gas	400	
3.	Renewable Energy	0	
	Energy type	CO2 (gCO2-eq./MJ)	g Co2/Ton(EPA, 2022)
4.	Wood and charcoal/ Ton	145	606680.00
5.	LPG (Ton)	80	334720.00
6.	Kerosene (Thousand Liter)-m3	91	380744.00

To calculate the rate of energy that saved from insulating materials, and according to the current situation in buildings, the method of calculating the energy used for CDD and HDD was adopted in standard conditions, according to the hours of heating and cooling that buildings will need without insulating materials, and the amount of energy savings after applying the use of insulating materials by 100% on buildings In the study area and then converted to the rate and approved for the current situation, to calculate the saving of emission by using thermal insulation.

Chapter Three
Results and Discussion

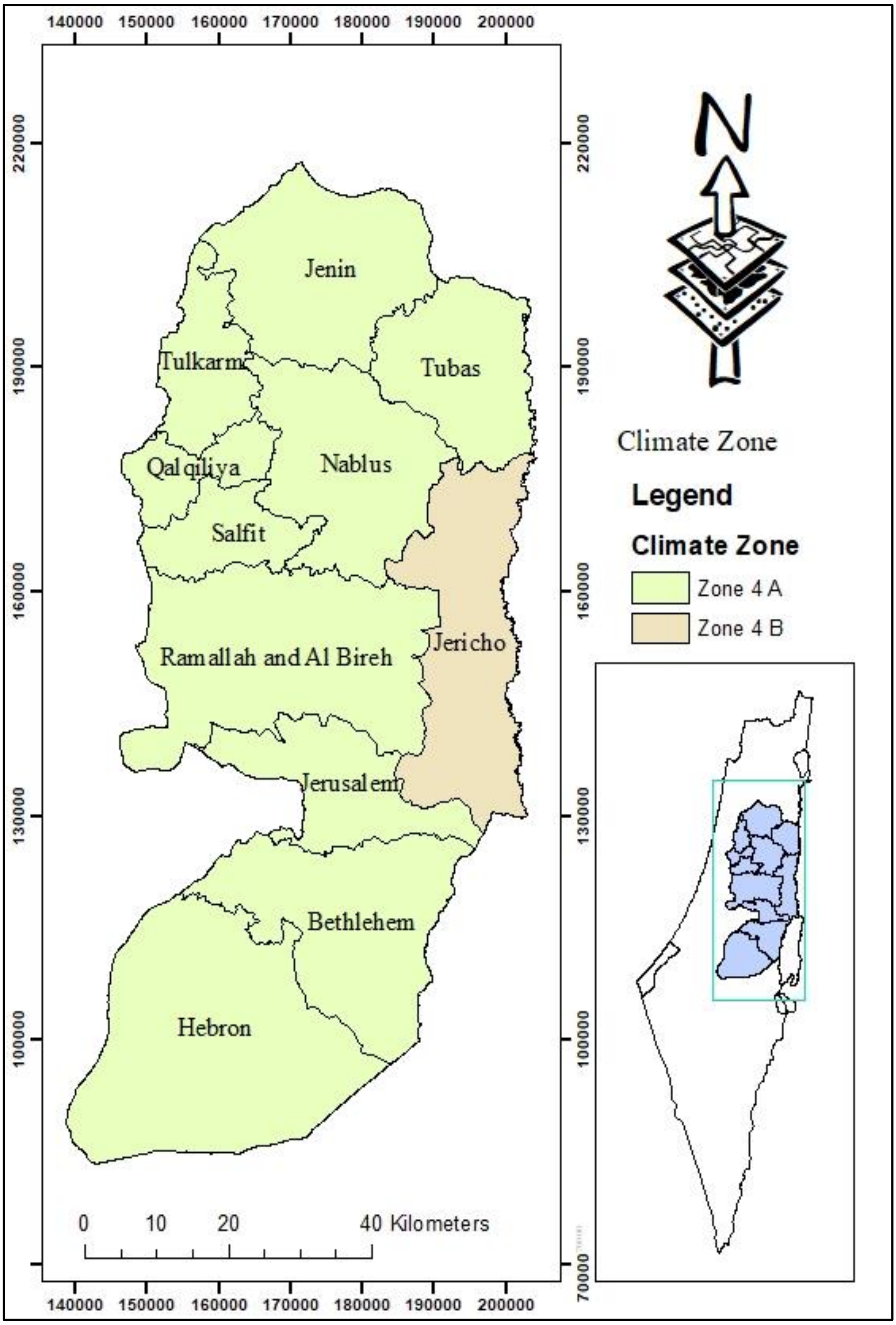
The researcher studied the requirements of installing the insulating materials correctly, whether on retrofitting the building or on new building in construction, which was discussed in Section 1.6.3 of this research.

3.1 Climate Zone

This research also studied the average temperatures for the governorates, the average rainfall for each governorate, and the hours that need heating and air conditioning throughout the year were obtained for each governorate separately, and a review of ASHRAE standards, and Table No. (301.3 (1)) and Table No. (301.3(2)) from the IECC 2021 show in Figure (3-1) all the West Bank governorates are located Within climate zone 4A, except for Jericho, which is located within Area 4B.

Figure 3.1

West Bank Climate Zone According to IECC2021



This mean that the requirement for the insulation material in Jericho different from another governorate, that’s because of high temperature most of the year, and its below sea level.

3.2 CO2 Emission from Study Area

The researcher studied the types of buildings in the West Bank and the energy consumption throughout the year were determined for each governorate separately. The amount of energy used in the buildings for heating and air conditioning was estimated, whether from electricity, firewood, kerosene or gas, and the values were converted into an average amount of carbon dioxide emissions, which shows all in figure No. (3-2) and figure (3-3) The rate of emissions issued by each governorate separately, according to its consumption rate, as the type of buildings and temperatures were taken into account, which affect the average hours that each governorate needs for heating and air conditioning, However, it must be noted that the mechanism for calculating the electric energy used for heating and air conditioning has some approximation, as the increase in electricity consumption in the winter season is due to heating in addition to the use of electric boilers to heat water with solar energy, while in the summer the increase in electricity consumption is due to the use of air conditioners and an increase in the withdrawal of electricity by refrigerators, and it has been approximated Considering the increased consumption of refrigerators in the summer as equivalent to the use of water heating in the winter.

