An-Najah National University
Faculty of Graduate Studies

GEOTHERMAL POTENTIAL FOR ENERGY EFFICIENCY IN BUILDINGS IN PALESTINE

By

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This Thesis was Defended Successfully on 28/5/2023 and approved by

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Dedication

‘’Dedicated to the memory of Palestinian martyrs’’

I literally dedicate this work

Acknowledgements

Praise is to Allah who gave me the ability and patience to complete this success. Peace and blessings be upon His Prophet and his truthful companions.

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Declaration

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

GEOTHERMAL POTENTIAL FOR ENERGY EFFICIENCY IN BUILDINGS IN PALESTINE

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: Aref Rashad Aref AbdulKarim

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Date: 28-5-2023

Table of Contents

List of Tables

List of Figures

List of Appendices

GEOTHERMAL POTENTIAL FOR ENERGY EFFICIENCY IN BUILDINGS IN PALESTINE

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Abstract

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Almost 40% of energy consumption worldwide is associated with buildings. Thus, the construction sectors are essential to achieving energy and environmental targets for decarbonization by 2050. However, the majority of buildings in Palestine are built with low energy efficiency standards which results in buildings with high energy consumption. In recent years, a lot of studies and applications on energy-saving renovation of existing buildings have been carried out to properly address the above problems in various countries.

Geothermal energy, as one of the most popular renewable energy technologies, has been used and explored to build heating and/or cooling transitions and carbon neutrality put it into practical application. Geothermal energy means geothermal resources less than 200 meters deep, also is defined as surface geothermal energy. This energy is not geographically restricted, and this energy is available continuously and reliably almost everywhere in the world where its temperature ranges from 5 - 30 (c˚) . It is worth mentioning that, this renewable energy resource in Palestine has not been extensively explored with few studies on its feasibility. However, this technology is different from common energy-saving technologies (for example, photovoltaic solar panels), solar panels and wind energy can produce electricity only at day time and when there is wind, also approval and contract is required from the authorities to install it, and the area to install these systems is not always available. But, in Geothermal energy case, it's available all year long and utilizing this renewable energy source require no contracts or approvals from authorities. Moreover, it's available every were on earth and it require less space and less maintenance. All these advantages over other renewable system makes Geothermal energy one of the most promising renewable energies.

In this research, two types of applications of geothermal energy were studied; “Ground Heat Assisted Heat Pump Technology (GAHP) and “Earth Tube Technology (ET)” for various climatic regions in Palestine, which are hot dry summer and warm winter in Jericho city, hot and dry summer and cold winter in South-Hebron, hot-humidity summer and moderate winter in Gaza and Tul-Karim, finally moderate summer and cold winter in Jerusalem city, the capital of Palestine. It was found that energy consumption for heating and cooling can be decreased by (42% in heating to 58.8% in cooling) when implementing GAHP system, and when applying ET system this reduction ranges between 33.7% to 50.1% in heating, and 26% to 35.7% in cooling%). This proves that the use of this permanent and clean energy is feasible in Palestine, and can effectively reduce energy consumption, provide better comfort and reduce the environmental impact of buildings for heating and cooling.

Keywords: Geothermal Energy; Renewable Energy; Heat Pump; Earth Tubes.

Chapter One
Geothermal Energy

1.1 Introduction

Geothermal energy can be viewed as the Earth's natural heat source. The Earth's core is thought to have a temperature of about 5,500 ^{o}C. This temperature is the result of both the planet's initial creation and the radioactive elements decaying in the crust of the Earth. By conduction and convection processes, it goes up to the subsurface. Geothermal gradient is the term used to describe increasing in temperature with depth. This energy is used by people for a variety of things. For ages, human beings have been using geothermal springs for heating and bathing. However, only in the early 20th century people started to get intrigued by the heat emanating from inside the Earth as a helpful source of energy with enormous potential. Geothermal energy is presently employed for a variety of purposes including power generation, heating and cooling of buildings; in addition to industrial processes such as drying of grain and lumber, production of paper and pulp, cultivation of fruit and vegetables, as well as warming of soil. Geothermal energy has proved to be a dependable and safe source of energy. Given its high availability and load factors without being dependant on external sources, Geothermal energy ranked among the most significant resources for a future with sustainable energy. There are still plenty of prospects for expansion and development in both the direct use of geothermal energy and the generation of electricity, as only a small portion of the global geothermal potential has been used thus far. So far/ Till the moment, the huge potential of the world's geothermal has been utilised/employed to minimum, which creates considerable opportunities for growth/progress and development both in electricity/ power generation and Geothermal energy direct use [1-4].

1.2 Geothermal Energy Utilization and Resource Temperature

As American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defines, the GAHP application is one of four types of geothermal energy resources.

These types are:

(1) High-temperature uses $T_{\text{resource}} > 150℃$ electric power production. The top 10 geothermal countries in year-end 2021 which installed electricity generation are; United states with installed capacity of 3722 MW, Indonesia with 2276 MW, Philippines with 1918 MW, Turkey with 1710 MW, New Zealand with 1037 MW, Mexico 963 MW, Italy 944 MW, Kenya with 861 MW, Iceland 754 MW, and finally Japan with 603 MW [5].If we back to history, the Larderello-1, which was constructed in 1913 and used a 250kW backpressure steam turbine made by Franco Tosi as part of an indirect-cycle pure-steam system, was the world's first commercial geothermal power factory. All the chemical plants of the Boraciferous region were fed by the electricity from the factory, while the surrounding settlements of Pomarance and Volterra received geothermal power through the first electrical line. The first geothermal plant in the USA went into service in 1922 and had a 250-kilowatt capacity. It had to be shut down given its low output and due to series of technical glitches. In 1923, a 23kW turbine was used to test direct-cycle geothermal technology in Serazzano, a town close to Larderello. The geothermal steam source of extremely high chemical quality made it possible for the unit to operate without interruptions for about two years. In 1932, in order to feed a nearby resort with electricity, a 35 kW experimental plant was established in the Geysers, California, USA [6].

(2) Medium-temperature uses $90 ℃ < T_{\text{resource}} < 150 ℃$ direct-use applications.
Some examples of direct-use applications are road ice melting, hot water use in building,
grow plants in greenhouses, dehydrate onions and garlic, heat water for fish farming, pasteurize milk, and for many other applications.

(3) Low temperature uses: $30 ℃ < T_{\text{resource}} < 90 ℃$Utilising this low temperature in aquaculture (heating primarily fishponds and raceways), space heating and cooling (including district heating), heating swimming pools and baths for therapeutic purposes, agriculture (mostly greenhouse heating, crop drying, and some animal husbandry), and supplying heat for industrial processes are the main forms of direct use. In some cities pipes with the hot water are used under roads and pavements for pedestrians to melt snow [7].

(4) These are low geothermal fluid temperature applications.

(5) GAHP indirect applications generally $T_{\text{resource}} < 30\ ^\circ\text{C}$.

Heat pumps indirect use (also known as geoexchange systems or ground source heat pumps).

Given their ability to function at relatively low temperatures, GAHP applications stand out from other technologies. A heat pump system that employs the soil, ground water, or surface water as a source of heat and/or sink is now universally referred to as a "ground source heat pump." [8].

1.3 Geothermal Heating and Cooling

In many places, heating and cooling are essential, and rising energy needs and pollution emissions have made it possible to explore non-traditional heating-cooling technologies like geothermal [9]. With the rise of green building, ET and GAHP systems are gaining popularity. Nevertheless, a lack of awareness and the perception of hazards related to a novel system limit their acceptability. These systems do not harm the environment because they use the natural energy of the earth and do not change chemical substances. In the long run, GAHP systems can be economically visible if the number of operating hours in electricity for Heating, Ventilation, and Air Conditioning (HVAC) system was long and the climate is extremely hot in summer or extremely cold in winter. While for ET it's not necessarily to have long operating hour because the initial cost of installing this system is relatively low. GAHP increases the heat pump's coefficient of performance, which results in more effective cooling and heating.

In contrast to furnaces, which produce heat by turning chemical energy into heat, geothermal heating and cooling systems operate by transferring heat. In general, there are three essential components that make up these systems: an earth loop to transfer heat from the fluid to the soil; a geothermal heat pump, which is used to transmit heat from the building to the liquid in the loop; and a distribution subsystem to supply heating or cooling to the building. A desuperheater or a full-demand water heater, which can provide all of the building's hot water demands, may also be included in each system. [10].

In a geothermal heating and cooling system, the distribution system, most frequently air ducts, links the heat pump to the building. In addition, a "loop heat exchanger"— which is a path of pipes—connects the heat pump to the ground. The heat is interchanged between the system and the earth, hence, there is no need in an obtrusive outdoor unit.

1.4 Benefits of Using Geothermal Energy in Heating and Cooling

There are many benefits in using geothermal energy compare to other renewable systems.

1. Reliability: Unlike wind or solar energy, geothermal energy is a reliable and consistent source for renewable energy 24 hours a day, and you can find it at any place on the planet.
2. Area is not a problem: GAHP did not required a big area to install like Photovoltaic case, both option vertical or horizontal install of the underground heat exchange pipe is available.
3. Low maintenance cost: solar panels need to be cleaned every month at least twice, inverters and other components may need to be replaced after a few years of use, also wind turbine break paddle part need to be change from time to time. But GAHP do not need a lot of maintenance while operating.
4. Required no approval from authorities: In order to install photovoltaic system or wind turbine, you need to get approval from authorities first, and it is not always guaranteed. While installing GAHP required not approval, you can install it immediately.

Chapter Two
Energy Consumption in Buildings

2.1 Introduction

Over the past ten years, due to the rise in population number, extra time spent inside the buildings, growing demand for quality of building features and indoor environment, as well as global climate change consumption of energy in buildings has increased considerably. A revived interest in environmentally friendly cooling, and heating systems is a result of accelerating understanding of the negative effects of Carbon Dioxide (CO_2), Nitrogen Oxides (NOx) and Chlorofluorocarbons (CFCs) emissions on the environment. In regards to 1997 Montreal Protocol, governments came to a consent to ban using chemicals like refrigerants that potentially can impair the ozone layer. Consequently, it was deemed desirable to limit the use of energy and thus to abate the rate of depletion of global energy deposits and the environment contamination, at present times, the United State and European Union consume more than 40% of their total primary energy for building energy use. However, if buildings are designed, built and operated in a right way, much of energy savings can be attained [11]. Great portion of this energy is consumed for cooling, air conditioning, heating, and lighting. If we compare the percentage of each civil electrical use, power for lighting constitutes 15% to 25% [12], making it a significant factor. Consequently, energy-saving lighting is crucial for energy conservation. The main active methods to change the internal thermal conditions of a building are space heating and cooling using mechanical systems, but this is achieved by using a lot of energy. For instance, the space heating and cooling in residential structures constitute 58% and 41% of power used by urban and rural households in China; 48% of electricity used by homes in the United State; 70% of energy used by households in the United Kingdom and 65% of energy used by households in the European Union. Space heating and cooling in non-residential buildings amounts for 34% of commercial building power use in the United States, 50% to 60% of public building energy use in China, and 45% of non-domestic premises energy use throughout England and Wales. Therefore, if customized building retrofit measures are performed, the high energy demand for space heating and cooling implies potential of huge building power saving and carbon emission reduction [13].

2.2 Ways of Declining Buildings Energy Consumption in HVAC Systems

Designing buildings passively or actively are two key ways to lower their energy use for HVAC systems and to save money. Heating and cooling loads can be reduced, and mechanical systems can be significantly scaled back by putting a strong emphasis on building form and a high-performance envelope. This can help to outweigh the extra expenses of installing premium (high efficiency) equipment throughout the building as well as the increased expense of a high-performance envelope. When compared to standard practice, these measures alone can normally save 35–50% of the energy needed for a new commercial building, while the use of more sophisticated or non-traditional methods has resulted as a rule in savings of about 50–80% [14]. The principal methods for utilizing passive and active design will be briefly discussed in the section that follows.

2.3 Energy Sector in Palestine

"The energy sector, specifically electricity in the State of Palestine, is in a unique situation. This is essentially due to its vital role in driving sustainable development at economic and social levels, but it is also profoundly linked to political considerations, in which energy security is considered to be a critical issue for Palestinians across the State of Palestine. Palestinians are heavily dependent on imported electricity from the Israeli networks: 87 percent of electricity consumed is secured from Israel and around 4 percent from Egypt and Jordan. The remaining 9 percent is produced locally in Gaza and used to fuel the region's power plant on a continuous basis. Electricity debts to Israel's Electric Corporation constitute a major challenge. In Gaza, the deficit in power supply imposes a huge constraint on its residents" [15].

"Palestine is a net importer of oil and petroleum products. Total energy consumption in the Palestinian Territories is considered the lowest in the region, while its costs are relatively high compared to its neighbours. The largest portion of the different types of imported fossil fuels consumed in the Palestinian Territories originates from Israel, while the remainder comes from Jordan and Egypt. The energy provided by the three sources, however, does not meet the power needs of the Palestinian Territories. According to Palestinian officials, current demand for electricity in the West Bank and Gaza Strip is 1,200 MW. Demand is grown in 2020 by 2,000 MW. According to the what so called ''Israel Electrical Corporation'', Israel 'occupation state installed generating capacity is

13,248 MW. This is nearly 100 times current indigenous Palestinian generating capacity. In its country note on Palestine, The United State Energy Information Centre said that: “in 2010, the Palestinian Territories generated only 445 million kilowatt hours of electricity, enough to meet just 10% of demand.” Electricity imports, mainly from Israel, accounted for the remaining 90% of demand. The electricity distribution system in the West Bank thus requires substantial investment to cope with expanding demand. In 2007, the World Bank estimated losses during distribution to be around 25%. An equivalent figure for Jordan was half this, and for Israel it was around 3%” [16].

2.3.1 Building Sector in Palestine

“Building sector in Palestine is responsible for approximately 40% of the energy consumption, 36% of CO2 emissions, 33% water consumption, and 30% of waste generation. In addition, the building construction industry consumes a significant number of resources: 25% of wood and steel products and 70% of cement. There is a concern of the application of sustainability in public buildings, which provide services to the community such as education, health, sport, culture, and administration. They also host the administrative and technical staff of the public sector. Public buildings also significantly impact the environment, primarily through energy and water consumption. Moreover, this sector requires high investments to meet the sustainability challenges” [17].

2.3.2 The Importance of Insulation in Building

Most of the buildings in Palestine are not insulated or have a low insulation quality, walls and ceilings are made of concrete and stone which have a high thermal conductivity index (12 British Thermal Unit (BTU)/ hour (hr). Square Feet (ft²). Fahrenheit (Fº)) which is a very high value if compared with the material are used in Europe and United State like would for example which have a very low thermal conductivity index (1.1 BTU/hr.ft².Fº). The high value of thermal conductivity index in Buildings in Palestine, will make it uncomfortable to live in, it’s very cold in winter and very hot in summer. Due to the hight thermal mass storage capacity for the heavy concrete materials, this makes it reserve the heat in summer and the cold in winter for log time period, which make us feel that the climate outside our homes is much better than inside it and this makes people feel that the want to spend their time outside their homes in summer and they suffer from the coldness inside home in winter. In addition to the lack of a suitable climate for human comfort in these buildings, the cost of heating and air conditioning for these buildings is very high and exceeds the ability of most of the local community, which is considered mostly of low-income people. At the same time, the energy required for heating and air conditioning, such as fuel and electricity, is considered to be very expensive. Therefore, it very important to use insulation material with high quality in walls and ceilings such as mineral wool and polyurethane boards, and the insulation should be carried out with qualified technicians to assure a proper installation. This will lead to save a big amount of energy and create a comfort environment in our building and homes. Also prevent infiltration by using sealed material for windows and doors will help as well in saving energy. The simulation result this master thesis will proof how efficient is the insulation compare with uninsulated building.

2.4 Earth Tubes

An earth tube is a long, subterranean metal or plastic conduit through which air is brought and is used for natural ventilation in summer and winter. While entering and moving through the pipe, air transfers or absorbs part of its heat to/from the outlying soil and comes into the room. [18]. More details about how earth tubes help efficiently in reducing heating and cooling load will be discussed in the next sections.