Figure 3.2:

Total CO2 Emission in (Giga gram) from Study Area without using thermal insulation

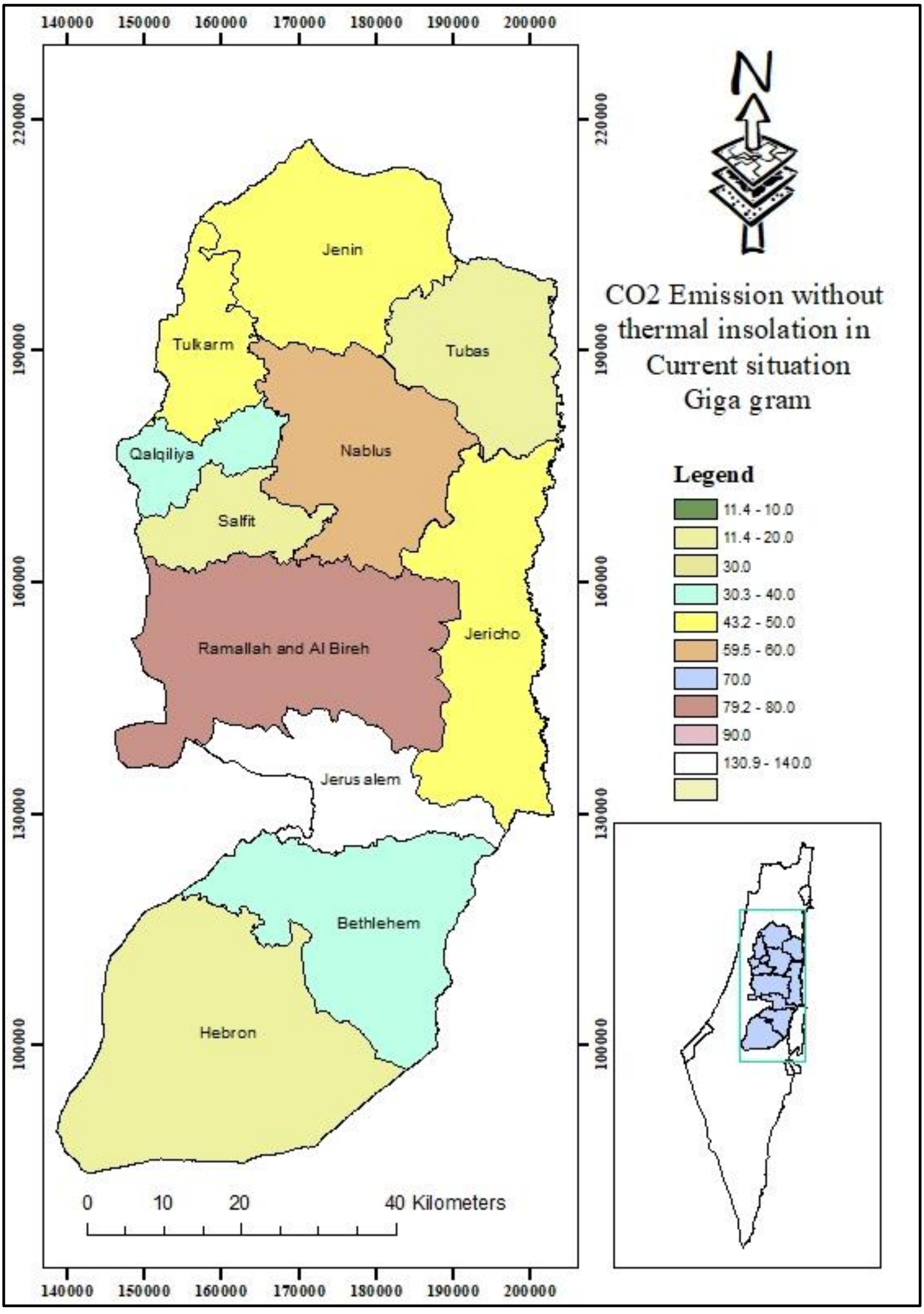


Figure 3.3

Total CO2 Emission in (Giga gram) from Study Area with using thermal insulation

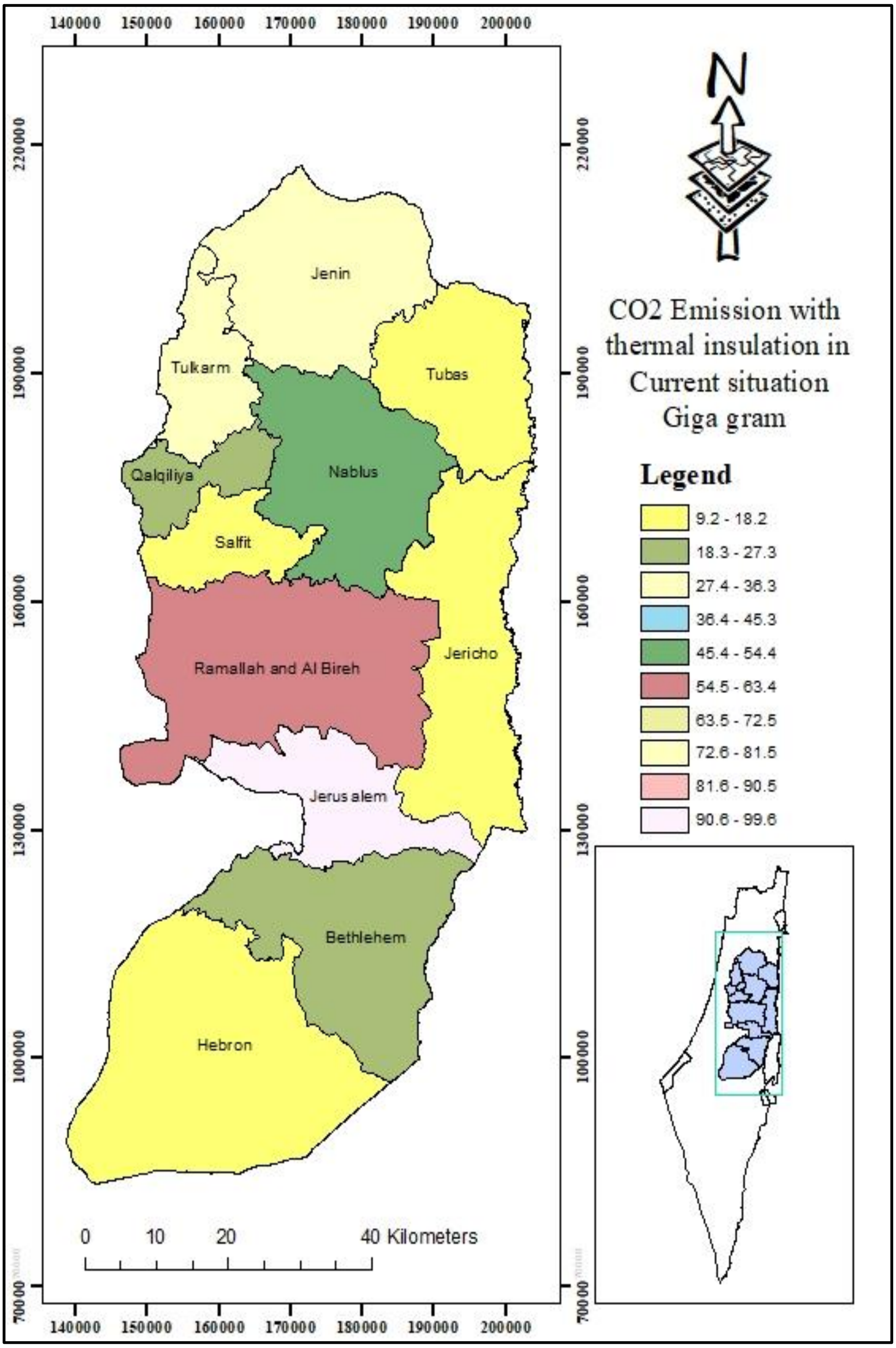


Figure 3.2 and 3.3 highlight variations in the percentage reduction of emissions among different governorates. For instance, Jenin governorate achieved a reduction of approximately 20.91% in its emissions rate, whereas Jericho governorate significantly reduced its emissions by 76.48%. These discrepancies can be attributed to various factors, with the temperature difference being a significant contributor. Additionally, factors such as population size and the number of buildings, which are comparable across governorates, play a role. It is worth noting that Hebron, Bethlehem, and Jerusalem governorates ranked second highest in adopting thermal insulation measures, primarily due to a greater prevalence of clean stone buildings compared to other governorates.

Furthermore, it is noteworthy that the consumption of kerosene, gas, and coal for heating purposes contributes to the higher emissions rates observed among the governorates. This factor plays a significant role in accounting for the discrepancies observed in the results across different regions.