2.5 Reducing the Heating and Cooling Load.

In addition to selecting high efficiency HVAC system, using of smart building can lead to a good saving in consuming the power. Utilizing solar energy in houses, however, can, as well, make a remarkable contribution to decreasing reliance on fossil fuels. Hence, encouraging cutting-edge renewable applications and supporting the market for ground source energy will help to preserve the ecosystem by lowering emissions both locally and globally. By substituting renewable energies, free of greenhouse gases and air pollutants, for conventional ones, this will also help to improve the environment. Renewable energy integration requires a strategy to achieve high building performance. Nonetheless, due to the fact that renewable energy sources are stochastic and geographically outspread, their capacity to address the need is determined by choosing between the two strategies listed below: either using a capture area larger than that occupied by the community to be supplied, or lowering the community's energy needs to a level compatible with the region's renewable energy resources.

GAHP structures, also known as geothermal heat pump, earth energy, and Geo Exchange systems, have drawn a lot of interest recently as a substitute energy source for applications involving the heating and cooling of homes and businesses. By raising the heat pump's coefficient of performance (COP), GAHP decreases use of heating and cooling. More details about how GAHP helps efficiently in reducing heating and cooling load will be discussed in the next sections.

In this thesis, earth tubes system as a passive method and geothermal assisted heat pump system as an active method would be discussed and simulating work will be done using DesignBuilder software.

2.6 Geothermal Applications in Buildings

Earth tubes are subterranean pipelines that are used to bring cooler air into a home. The warm or hot outdoor air, when going through these pipes, is cooled due to the low stable temperature under the surface of the earth. A network of pipes known as earth tubes or ground loop heat exchangers is used to transmit liquid between the heat pump unit and the soil.

2.6.1 Geothermal Loops Define

There are three key designs of the ground loop system: closed loop, open loop, in addition to combination system. In open loop system, the air from outside is pull from a filter to cool or warm the air. The length of the earth tubes around 30 m in to the house. When added, energy recovery ventilation systems can increase the loop's efficiency to 80–95% as close loop, while also ensuring that incoming fresh air is filtered and tempered. In a closed loop system, air from inside the home is forced through a U-shaped earth loop made of 30 to 150 meters of tubes, where its temperature is close to that of the ground before returning to be circulated all over the house via ductwork. The closed loop system is more efficient in cooling the air than an open system, since the same air is cooled and re cooled again. In combination system, both open and closed loop systems can be used at the same house, depending on how much fresh air ventilation do we require [19].

In [20], Jevgeni Fadejev and Jarek Kurnitski focus on modelling concerns in a full building simulation environment, and come up with a solution for a design of a heat pump system comprising boreholes or energy piles, which was designed for a study case of store trading hall building. The entire building was modelled using Indoor Climate and Energy software simulation tool (IDA-ICE) simulation software and two different types of vertical earth tube systems: a borehole heat exchanger (BHE) situated next to the structure and geothermal energy piles (GEP) employed as the building's load-bearing to the ground and ground heat exchanger. These two characteristics allow GEPs to be very cost-effective. The results of a simulation that lasted 20 years demonstrate that a modified plant with GEPs functioned 23% more efficiently than a similar plant with a BHE field. Due to divergent ground surface boundary conditions, GEP thermal performance is different from the typical BHE field performance. The ground surface of a BHE field is typically exposed to external air and solar radiation because it is situated adjacent to a building. As results of the conducted simulations show, the GEPs and field of BHEs can give high COP of a heat pump reaching up to 5.3 in Finland cold climate.

Morley in [21] examined the effect of using earth tubes as a passive design in houses to reduce energy consumption in cooling and heating system and reduce global carbon emissions, a simulation was performed using earth tubes for typical houses in south Australia, Adelaide city, the findings demonstrated that earth tubes have enormous potential for being used as an environmentally friendly approach for passive cooling and heating of conventional suburban residential buildings. Reza Saeidi et al. in [22] performed research on using a novel spiral shape earth tube as a Ground Heat Exchange (GHE) to improve the geothermal heat pump system cooling performance; Finite element analysis, solver, and simulation environment software was used to conduct a numerical simulation for a 1Dimension -3Dimension model of the ground source heat pumps in cooling mode. Results from this reference enhance the heat transfer rate by up to 31% as a result of the increased surface area and the high thermal conductivity system. Another paper done by Changxing Zhang et al. in [23] focused on determining the ideal combination of the distance between boreholes paired with heat exchangers, size and depth of a borehole as well as borehole number under a given cooling/heating load throughout the year by using a mathematical model; the obtained result revealed that the whole length of borehole, total areas required for installation of BHE corresponding to ideal result might be effectively reduced once double U-pipe BHE was introduced in favor of single U-pipe BHE. The research done by Yuehong Bi et al. in [24] examine the relationship between the rate of heat exchange per borehole depth as well as important variable’s such as radius, distance between centers of two branch single U-shaped pipes, and borehole depth. A dynamic simulation for one year using software was performed, the result cleared that the action radius of borehole was 1.9m, it is reasonable that centre to centre borehole distance was 3.8m. Also results of pipe group showed that temperature of the soil centre surrounded by four boreholes at the beginning of heating in winter is greater than the initial temperature of soil, but the opposite is true for cooling in summer, which contributes to the efficient operating of ground source heat pump. In order to identify which parameters should be calibrated, while avoiding biases of the modeler and decreasing the number of iterations required in the calibration by approximately 89%, Marta Fernández et al. in [25] conducted a sensitivity analysis of a vertical Geothermal Heat Exchanger model from a Ground using Transient System Simulation Software (TRNSYS). The findings indicate that the procedure for calibrating the geothermal heat pump system has improved and yields better calibrated models of the entire structure.

2.6.2 Mathematical Considerations

"The basic equation used to calculate air flow rate of Earth Tube in Design Builder is:

Earth Tube FlowRate = $E_{design}\, F_{schedule}(A + B \cdot abs(T_{zoneair} - T_{odb}) + C \cdot WindSpeed + D \cdot WindSpeed^{2})$

Where A is: Constant term flow coefficient, it is part of the user specified modifying parameters that are a function of environmental factors. This parameter, however, is a constant under all conditions and is not modified by any environmental effect. As a result, it is dimensionless

Where B is: Temperature term flow coefficient, this number is the "B" parameter, it is part of the user specified modifying parameters that are a function of environmental factors. This parameter is modified by the temperature difference between the outdoor and indoor air dry-bulb temperatures. The units for this parameter are inverse Celsius.

Where C is: Velocity term flow coefficient, this number is the "C" parameter It is part of the user specified modifying parameters that are a function of environmental factors. This parameter is modified by the speed of wind being experienced outside the building. The units for this parameter are s/m.

Where D is: Velocity squared term flow coefficient, this number is the "D" parameter, It is part of the user specified modifying parameters that are a function of environmental factors. This parameter is modified by square of the speed of wind being experienced outside the building. The units for this parameter are s2/m2.

Where $T_{zoneair}$ is: Indoor temperature.

Where T_{odb} is: Outdoor temperature.

- Pipe radius

This is the radius of the earth tube /pipe (m). This plays a role in determining the amount of heat transferred from the surrounding soil to the air passing along the pipe. If the pipe has non-circular cross section, user can use the concept of hydraulic diameter as follows.
D = 4. A / Perimeter
However, since this field requires the pipe radius, hydraulic diameter should be divided by two".
The main objective of this work is to examine the effect of earth tubes as a passive system with Geothermal Assisted Heat Pumps as an active system under Palestine weather conditions and on a selected building that reflect the type of buildings that using in Palestine.

DesignBuilder Software which is dedicated to investigate how the climate affects the earth tubes and operating conditions of the heat pump and ultimately, how good they perform.

2.6.3 Geothermal Heat Pump

Geothermal energy is currently most frequently used for ground source heating and cooling. A ground source heat pump, or GAHP, uses the stable temperature of the earth's surface to heat a space instead of typically heating a space with heat from the outside air. GAHP s are among the most efficient and sustainable technologies in use today since this constant temperature can be obtained from practically anywhere in the world. Specifically, this system transmits heat from the earth into a building in the winter and then transfers it back into the earth in the summer. Heat from the earth can be used to regulate the temperature.

A network of pipes is used by geothermal heat pumps to transmit heat from the earth into a house. To create a continuous loop between the house and the earth, these pipes are welded together in a proper way and filled with a water solution. When cold, the energy from underground is absorbed by the water solution in the pipes because it is colder than the surrounding ground. This water solution then transports the energy to a heat exchanger.

Over time, geothermal systems have evolved into a very cost-effective option for both home and commercial settings. Depending on the scope of the project, their return on investment ranges from two to ten years, with installation costs for residential geothermal heat pumps usually 40%–60% less than conventional rates. Financial incentives are additionally offered to reduce upfront expenditures and raise savings in the course of time. Geothermal heat pumps are both safe and effective. When compared to underground piping, which have warranties of 20 to 50 years, these pumps are durable for 20 years or more. Geothermal is generally quite reliable as the system is shielded from external risks like damage or accumulation of debris [26].

Geothermal pumps require almost no maintenance. When set up correctly, maintenance costs are typically lower and operation is comparable to that of traditional systems. Additionally, a geothermal heat pump system is easily accessible since it is commonly situated in one's home. Geothermal heat pumps function in two ways: by cooling a space in the summer and by heating a space in the winter. Thus, users generally experience year-round comfort.

Geothermal heat pumps are remarkably quiet. They are designed for quiet and effective functioning because they are installed inside.

2.7 Literature review

2.7.1 Previous Studies About Geothermal Heat Pumps

Many studies have been carried out on the geothermal assisted heat pump to figure out its effectiveness in saving energy for the purpose of heating and cooling the buildings. Efficient utilization of geothermal energy, as a renewable power source, can be achieved applying a GAHP combined with a GHE. It is a common practice worldwide to use GAHP s to address buildings demands for heating and cooling systems of high energy performance.

In general, classification of GHEs is done based on the position of their installation – either horizontal or vertical. Some researchers [27-28] have implemented series of studies in the design, modelling and testing of GAHP s over the last ten years; both the theoretical performance evaluation of a horizontal ground source heat pump system with R-22 designed and the performance experimental evaluation of a vertical solar assisted GAHP with R-22 as the refrigerant in the heating mode are investigated by Onder Ozgener and Arif Hepbasli in [29]. For all systems, energy and exergy specifications as well as a few thermodynamic characteristics are presented and studied.

In accordance with findings, the values for the heating coefficient of performances of the two ground-source heat pumps (COPHP) and the overall Coefficient Of Performances of system (COPsys) were, respectively, 3.6 and 3.4. For both complete systems on a product/fuel basis the exergy efficiency peak estimations varied between 80.7% and 86.13%. In this case, the circulator wattage for the closed loops of the Ground source heat pump system I and the Ground source heat pump system II may be classified as effective and acceptable technologies, respectively. R. Chargui et at. have conducted extensive research on modling and simulating GAHP s using TRNSYS software. In [30], the author uses TRNSYS simulation to conduct a study on a geothermal heat pump in heating mode and develops a mathematical description of the heat pump. According to the simulation findings, the heat pump's COP increases when water at the level of the evaporator is used to power it.

When the system is appropriately built, the numerical results demonstrate that CO2 can be successfully used as a working fluid in heat pumps with very competitive performance. Building foundation is used as a heat exchanger in the Energy-Foundation System designed by Yujin Nam and Ho-Byung Chae in [31], and heat exchange rate was predicted using a numerical simulation model.

It was proven through the simulation results that the energy-foundation system could be energy efficient but that its condition might be restricted. By balancing ground thermal loads in cold winter multifamily buildings throughout the year, A. Alkhwildi et al. tried to reduce the size (and cost) of ground heat exchangers (GHX). Using TRNSYS, a simulation was tested on a geothermal heat pump system combined with a Phase Change Material (PCM) storage reservoir. According to findings of long-term life cycle simulations, integrating a PCM storage reservoir with GHP demonstrates how sensitive the system was to the chosen melt temperature and how sizing a GHX with balanced annual ground thermal loads can greatly reduce the size of a GHX.

The acquired findings further demonstrate that for the studied cases, a PCM melt temperature of 27 °C resulted in the smallest PCM tank size and lowest PCM tank cost. Two sets of measurement data were utilized to validate the simulation findings by Johann-Christoph Ebeling et al. in [32], who developed a simulation model to forecast the heat transfer performance of a vertical two-phase closed thermosyphon employed in a geothermal heat pump system. For long-term use, the created model offers good agreement with the measured data. It was discovered that heat conduction via the soil dominated all heat transfer processes due to the low thermal conductivity of the soil. The research done by Xianbiao Bu et al. in [33] focus on employing both the shallow ground source heat pump and the hot water tank for building heating, an experimental test for single well geothermal heating provided heating of the structure is conducted for a duration of 138 days.

During the experiment, the heat pump's average extracted thermal output was 448.49kW, and its average COP was 3.8, resulting in an overall thermal output for the heat pump of 608.67kW, which can warm up an area of about 17,391 square meters with a heating load of 35 watts per square meter. The viability of dynamic modelling and simulation of both traditional and direct utilization of exchange geothermal heat pump is examined by Roozbeh Sangi et al. in [34], with a special focus on performance assessments. Energy and exergy evaluations have been performed on the entire traditional and direct exchange geothermal heat pump systems with vertical and horizontal heat exchangers using simulation software. According to the findings, 750 direct exchange geothermal heat pump systems have a potential advantage over traditional ground source heat pump systems. Additionally, vertical direct exchange heat pumps are potentially more effective than horizontal ones.

In my thesis I will study how efficient is the GAHP when use it under Palestine different climate condition, using Design Builder software (energy plus).

2.7.1.1 Ground-source assisted heat pumps types

The site hydrological features, underground temperatures, thermal energy, and geological characteristics all have an impact on the system design and associated cost. As a result, system performance is dependent on the level of uncertainty in the design input parameters, particularly with regard to the thermal characteristics and source temperature. [35].

1. The load side of the application being studied has either an air-water or a water-water loop.
2. The water source heat pump's refrigerant loop.
3. The soil and refrigerant exchange heat through a ground loop with water.

The heat is absorbed by the system at a lower temperature level and then it is transferred to a higher temperature level. The vertical or horizontal heat exchange systems buried below the ground surface level are the two principal differing geometries of the loops used by the GAHP s to use the thermal energy stored in the ground.

The system has the capacity to operate in two modes—as a heating and cooling system—and may be converted into a dual-mode GAHP system by switching the refrigerant flow direction with a reversing valve. The four types of GAHP systems are based on the technology they employ:

1. The first form of GAHP system was the ground-water heat pump (GWHP), sometimes known as an open-loop system, They are vertical ground-water heat-pump systems, and in order to feed ground water to a heat pump or directly to the applications, wells and well pumps are required.
2. CHP, also known as closed-loop GAHP systems, are ground-coupled heat pump systems. In these systems, heat exchange is carried out by a high-density polyethylene pipe heat exchanger buried under the ground in vertical boreholes or horizontal trenches, Water or antifreeze fluid can be used as the solution. In the case of vertical borehole GAHP systems, the ground heat exchanger may be composed of (30.5–120 m)-deep and (76–127 mm)-diameter ducts. Surface water heat pump (SWHP) systems can be of two different types:

1. The closed-loop, where a heat rejection and extraction circulation system is situated at a predetermined depth in a tank, pond, lake.

2. The open-loop design which uses a screened capacity area to draw water from a water place in the surface. The water is then released to a receptor; by the moment, this technology is still being developed.
3. Standing column well (SCW), Although standing column wells have existed since the invention of geothermal heat pump systems, the ground heat exchanger consists of a vertical conduit that is topped off with groundwater to the water table level. An open loop pipe circuit transports water from the well through the heat pump and back to the well.

2.7.1.2 Categorization of heat pumps

When used for space or water heating, electrically powered heat pumps transfer renewable thermal According to the heat source and the Heat Transfer Fluid (HTF) utilized for energy distribution, heat pump systems can be divided into the following categories:

1. Air Source Heat Pumps (ASHP), which use outside air as their heat source. Based on the heat transfer medium utilized for energy distribution (air or water), two types of ASHP are distinguished: air-to-air and air-to-water. The most popular type of heat pumps is air-to-air, and are ideal for mono-split (plant-build unitary heat pumps).
2. "Water source heat pumps" (WSHP) Heat pumps that use water as their heat source. The water may come from solar collectors, lakes, ponds, streams, or wells that extract groundwater. They are categorized as ground source heat pumps if they utilize groundwater. In addition, they are split into two groups based on the HTF that is utilized for energy distribution. Air is used by water-to-air HPs to transfer heat into or out of the conditioned room. Water is used as the heat source and heat sink in water-to-water heat pumps (HPs). Changeovers for heating and cooling can be made in either the water circuits or the refrigerant circuit.
3. GAHP, are heat pumps that utilize the earth as a heat source and sink. But when the HTF fluid moves in underground pipes, known as GHE or BHE, the term GAHP is commonly used. The most prevalent system is one that uses horizontal, vertical, or helical heat exchangers to flow water or an antifreeze solution through them. This system is the refrigerant-to-water heat exchangers system. Water is also a typical HTF used in GAHP systems for energy distribution. In this thesis, GAHP refers to this final idea whenever it is mentioned [36].