The researcher conducted a study on energy analysis for heating and air conditioning buildings, with and without use of insulating materials on buildings as shown in figure (3-4), (3-5). 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 (3-1) the different between four scenarios which studied.

Table 3.1

Different in CO2 Emissions with thermal insulation and without thermal insulation

Gov.	Current condition		Ideal condition		
	Total Emission Ton CO_2* 10^3 Without using thermal insulation in building	Total Emission with using thermal insulation in building in current condition Ton* 10^3	Ideal condition-Emission without using thermal insulation in building * 10^3	Ideal-Emission with using thermal insulation in building * 10^3	% Emission Saving
Jenin	44.92	35.53	1491.45	1179.64	20.91%
Tubas	11.77	9.44	276.42	221.66	19.81%
Qalqilya	32.45	26.32	192.84	156.43	18.88%
Tulkarem	43.22	34.68	441.58	354.35	19.76%
Nablus	59.59	47.09	1467.55	1159.63	20.98%
Salfit	11.47	9.22	274.84	220.96	19.61%
Jericho	49.88	11.73	290.09	68.24	76.48%
Ramallah	79.21	61.44	1469.31	1139.60	22.44%
Jerusalem	130.91	100.03	900.60	688.17	23.59%
Bethlehem	30.35	23.20	999.41	763.96	23.56%
Hebron	18.41	14.06	3099.13	2365.81	23.66%
Total	512.18	372.74	10903.23	8318.44	
Different in CO2 saving emission in Giga gram	139.44		2,584.79		
% of reduce emission	27.23%		23.71%		

Figure 3.4

Total CO2 Emission in (Giga gram) from Study Area without using thermal insulation with Ideal Condition