Although ASHP are the most popular systems in regions with moderate weather, they have certain drawbacks since, as the external air temperature (TL) lowers, their efficiency declines (as was the case for the ideal heat pumps) and their heating capacity reduces. The evaporator freezes and the HP is unable to function effectively when the outside air temperature falls below 0°C.

This is the rationale behind why installing ASHPs in areas with cold weather is uncommon. GAHP s, on the other hand, have been primarily used in frigid climates, though theoretically they can be deployed anywhere. From a thermodynamic perspective, using the earth as a heat source or sink in space conditioning systems is appealing since the earth temperature is almost constant and typically much closer to room conditions than the external dry-bulb or wet-bulb temperatures throughout the whole year. Water-to-water heat pumps connected to closed loop vertical borehole heat exchangers are the most typical component of ground source heat pump systems. This kind of closed loop ground heat exchanger consists of a borehole (75–150 mm in diameter) into which one or more loops of high-density polyethylene tubing are put. Furthermore, the borehole is either backfilled or, more frequently, grouted across its entire depth (e.g., filled with graded sand). The borehole depth normally ranges from 30 to 120 meters. A number of factors affect a heat pump system financial feasibility. Firstly, compared to installing an ASHP system, installing a ground source heating and cooling system is more difficult and costly.

It requires high-cost and labor-intensive pipe drilling, excavating, and laying. However, the advantages outweigh the disadvantages. Regional factors, including the hydrological, geological, spatial features, and amount of open area surrounding the building are what determines the sort of system that can be built.

Various technologies and geological conditions have different costs for ground connection. A borehole heat exchanger currently costs between 30 and 60 €/m, with Scandinavia having the lower pricing and Austria and Germany having the higher prices. The cost of the BHE in this specific instance of the GAHP system constructed in Coimbra was 37 €/m, with drilling, excavating, laying pipes, and grout material being included.

The European Technology Platform on Renewable Heating and Cooling advises to consider as a requirement in order to achieve optimal ground-coupling technology with regard to drilling costs and BHE efficiency for GAHP systems. The objectives set were to reduce installation costs by at least 25% in 2020 and by 50% in a long-run, as well as to increase borehole heat exchanger efficiency by 25% till 2020 [37].

2.8 Residential Structures GAHP Modelling and Installation

While designing ground heat exchanger, such parameters as the climate, soil properties, and the building's specifics should be considered. In general, there are two categories of ground features that have an impact on GAHP system design parameters: ground thermal properties and the groundwater hydraulic features.

2.8.1 Factors Impacting on the Ground Component of a GAHP System

An important influence on a GAHP system efficiency is done by geological variables. For example, silt or clay-based terrain would be preferable for GAHP systems than sand-based terrain, and rock strength should be considered while drilling a vertical loop. The key aspects impacting ground qualities were presented hereunder.

2.8.2 Thermal Properties

Thermal conductivity (λ) and thermal capacity (Cp) are the two characteristics of rocks and soil that have the most influence on the design of a GAHP system Cp. Thermal diffusivity ($\rho \ \lambda \ \alpha$ Cp =) measures the rate at which heat is transferred across a medium and is correlated with λ, Cp, and density (ρ). For UK rocks, Rollin and Bloomer gave standard values of thermal conductivities. The predicted thermal characteristics of superficial deposits are listed in the thesis, together with the λ and ($\rho \ \lambda \ \alpha$ Cp values for different types of rocks.

2.8.3 Temperature

The temperature gradient of the ground source heat pump collector loops is identified by the ground temperature [49]. Up to a depth of around 15 meters, the temperature of the soil varies according to both daily and seasonal cycles. Nevertheless, the temperature below a depth of 15 m is relatively stable, and will be close to the average yearly air temperature of the area.

2.8.4 Ground Conditions and Geotechnical Properties

It is crucial to take into account a number of preliminary ground engineering aspects, in particular: the thickness and nature of any geological deposits; the depth of any weathered bedrock geology; the strength of the bedrock geology; and any potentially risky ground conditions, in order to ensure that the proper GAHP system is designed and the proper installation method (trenching or drilling) is chosen. Extensive study is required, comprising theoretical analysis and field experiments, to assess ground qualities in order to obtain more precise data [38].

2.9 Heat Pump Sizing

The following process should be followed to calculate the size and choose a heat pump properly, as stated in Microgeneration Installation Standard: MIS 3005.

1. A method that conforms with British Standard and European regulatory standard (BS EN) 12831' should be used to calculate the building heat loss.
2. Indoor and outdoor temperatures indicated in BS EN 12831 should be considered to calculate the heat loss.
3. At least 100% of the calculated power needed for design space heating must be met by the heat pump that was chosen.

2.10 Ground Loop Sizing

One of the most crucial tasks in projecting GAHP systems is sizing of the ground heat exchanger. Thoroughly measuring the ground loop size is essential for the GAHP to work well. The following will happen if the ground loop is under-sized: a. decrement in the buildings comfort level; b. decrease in the annual energy gained from the earth over time as the earth temperature that was diminished might not be able to restore; c. probability of using supplementary heating by householders, and transition of the antifreeze into more viscous state due to the drops of soil temperature, and thus intensifying the pumping requirement, which together will cause reduction in the system efficiency. On the other hand, oversizing of the ground loop will get the system lifespan shorter, the installation cost higher and the performance less efficient. A variety of design methods are used to estimate the length of the GAHP system ground loop. These methods are using computer software programs, manual techniques [49], and using rules of thumb.

Nonetheless, using practical rules in determining the length of the ground loop in many instances results in overly complex, high-cost systems or undersized failures Geothermal Heat Pump Installation. It would be better to determine the length of the loop employing manual methods or computer Software such as Ground Loop Heat Exchanger Design Software (GLHEPRO), that take into account the following aspects of the design: thermal properties of the ground, building loads, operating temperature range of the loop, heat pump features, field geometry, grout or backfill thermal properties, pipe qualities, local drilling practices and limitations, and local ground water conditions.

2.11 GAHP System Efficiency

The GAHP systems' efficiencies are significantly higher than those of traditional air-source heat pump systems. A GAHP can obtain a greater COP since the source/sink ground temperature is more stable than air temperatures. In addition, water is also used for heat absorption and rejection because of its relatively high heat capacity, making it a more preferable medium for heat transmission. GAHP technologies rely on the fact that the earth's temperature is approximately stable in a zone spanning from about 20 feet (6.1 meters) deep to about 150 feet (45.7 meters) deep under standard geothermal gradients of about 0.5oF/100 ft (30oC/km). The interplay of heat fluxes from above (the sun and the atmosphere) and below (the earth interior) has led to the earth being at a steady temperature span. Consequently, this span of the earth temperature is roughly equivalent to the average value of the annual air temperature. The earth temperature above the zone, which is no deeper than 20 feet (6.1 meters), is a tamed version of the air temperature at the surface of the earth. The earth temperature goes up in accordance with the natural geothermal gradient below this zone (more than roughly 150 ft (45.7 m) deep) [39].

2.12 Coefficient of Performance of a Heat pump

The COP, which is the ratio of the system heat output to the entire amount of power required to run the heat pump, is used to assess a “heat pump” efficiency. The ratio between the system heat output and the quantity of electricity required to operate the entire heating system (including pumps, domestic hot water, and auxiliary heating) is defined as the system efficiency. Geothermal heating and cooling technologies can only consume up to 75% less power and decrease greenhouse gas (GHG) emissions by 66%

or more when compared to traditional heating or cooling technologies that consume fossil fuels [40]. COP can be described as: -

$$COP = h_h / h_w \quad (1)\ [41].$$

were

h_h = produced heat (Btu/h, J, kWh)

h_w = equivalent electric input energy (Btu/h, J, kWh) = 3413 P_w

were

P_w = electrical input power (W)

Highest COP

The highest theoretical heating process efficiency is

$$COP_{heating} = T_h / (T_h - T_c) \quad (2)$$

$COP_{heating}$ = Coefficient of Performance – process of heating

T_h = hot side absolute temperature (K)

T_c = cold side absolute temperature (K)

The cooling process maximum theoretical efficiency is

$$COP_{cooling} = T_c / (T_h - T_c) \quad (3)$$

$COP_{cooling}$ = Coefficient of Performance - cooling process

Note! - By decreasing the difference of temperature (Th - Tc) between the hot and cold sides, a cooling or heating process can operate more effectively.

2.13 Building energy requirements

The following equations are used to design the building heat pump system and the ground loop heat exchange.

The overall equivalent transmittance coefficient Û is given by:

$$\widehat{U} = \frac{k.EP_i}{\frac{S}{V}.DD.t} \tag{4}$$

Where k factor determines the power requirement of the specific energy label that was selected, EP_i is the highest energy required for building's unit volume space heating, t is the time of daily functioning expressed in hour if EPi is given in kWh/m3 per heating season, DD is degree-days and $\frac{S}{V}$ is the ratio of the shape of the building [42].

The indoor temperature T of the building can be calculated by equation (2)

$$T(t) = T^{air} + \left(T_0 - T^{air}\right).e^{\frac{S.\widehat{U}.(t-t_0)}{V.r\rho c}} \tag{5}$$

where **r** is plenum volume to total building volume ratio, $\boldsymbol{\rho}$ is the density of a wall in kg m-3, c is specific heat of a wall in Kj kg-1 K-1, T_0 is the air temperature inside the building at time step t_0, when the plant is turned off. From this point on, the inside temperature T varies in accordance with the overall transmittance Û and the exterior temperature T_{air}.

The energy requirement is related only to the outdoor air temperature, as follows:

$$q(t)= \mathrm{r}\rho\mathrm{c}.\left(T^{\frac{h}{c}} - T_0\right)+\widehat{U}.\frac{S}{V}.\left(T^{\frac{h}{c}} - T_{air}\right).\Delta t \tag{6}$$

Where $\boldsymbol{q(t)}$ is the energy requirement, T^c is the interior temperature targeted for cooling in ℃, T^h is the interior temperature targeted for heating in ℃.

The following equation is used to calculate the GHE flow rate (5)

$$\dot{V}_N^w=\dot{V}_L^w + \frac{c_s\rho_s V_s}{c_w\rho_w\Delta T_{67}\Delta t_L}.\left(\bar{T}_N^{air} - \bar{T}_L^{air}\right) \tag{7}$$

Where $\boldsymbol{\dot{V}_N^w}$ is the GHE new flow rate, $\left(\boldsymbol{\bar{T}_N^{air}} - \boldsymbol{\bar{T}_L^{air}}\right)$ is the variation in annual average air temperatures, Δt is the time of heating, L is limit case, N is the GHE water leaving temperature in each new instance. Using a precise numerical loop provided by developers of the FEFLOW software, the flow rate into the GHE was estimated to have water with a 3°C between the inlet and outlet temperatures ($\Delta \boldsymbol{T_{67}}$). And lastly, the following proportion represents the new GHE water leaving temperature:

$\Delta \boldsymbol{t_L}$ is heating time period

$$T_N(t) = T_L(t) - \left(\bar{T}_N^{air} - \bar{T}_L^{air}\right) . \left(1 - \frac{t}{\Delta t_L}\right) \quad (8)\ [42].$$

Chapter Three
Energy Modelling for Buildings

3.1 Introduction

The most well-known and sophisticated user interface for Energy Plus, the industry typical Building Energy Simulation tool, is Design Builder. It gives users access to all of the most frequently needed modelling features, including financial analysis, HVAC, solar energy, thermal mass, glazing, and shading. The modelling environment is user-friendly and allows you to work with virtual building models. Various environmental performance information is provided, including energy usage, carbon emissions, comfort levels, daylight illumination, peak summertime temperatures, and sizes of HVAC component.

The program's compatibility with Building Information Modelling (BIM) makes importing 3D models simple. The adaptable software Design Builder offers a variety of simplified solutions for preliminary design stages and model detail options for more difficult calculations. Analysis of energy use, carbon emissions, occupant comfort, illumination, computational fluid dynamics (CFD), environmental impact assessment, etc. are all possible with this tool.

The use of simulation tools to test and evaluate design options and to analyse the entire performance of buildings becomes more significant in a setting where there is a demand for high-performance buildings due to the requirement for quantitative analysis.

Robust HVAC tools: -

Utilizing templates for early and thorough design, size and simulate conventional and cutting-edge HVAC and mixed-mode systems. Real system performance is mimicked by detailed system models with adaptable control schemes. You can accurately match the system to the building and observe performance directly down to the component level with the help of simultaneous HVAC and building modelling.

3.2 Geothermal simulation assignment Methodology

Twenty simulations were carried out in total. For a building mode provided. Al Rasheed building is assumed to be located in five different Palestinian cities; the simulations were prepared as follows:

1. The models were built using Design Builder.
2. Their HVAC schematics were reviewed under the HVAC tab in the software.
3. New HVAC systems were loaded for the respective buildings by loading and selecting relevant HVAC systems.
4. The location of the building was set at five different locations in Palestine. The external conditions would determine the performance of the HVAC systems and what the energy readings would be for specific instances and durations.
5. A heating design analysis was carried out. This was done to determine the temperature readings in and around the building as well as the estimated heating load values. These determine the performance levels for the HVAC system to ensure set temperatures are maintained throughout the day.
6. A cooling design analysis was also carried out. This was done to determine the temperatures, heating gains, and cooling loads on a specific day.
7. The final simulation is carried out when the aforementioned steps have been successfully completed. The data generated includes total energy used, total source energy figures, and individual energy figures for different utilities, just to name a few.
8. Modifications are then made to improve on the results based on what is required for the building. These modifications mainly include the addition of cooling or heat exchanging systems that either improve the system's overall efficiency or reduce its total energy usage. Later in the study, these topics will be discussed in further detail.

3.3 Coefficients of performance

A system's efficiency is expressed by its COP. "The efficiency relates to the use of all inputs in producing any given output, including personal time and energy. The COP of a heat pump is the ratio of the heating or cooling provided over the electrical energy consumed" [43].

The COPs for all the systems that were simulated were automatically calculated by the software, yielding the following results:

1- Building simulations without geothermal heat exchange system 1.8 – 3.20
2- Building simulations when adding geothermal heat exchange system 5.26 – 4.80

The higher the coefficient, the more effective the power system is, and vice versa. All the systems that will be analysed have COPs range from 1.8 - 5.26. This is because Design Builder software select these COP values automatically based on the climate data for each city. This will be discussed at length later in the report. COPs should ideally be above 1. Once these were determined, the aforementioned steps were carried out for each of the twenty simulations that will be discussed.

Chapter Four
Simulation Results and Analysis

4.1 Ground Assisted Heat Pump

In this study, five Palestinian cities are considered, Jerusalem, Jericho, Tul-Karim, Gaza, and South-Hebron. For each city, four simulations are carried out on it, two simulations involved their basic HVAC system and using a ground heat exchanger was one of the advancements, and the other two simulations involved their basic HVAC system and the improvements involved the use of the earth tubes. Firstly, I will discuss and analyse the simulation results for Jerusalem city only, then the simulation results for the other four cities will be discussed.

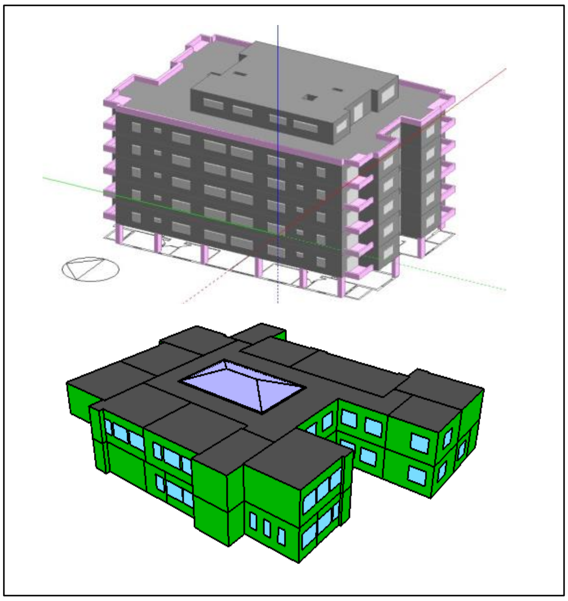
4.2 Al Rasheed Building and The School Building

Al Rasheed building is a case study for testing the adding of GAHP to the traditional Variable Refrigerant Flow (VRF) HVAC system for the purpose of energy saving in cooling and heating. This building has multiple rooms and multiple users per room. It has five floors in total. Each floor has 12 rooms, 4 kitchens, 4 living rooms, one circulation area, and 11 water closet rooms. This is a combined total of approximately 160 rooms in this building, notwithstanding the roof section which has its own zonal requirements. It therefore means that its energy requirements are significant.