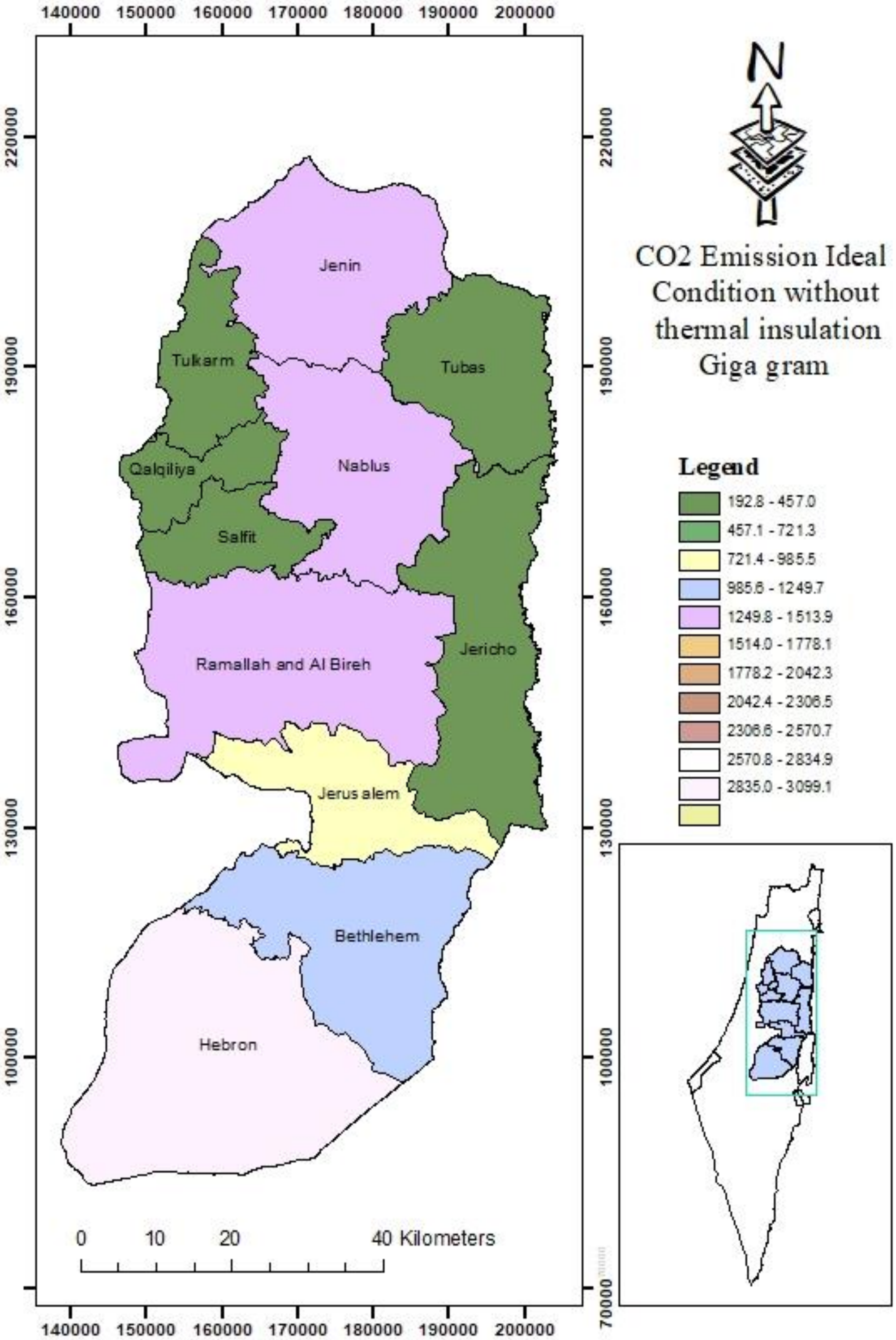
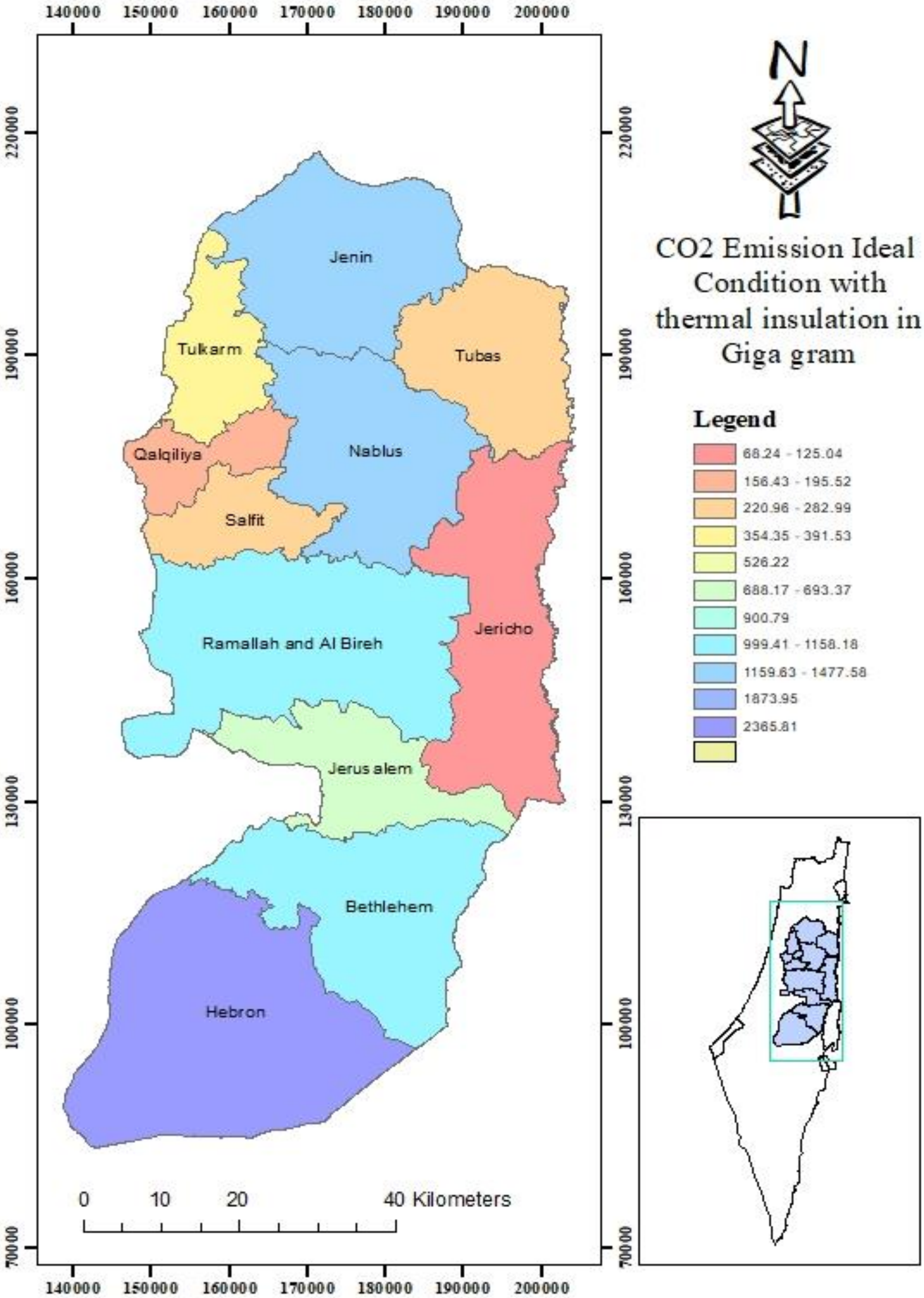


Figure 3.5

Total CO2 Emission in (Giga gram) from Study Area with using thermal insulation with ideal condition



Figures 3.4 and 3.5 provide a comparison between electricity consumption and the resulting emissions rates, highlighting the impact of the absence or presence of

insulating materials in buildings across the governorates. In the absence of proper insulation, buildings require continuous heating and air conditioning, resulting in higher emissions than those calculated based on the current building conditions. Conversely, when buildings are equipped with insulation and maintained at a comfortable temperature throughout, both emissions and electricity consumption are reduced. The percentage of savings in emissions corresponds to the savings achieved in electricity consumption. 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 (M.Haj-Hussain, 2010), differences in population, the number of buildings, and their characteristics contribute to the slight variations in emissions rates observed.

3.3 Percentage of Building Envelope in Study Area

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.

3.4 Cost Benefit Analysis

The insulating materials available in the local market were inspected and compared, and their technical specifications and ability to leak heat were studied, in addition to comparing their cost with the amount of their ability to save energy, according to the attached table as follows:

Table 3.2

Cost Benefit Analysis for retrofitting and new building/m²

Governorate		Wall						Slab		
		Cleaned Stone	Stone and Concrete	Concrete	Cement Block	Adobe Clay	Old Stone	Rib Slab	Solid slab	Floor
		Cost Benefit Analysis – year								
Jenin	Retrofitting Building	2.02	2.02	1.94	1.93	4.55	2.71	4.38	4.67	4.2
	New Building	.54	.54	.52	.52	1.22	.73	.89	.33	.3
Tubas	Retrofitting Building	2.02	2.02	1.94	1.93	4.55	2.71	4.38	4.67	4.2
	New Building	.54	.54	.52	.52	1.22	.73	.89	.33	.3
Qalqilya	Retrofitting Building	3.1	3.1	2.98	2.96	6.97	4.15	6.71	7.16	6.44
	New Building	.83	.83	.8	.79	1.87	1.11	1.37	.51	.46
Tulkarem	Retrofitting Building	3.1	3.1	2.98	2.96	6.97	4.15	6.71	7.16	6.44
	New Building	.83	.83	.8	.79	1.87	1.11	1.37	.51	.46
Nablus	Retrofitting Building	2.87	2.87	2.76	2.74	6.45	3.84	6.21	6.63	5.96
	New Building	.77	.77	.74	.74	1.73	1.03	1.27	.47	.43
Salfit	Retrofitting Building	2.87	2.87	2.76	2.74	6.45	3.84	6.21	6.63	5.96
	New Building	.77	.77	.74	.74	1.73	1.03	1.27	.47	.43
Jericho	Retrofitting Building	1.2	1.2	1.15	1.15	2.7	1.61	2.6	1.87	1.58
	New Building	.322	.32	.31	.31	.72	.43	.53	.13	.11
Ramallah	Retrofitting Building	3.52	3.38	3.36	7.9	4.7	7.61	8.12	7.3	5.96
	New Building	.94	.91	.9	2.12	1.26	1.55	.58	.52	.43
Jerusalem	Retrofitting Building	3.52	3.38	3.36	7.9	4.7	7.61	8.12	7.3	5.96
	New Building	.94	.91	.9	2.12	1.26	1.55	.58	.52	.43
Bethlehem	Retrofitting Building	2.76	2.65	2.63	6.19	3.69	5.96	6.36	5.72	5.96
	New Building	.74	.71	.71	1.66	.99	1.22	.46	.41	.43
Hebron	Retrofitting Building	2.76	2.65	2.63	6.19	3.69	5.96	6.36	5.72	5.96
	New Building	.74	.71	.71	1.66	.99	1.22	.46	.41	.43

Table 3.3

Appendix A 2 Cost Benefit Analysis for retrofitting and new building for one building

Item No.	Governorate	Cleaned Stone	Stone and Concrete	Concrete	Cement Block	Adobe Clay	Old Stone	Cleaned Stone
1	Jenin	Retrofitting Building	2.02	2.02	1.94	1.93	4.55	2.71
		New Building	.54	.54	.52	.52	1.22	.73
2	Tubas	Retrofitting Building	2.02	2.02	1.94	1.93	4.55	2.71
		New Building	.54	.54	.52	.52	1.22	.73
3	Qalqilya	Retrofitting Building	3.1	3.1	2.98	2.96	6.97	4.15
		New Building	.83	.83	.8	.79	1.87	1.11
4	Tulkarem	Retrofitting Building	3.1	3.1	2.98	2.96	6.97	4.15
		New Building	.83	.83	.8	.79	1.87	1.11
5	Nablus	Retrofitting Building	2.87	2.87	2.76	2.74	6.45	3.84
		New Building	.77	.77	.74	.74	1.73	1.03
6	Salfit	Retrofitting Building	2.87	2.87	2.76	2.74	6.45	3.84
		New Building	.77	.77	.74	.74	1.73	1.03
7	Jericho	Retrofitting Building	1.2	1.2	1.15	1.15	2.7	1.61
		New Building	.322	.32	.31	.31	.72	.43
8	Ramallah	Retrofitting Building	3.52	3.38	3.36	7.9	4.7	7.61
		New Building	.94	.91	.9	2.12	1.26	1.55
9	Jerusalem	Retrofitting Building	3.52	3.38	3.36	7.9	4.7	7.61
		New Building	.94	.91	.9	2.12	1.26	1.55
10	Bethlehem	Retrofitting Building	2.76	2.65	2.63	6.19	3.69	5.96
		New Building	.74	.71	.71	1.66	.99	1.22
11	Hebron	Retrofitting Building	2.76	2.65	2.63	6.19	3.69	5.96
		New Building	.74	.71	.71	1.66	.99	1.22

Note: (one Flore with mean area for every governorate according to Palestinian Monetary Authority2021

Table No. (3-2) shows that the insulating materials are greatly saved if they are installed in the new building. As for the existing buildings, they need a period to recover the installation costs. This is due to the construction and electrical costs that the building needs when installing the insulating materials. It is also noted that the cost of recovering insulating materials varies from one governorate to another due to the different hours of CDD and HDD. It is noted that Jericho is considered the most governorate in need of insulating materials to protect energy leakage, save electricity and thus save emissions.

The study shows in table No. (3-3) the percentage of complete cost recovery 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 calculation found that if thermal insulation is used for retrofitting the building, it would take between (7.2-4.34) years to recoup the cost, and between (0.39-1.09) years if thermal insulation materials were used during the construction phase.

Chapter Four
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. The results of the study have unambiguously shown how using insulating materials has a substantial impact on how much energy heating and cooling systems use. Buildings in the study area had a stunning 27.23% increase in efficiency when these materials were used. It is necessary for the Palestinian administration to adopt proactive and coordinated efforts in conformity with international accords given the critical link between cutting energy use and decreasing carbon dioxide emissions. The broad use of insulating materials in all new construction projects must be promoted, and incentives for retrofitting older structures must also be provided. Such initiatives will not only increase energy efficiency but also help the world achieve its sustainable development objectives while lowering emissions.

As a result, the use of insulating materials must be in accordance with both international standards and local regulations, while also taking into account the guidelines established by international organizations like ASHRAE and the materials that are accessible on the local market, once standards are followed and suitable materials are used from the local market, more energy is saved and more efficiency is achieved. lowering carbon emissions, and contributing to a sustainable future, also the findings of this study provide valuable insights for policymakers, industry professionals, and stakeholders involved in building construction and energy management.

The use of insulating materials in the West Bank faces several restrictions that need to be addressed. Firstly, the relatively high cost of insulating materials poses a significant barrier. Additionally, there is a lack of awareness and community culture regarding the importance of utilizing these materials to reduce electrical energy consumption and achieve long-term economic feasibility.

Furthermore, the shortage of technical expertise in the proper installation of insulating materials hampers their effectiveness. It is crucial that regulations and standards explicitly prioritize the installation of insulation materials as a fundamental practice in construction.

To overcome these challenges, this study proposes a set of recommendations. Firstly, efforts should be made to raise awareness among the public about the significance of insulating materials. This can be achieved by emphasizing the cost recovery aspect and showcasing the long-term benefits. Additionally, monitoring and incentivizing the use of insulating materials in new buildings within technical standards is essential.

Moreover, there is a need to encourage investment in insulating materials and ensure their availability in the local market. This can be accomplished by developing high-quality resources at the lowest possible cost. Training courses should also be provided to construction technicians to enhance their skills and capacities in working with insulation materials.

Lastly, it is vital to enforce building laws and standards that explicitly address energy efficiency through the utilization of insulating materials. By implementing these recommendations, the West Bank can overcome the existing restrictions and pave the way for widespread adoption of insulating materials, ultimately leading to improved energy efficiency and sustainable construction practices.

Besides that, there are various complementary strategic approaches to decrease emissions and enhance energy efficiency in buildings in addition to the use of insulating materials. 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.