While the school building is another case study for testing the adding of Earth Tubes system to the traditional split unit HVAC system also for the purpose of ventilate the building and saving energy in cooling and heating Its design is as shown on below.

Figure 1

A 3D model of Al Rasheed Building on the left utilizing GAHP system. And A 3D model of School Building on right utilizing Earth Tubes system

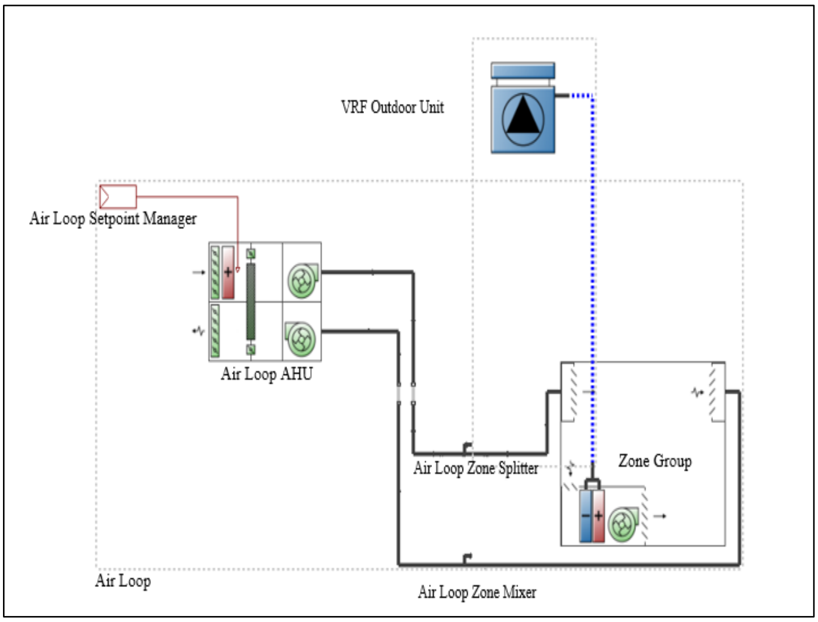


Earth Tubes system study for school building will be discussed on chapter 5.

The HVAC system that was chosen for Al Rasheed building is a relatively simple VRF system [44] and Dedicated Outdoor Air System (DOAS). The schematic of its design is presented hereunder.

Figure 2

A schematic of the VRF DOAS air cooled system that the building uses



A specialized outside air system is created to provide heated outdoor air during the winter into a building and cooled, dehumidified outer air during the summer [45]. A variable refrigerant system operates as a heat pump by using the refrigerant either for air conditioning or heating [46]. During the summer, the hybrid system on the previous page operates by having outdoor air drawn in, cooled, dehumidified, and filtered before being channelled into the room. A setpoint manager is used to ensure the set temperature is maintained. Hence, air enters the system; is heated, and then is circulated and filtered back out into the room when the temperature is lower than intended. This is done until the desired temperature is attained. This is done until the desired temperature (which is set on the set point manager) is attained. The buildings in question have multiple energy requirements e.g., lighting and the running of equipment, but the main ones are air conditioning and heating.

Firstly, the heating and cooling design parameters had to be determined. These were obtained after calculating the system's COP.

The table on the next page is a summary of the key statistics for the building.

Table 1

A summary of Heating Design for Al-Rasheed Building parameters

Parameter	Value
Steady-State Heat Loss (kW)	69.51
Intermittent Heat Loss (kW)	0
Design Capacity (kW)	85.92
Glazing Gains (kW)	-18.19
Wall Gains (kW)	-26.99
Floor Gains (kW)	-3.29
Roof and Ceiling Gains (kW)	-18.82
Ventilation Gains (kW)	-1.47
Infiltration Gains (kW)	-18.52

The building's estimated steady state heat loss is 69.51kW. This means that the existing power system must compensate for this when heating the building. This has much to do with the materials used to make the buildings as well as the design which facilitates air and heat movement both in and out of it [47]. The buildings design capacity is 85.92kW, meaning this is the power level that should be met by the energy system of choice. The variables that are negative, they are the values of heat gain caused by different part of the building, DB used it to calculate the cooling load the cooling parameters that the building's design requires. Perhaps this is the case because Jerusalem is a predominantly hot area, and the building is designed using materials and airflow channels that readily let heat out.

The cooling design results for the building are as shown below. They are what will be used when the building is being cooled.

Table 2

A summary of the different cooling design values for Al-Rasheed Building

Parameters	Values
Design Capacity (Kw)	216.22
Design Flow Rate (m3/s)	137.61
Total Cooling Load (Kw)	188.02
Sensible (kW)	187.56
Latent (kW)	0.46
Air Temperatue (˚C)	19.35
Humidity (%)	57.8
Time of Max Cooling	N/A
Max Op Temp in Day (˚C)	28.17
Floor Area (m2)	3072.792
Volume (m3)	9085.584
Flow/Floor Area (L/s-m2)	44.783
Design Cooling Load Per Floor Area (W/m2)	70.366
Outside Dry-Bulb Temperature at Time of Peak Cooling Load (˚C)	0
Glazing Gains (kW)	7.16
Wall Gain (kW)	72.34
Floor Gains (kW)	30.6
Roof and Ceiling Gains (kW)	15.91
Ventilation Gains (kW)	0.32
Infiltration Gains (kW)	6.8
Elecric Wquipment Gains (kW)	24.7
Lighting Gains (kW)	10.57
People Gains (kW)	2.28
Solar Gains (kW)	13.91
Mechanical Ventilation fresh air rate (m3/s)	0.07
Freash air % of supply air (%)	0.051

The design capacity for the entire building is 216.22kW. this is based on the average climatic conditions throughout the hotter parts of the year 15 July. The HVAC design flowrate is 137.61m^3/s for the entire building. This is a total figure based on the volume of the rooms and the average annual temperatures throughout the summer and other hot periods.

The average humidity in the region is 57.8 %, which is high when compared to other parts of the world. From this, it is clear that HVAC will be required for most parts of the year because high levels of humidity make people uncomfortable, especially in rooms that are not properly ventilated. The maximum operating temperature is Max Op Temp in Day °C is the maximum operative temperature in the zone (using radiant fraction = 0.5) over the design day including periods when the zone may be unconditioned its value from the summary result above table is 28 degrees Celsius, which is typical for where this building is situated. While the high temperatures will necessitate the use of HVAC systems, humidity often plays an equally significant part in this. Should the temperature and humidity levels rise, HVAC systems will need to be in place to ensure they adequately make the rooms in the building comfortable and habitable. The flow per unit floor area has also been estimated to determine what the optimum airflow rate will be during cooling.

The optimum airflow rate ensures the time not comfortable hours are not long, lest they make people uncomfortable for an unacceptably long time. This parameter is discussed in more detail later in the report. The other parameters i.e., gains, have to do with how these parts of the building experience rises in temperature due to conduction, convection, and radiation. Fresh air flow rate during mechanical ventilation is much less than the planned flow rate. In comparison to the design value of the flow rate of 137.61m3/s, it is 0.07m3/s. This comes to show that mechanical ventilation will not be a major contributor to the climate control system in the entire building.

Lastly, the fresh air percentage contribution to the overall supply air is 0.051%, Fresh air % of supply air (%) is the % of the mechanical cooling design supply air that is from outside at the time of maximum load. The remainder of the supply air is assumed to be recirculated. This is due to the dedicated outdoor air supply system for the VRF system, which pulls fresh air into the system for purification and use in the different rooms of the Al-Rasheed Building.

The temperature and heat gains on a specific date (15^{th} July). This was estimated to be the hottest day of the year.

it is evident that as the temperature rises through the day, the relative humidity and natural ventilation reduce. Both the sensible and total cooling have an inverse relationship with the temperature, which is unexpected. This might be the case because the drop in humidity coupled with the use of ventilation perhaps creates a relatively comfortable atmosphere indoors and reduces the need for air conditioning. These trends will give an indication of what the energy usage trends will be like throughout the day and the year during the simulation.