List of Abbreviation

Abbreviation	Meaning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM C272	Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions
BTU	British Thermal Unit
CDD	Cooling Degree- Day
CFCs	Chlorofluorocarbons
CO2	Carbon Dioxide
GBC	Green Building Council
HDD	Heating Degree-Day
HVAC	Heating, Ventilation and air conditioning
IECC2021	International Energy Code 2021
K- Coefficient	Thermal Conductivity
LPG	Liquid Petroleum Gas
M.T. D	Mean Temperature Day
MTN	Mean Temperature Nighty
PCBs	Palestinian Center Bureau of statices
R- Value	Thermal Resistance
RT- Value	Overall Thermal Resistance
SHGC	Solar Heat Gain Coefficient
U- Factor	Thermal Transmittance
VLT Coefficient	Visual Light Transmission

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Appendices

Appendix A

Tables

Table A. 1

Number of Completed Buildings by Region, Utilization of Building, and Type of Ownership, 2017

Gov.	Cleaned Stone No.	Stone and Concrete No.	Concrete No.	Cement Block No.	Adobe Clay No.	Old Stone No.	Others No.	Not Stated No.
Jenin	9296	4302	6036	34058	379	1746	685	295
Tubas & Northern Valleys	1217	871	253	7694	46	307	359	42
Tulkaram	3892	1530	1631	20998	155	2114	321	16
Nablus	13393	3291	5350	24992	125	5870	688	180
Qalqilya	1605	562	557	13082	60	487	302	61
Salfit	2439	561	414	9898	25	1072	199	49
Ramallah & Al-Bireh	23409	2311	2982	14071	78	5216	835	172
Jericho & Al Aghwar	2113	776	63	6896	229	109	398	97
Jerusalem	13789	1277	1008	2712	18	2203	977	18128
Bethlehem	19768	1668	1714	4017	32	4039	434	75
Hebron	42828	14596	11052	20559	163	8113	1561	169

Table A.2

% of Completed Buildings by Region, Utilization of Building, and Type of Ownership, 2017

Gov.	Cleaned Stone %	Stone and Concrete %	Concrete %	Cement Block %	Adobe Clay %	Old Stone %
Jenin	16.65%	7.71%	10.81%	61.02%	0.68%	3.13%
Tubas & Northern Valleys	11.72%	8.38%	2.44%	74.07%	0.44%	2.96%
Tulkaram	12.84%	5.05%	5.38%	69.25%	0.51%	6.97%
Nablus	25.26%	6.21%	10.09%	47.14%	0.24%	11.07%
Qalqilya	9.81%	3.44%	3.41%	80.00%	0.37%	2.98%
Salfit	16.93%	3.89%	2.87%	68.69%	0.17%	7.44%
Ramallah & Al-Bireh	48.70%	4.81%	6.20%	29.27%	0.16%	10.85%
Jericho & Al Aghwar	20.74%	7.62%	0.62%	67.70%	2.25%	1.07%
Jerusalem	65.64%	6.08%	4.80%	12.91%	0.09%	10.49%
Bethlehem	63.28%	5.34%	5.49%	12.86%	0.10%	12.93%
Hebron	44.01%	15.00%	11.36%	21.13%	0.17%	8.34%

Note: 1. A total of 17,989 buildings have been added to the entire buildings in Jerusalem to match the previous census reports with the number of buildings and areas.

Table A. 3
Average temperatures for each month separately and for each governorate separately, day and night, according to the Palestinian Meteorological Department, (long term average)

No.	Gov.		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Months											
		No. of Days	31	28	31	30	31	30	31	31	30	31	30	31
		Sun Hour (shuruqalshshams, 2021)	10	11	13	13.5	14	14.5	14	13.5	12.5	11.5	10.5	10
		Night Hours	14	13	11	10.5	10	9.5	10	10.5	11.5	12.5	13.5	14
1.	Jenin	M.T. D	16.9	18.1	21.8	25.9	29.9	31.7	33.2	33.9	32.6	29.9	24.5	19.2
		MTN	8.7	9.9	11.8	14.5	18.4	21.4	23.8	24.4	23	19.8	14.4	10.5
2.	Tubas	M.T. D	16.9	18.1	21.8	25.9	29.9	31.7	33.2	33.9	32.6	29.9	24.5	19.2
		MTN	8.7	9.9	11.8	14.5	18.4	21.4	23.8	24.4	23	19.8	14.4	10.5
3.	Qalqilya	M.T. D	18	19.3	21.8	25.3	28.6	30.7	32.5	32.6	31.8	29.4	25.3	20.3
		MTN	9.9	10.6	13.4	15.1	17.9	23	23.7	25	23.7	21	15.7	12.7
4.	Tulkaram	M.T. D	18	19.3	21.8	25.3	28.6	30.7	32.5	32.6	31.8	29.4	25.3	20.3
		MTN	9.9	10.6	13.4	15.1	17.9	23	23.7	25	23.7	21	15.7	12.7
5.	Nablus	M.T. D	14.1	15.7	19.1	23.5	27.8	30	31.7	31.9	30.3	27.2	21.5	16.4
		MTN	7.1	8.2	10.3	13.1	16.7	18.9	20.8	21.3	20	17.4	13.1	9.5
6.	Salfit	M.T. D	14.1	15.7	19.1	23.5	27.8	30	31.7	31.9	30.3	27.2	21.5	16.4
		MTN	7.1	8.2	10.3	13.1	16.7	18.9	20.8	21.3	20	17.4	13.1	9.5
7.	Jericho	M.T. D	20.5	22.4	26.2	30.8	35.4	38.3	40	39.8	37.8	34	27.6	22.4
		MTN	9.9	11.1	13.7	17.1	19.8	24	26.1	26.8	25.1	21.6	16	11.5
8.	Ramallah	M.T. D	11.5	13.2	16.2	20.5	24.2	26.7	28.2	28.7	27.1	24.3	18.8	14.1
		MTN	6.9	7.8	9.6	12.8	15.8	18.2	19.7	20.1	18.8	16.9	13.3	9
9.	Jerusalem	M.T. D	11.5	13.2	16.2	20.5	24.2	26.7	28.2	28.7	27.1	24.3	18.8	14.1
		MTN	6.9	7.8	9.6	12.8	15.8	18.2	19.7	20.1	18.8	16.9	13.3	9
10.	Bethlehem	M.T. D	11.6	13.3	16.5	20.9	25.2	27.5	29.1	29.3	27.8	24.5	18.9	14.1
		MTN	5.4	6.5	8.6	11.7	15.5	17.5	19.3	19.4	17.8	15.5	11.4	7.7
11.	Hebron	M.T. D	11.6	13.3	16.5	20.9	25.2	27.5	29.1	29.3	27.8	24.5	18.9	14.1
		MTN	5.4	6.5	8.6	11.7	15.5	17.5	19.3	19.4	17.8	15.5	11.4	7.7

M.T. D = Mean Temperature Day. M.T.N = Mean Temperature Nighty

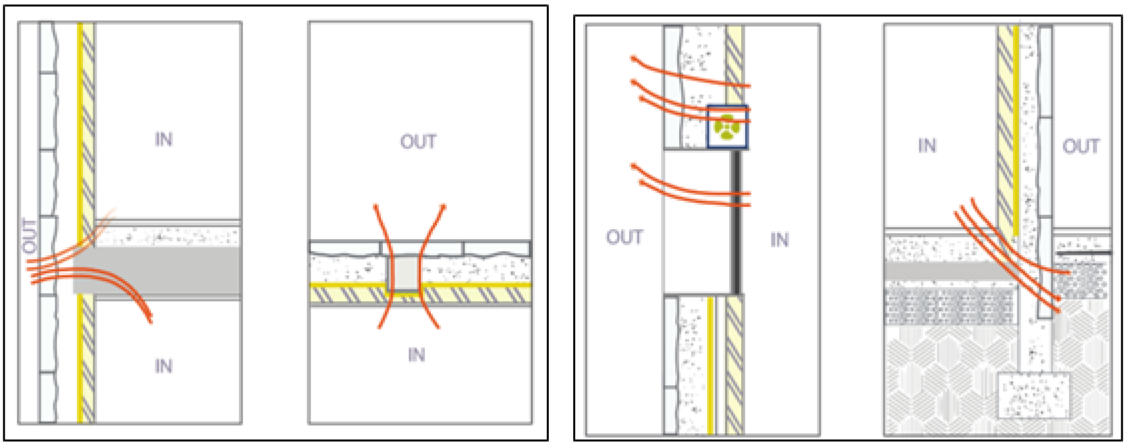
Table A.4
Average rainfall in the Palestinian governorates according to the Palestinian Meteorological Department, (long term average)

No.	Governorate	Participation mm
1	Jenin	468.2
2	Tubas	431.2
3	Qalqilya	624.9
4	Tulkarem	602.4
5	Nablus	660.1
6	Salfit	698.1
7	Jericho	166
8	Ramallah	615.2
9	Jerusalem	537
10	Bethlehem	518.4
11	Hebron	595.9

Appendix B

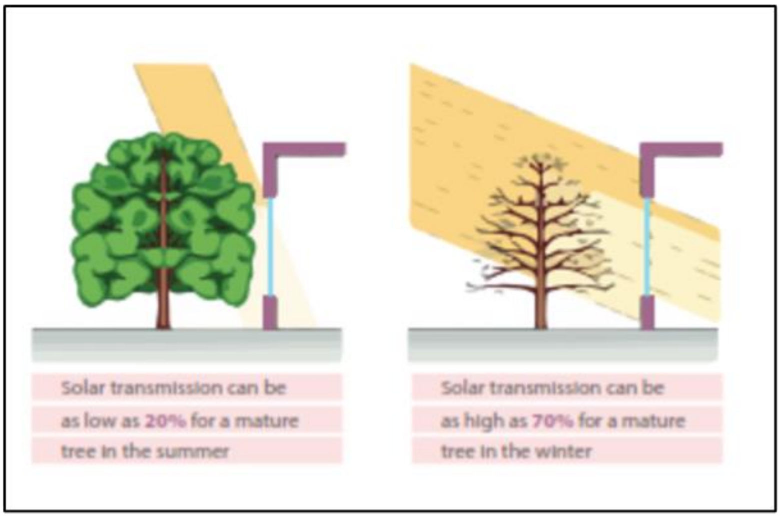
Figures

Figure B.1
Heat transfer from some construction elements



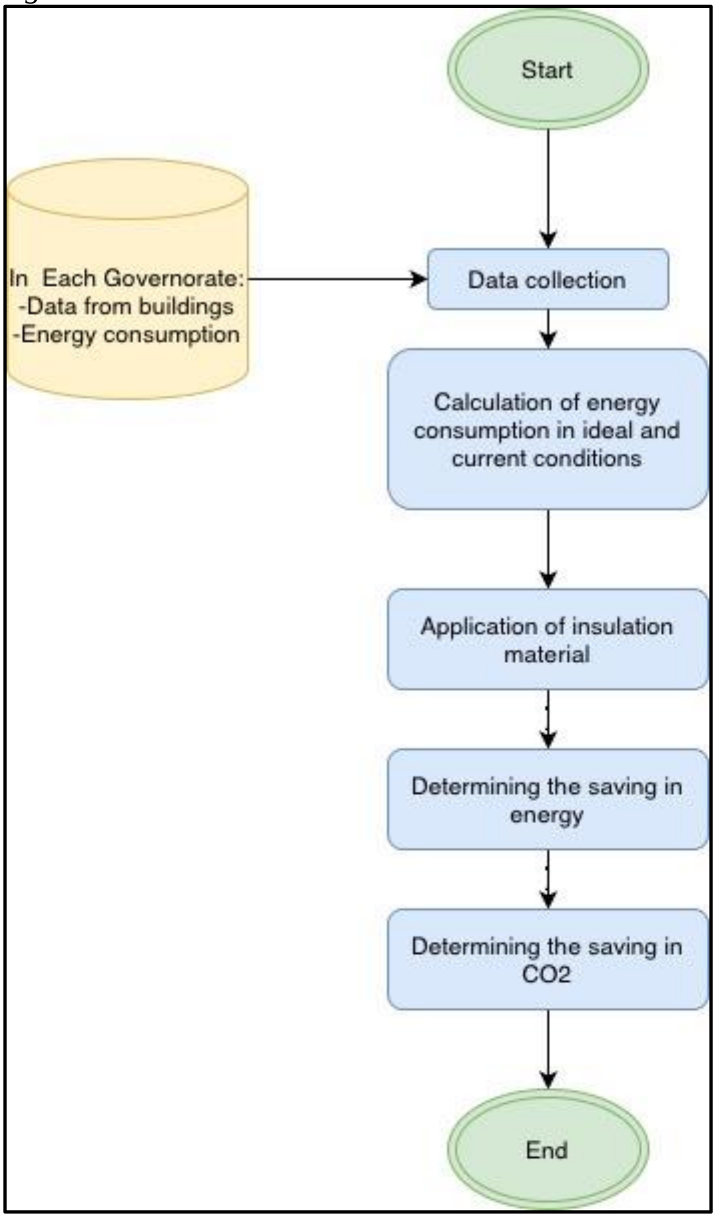
Note: (MOLG et al., 2004).

Figure B. 2
Vegetation shading



Note: (Source: American Institute of Architects (AIA) & Society of Building Science Educators (SBSE 2021)

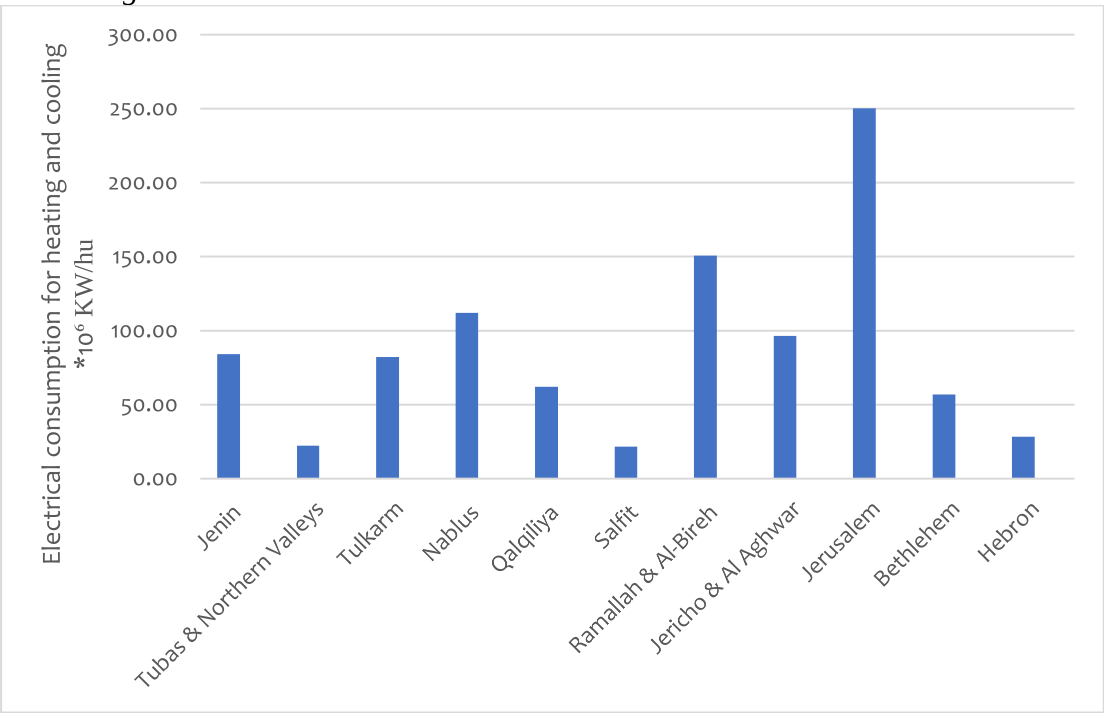
Figure B.3:
Vegetation shading



(Source: American Institute of Architects (AIA) & Society of Building Science Educators (SBSE 2021)

Figure B.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.

جـامعـــة النجاح الوطنية

كليـــة الدراســـات العليـــا

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قدمت هذه الرسالةاستكمالا لمتطلبات الحصول على درجة الماجستير في العلوم البيئية، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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الملخص

يعد تقليل انبعاثات ثاني أكسيد الكربون مصدر قلق كبير على مستوى العالم بسبب ارتباطه بالاحترار العالمي وتغير المناخ، تعتبر المباني مسؤولة تقريبا عن معدل 39٪ من الانبعاثات في جميع أنحاء العالم. لذلك، يعد توفير الكهرباء من خلال استخدام المواد العازلة خطوة أساسية في تقليل استهلاك الكهرباء وتقليل انبعاثات ثاني أكسيد الكربون.

في هذه الدراسة تم إجراء مسح شامل لجميع المباني في محافظات الضفة الغربية في دولة فلسطين، وذلك بالاعتماد على تقرير التعداد الفلسطيني لعام 2017 كقاعدة بيانات، لتحديد عدد ونوع المباني في مختلف محافظات الضفة الغربية. بالإضافة إلى ذلك، تم استخدام التقارير السنوية من نقابة المهندسين الفلسطينيين لحساب عدد المباني للأعوام 2018، 2019، 2020، 2021. أما عن اعتماد المساحات التقريبية لكل محافظة تم استخدام تقرير العقارات السكنية لسلطة النقد الفلسطينية في فلسطين لعام 2021 لتحديد معدل المساحة لكل مبنى وعليه تم احتساب عدد وأنواع المباني ومساحتها. أما عن حساب استهلاك الطاقة الكهربائية لكل محافظة على حدة تم حسابها باستخدام بيانات الشركة الفلسطينية لنقل الكهرباء لنفس سنوات الدراسة. وتم حساب متوسط الطاقة الكهربائية المستخدمة في التدفئة والتكييف، ومن ثم طبقت مواد عازلة مناسبة على المباني لقياس قدرتها على توفير الطاقة ولتقييم الأثر على زيادة أو نقصان انبعاثات ثاني أكسيد الكربون بناءً على مصادر

الكهرباء المستخدمة في فلسطين ، سواء من الغاز الطبيعي، أو الفحم الحجري، أو الطاقة المتجددة. كما تم حساب التكلفة التقريبية للمواد العازلة والمدة المطلوبة لاسترداد التكلفة من خلال التوفير في استهلاك الطاقة الكهربائية باستخدام أسعار المواد العازلة حراريا في السوق المحلي الفلسطيني

تشير النتائج إلى أن استخدام المواد العازلة يمكن أن يقلل بشكل كبير من انبعاثات ثاني أكسيد الكربون ويقلل من استهلاك الكهرباء بنسبة 27.23٪، وتقدر فترة استرداد التكلفة للمباني القائمة بحال تم عزلها وتغليفها ما بين 4.34 إلى 7.2 سنة، أما بالنسبة للمباني الجديدة، فهي تتراوح ما بين 0.39 إلى 1.09 سنة. قد تختلف هذه التقديرات حسب الموقع ومتوسط درجة الحرارة في المحافظات المختلفة.

توصي الدراسة بتشجيع الاستخدام الواسع النطاق للمواد العازلة في جميع مشاريع البناء الجديدة وتقديم حوافز لتعديل الهياكل الموجودة بالفعل. لن تؤدي هذه المبادرات إلى زيادة كفاءة الطاقة فحسب ، بل ستدعم أيضًا الجهود العالمية لتقليل الانبعاثات وتحقيق أهداف التنمية المستدامة.

الكلمات المفتاحية: البصمة الكربونية، انبعاثات ثاني اكسيد الكربون، مواد العزل الحراري، معامل الانتقال الحراري، المقاومة الحرارية، تحليل تكلفة المنفعة.