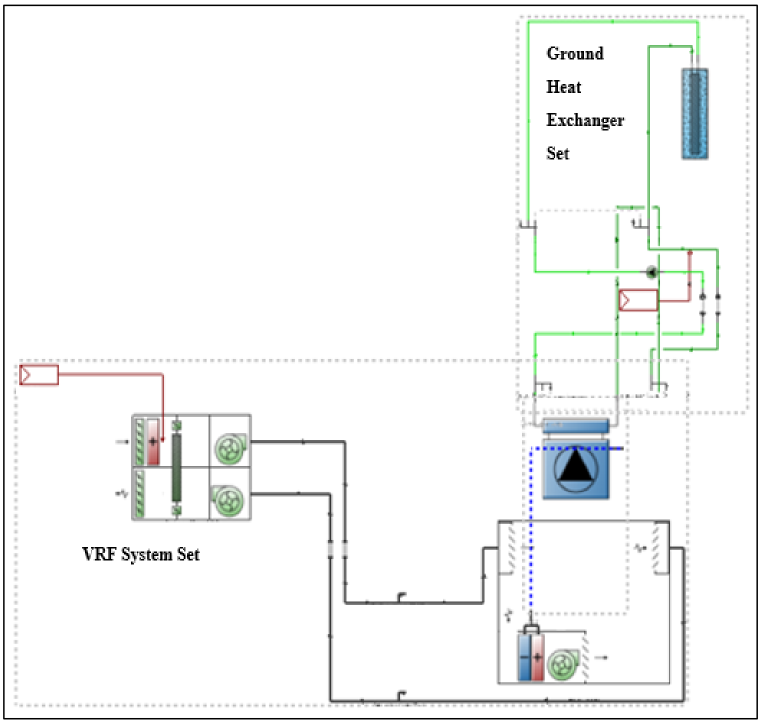
A full simulation was carried out for the building to determine its energy usage trends throughout the year. The simulation done when VRF HVAC system was chosen without the geothermal heat exchange, this traditional HVAC system make the heat change with outside air.

The temperature trends throughout the year show a rise from mid-April to about first-September, and a decline from that point on through to December. In line with this, the amount of energy used for cooling has followed this trend while heating has followed the reverse trend i.e., reducing from the mid-April to the first-December, before slowly increasing from that point through to the end of the year. Other energy consuming utilities such as lighting and equipment are constant throughout the year. The ventilation trend is largely similar to the cooling trend as the year goes by, apart from between first-January and mid- April, where the ventilation is significantly lower than at any other point throughout the year. This may be the case because users may be relying more on-air conditioning than natural ventilation because of temperature and humidity values. The values from this simulation will be compared to those of the improved energy system that was implemented with the existence of Geothermal heat exchange.

The use of geothermal energy as a substitute for the previous building's energy-intensive HVAC system is studied in this subsection as a way to save energy. The system used in the previous simulation was modified by adding a ground heat exchanger to it in order to increase its efficiency and to decrease the total energy amount consumed.
The lower section of the system i.e., the condenser loop’s demand mixer and demand splitter are connected to the earlier system’s VRF outdoor unit. This section is used for managing the heat loss of the system more efficiently. the water moves from the VRF unit through to the heat exchanger, where it is either heated or cooled before it is pumped back into the VRF and into the heating/cooling section of the entire system. The following page illustrates the entire system.

Figure 3

The modified system



The refrigerant in use goes through the VRF outdoor air unit and is channelled through the pipework, through the heat exchanger for a higher level of heat loss or heat gain before being pumped back into the system depending on the need, either for additional heating or cooling. The ground heat exchanger was designed to have 120 boreholes for optimum performance with depth of 76m for each borehole. The quantity of turns and length of pipeline that the refrigerant must go through before coming back to the system for use have a significant impact on the heat exchanger efficiency. [48]. The average ground temperature was taken to be 15°C. All year long, this would be employed for heating and cooling purposes. Once the system was checked, the simulation was run, yielding the results that follow.

From first-January through to April and from November to December, no cooling is used. This results in cooling energy savings when compared to the pervious system. No heating is carried out either as they year ends, which is different from the initial system where heating gradually began as the winter season began. This results in significant energy savings that will be evident in the graphs that follow. The same for ventilation usage in this period. Perhaps this is to compensate for the energy that is used for cooling. As for heating, the energy required reduces to the minimum from mid-April to first-November, at which point the energy levels are close to zero for the rest of the year. This may be the case because the geothermal energy is deemed adequate for heating use as winter begins, and the system goes back to electrical heating at the beginning of the year when geothermal energy may not be adequate for heating. The graphs that follow show the comparison of energy figures between the initial system and the new system with the ground heat exchanger added to it for Jerusalem city climate.

Given the limited use of energy for cooling purposes from mid-August to the end of the year, and virtually no energy used for heating from the same period until January, the total amount of energy used by the new heating system is significantly less than that of the previous system. The total energy used in a year by the old system is 213947.02 kWh compared to the new system's 188272.88 kWh. This is an annual saving of 25674.14kWh, or a 12% reduction in energy usage. Given the current energy cost of NIS 0.65/kWh [49] (as of 28th September 2022), this translates to annual savings of NIS 16,688.2 per year. While these savings are significant, the value of the additional materials needed to build and install the ground heat exchanger is a different matter and whether said investment will experience returns in a relatively short time.

The demand end use for cooling and heating was less when the GAHP installed (39000 kWh for cooling and 19000 kWh for heating). While when using only the traditional HVAC system VRF, the demand end use was greater compared to modifyed system (52000 kWh for cooling and 32000 kWh for heating) and the total demand end use electricity for VRF coupled with GAHP was (188272 kWh), while total demad for VRF system only was more (213947 kWh) . The modified system's equipment requires less energy to cool the building in one year. The new system requires approximately 13149.11kW less than the original system for the specified utilities. The differences between the two systems become apparent during use. The annual end use differs significantly because they consider the amount of time the aforementioned utilities are in use throughout the year.

The overall end use electricity figures give a better reflection of the electricity usage throughout the year. The amount of time allocated to heating and cooling is higher for the initial system than the new system. Consequently, the building requires more energy to heat and cool. As a result, the energy used to heat and cool the building is higher. Moreover, more ventilation is used to regulate internal temperatures with the new system than with the old one. This may explain why the heating and cooling energy values differ as shown on the graph on the left. Because of this, the total end use electricity figures differ as shown on the graph on the right. The 12% difference between the two final figures demonstrates that the installation of the ground heat exchanger and subsequent use of the HVAC system result in energy and financial savings for users. The saving in energy for heating found to be 41.67%, while for cooling the saving in energy found to be 26.96% when using the geothermal heat exchange system. Which considered to be a very good amount of saving that have been achieved. The practical implications of this are elaborated on in the discussion section of the report.

4.3 Simulation Results and analysis for different cities in Palestine

After discussing the simulation results for Jerusalem city, now simulation results for the other four cities will be discussed and shown on the following tables and graphs below. When adding the geothermal heat exchange system, DesignBuilder software set automatically the number of boreholes to be 120, and the depth for each borehole is 75meters. The simulations carried out for both HVAC systems, firstly using VRF system only, then when adding geothermal heat exchange system to the VRF system (The modified system).

Table 3

Heating and cooling loads/year for individual uses in both systems for Jerusalem city

Jerusalem city - State of Palestine (Represent cold winter and Moderate summer climate)		
	Heating Consumption (kWh)	Cooling Consumption (kWh)
Without Geothermal	32166.48	52253.58
With Geothermal	18761.91	38167.99
Saving in Energy (kWh)	13404.57	14085.59
Saving %	42	27

Table 4

Heating and cooling loads/year for individual uses in both systems for Jericho city

Jericho city -State of Palestine (Represent hot summer and warm winter climate)		
	Heating Consumption (kWh)	Cooling Consumption (kWh)
Without Geothermal	2473.8	209107.3
With Geothermal	2464.3	86180.8
Saving in Energy (kWh)	9.5	122926.5
Saving %	0.4	58.8

Table 5

Heating and cooling loads/year for individual uses in both systems for Tul-Karim city

Tul-Karim City- Palestine (Represent Moderate winter and hot and humidity summer climate)		
	Heating Consumption (kWh)	Cooling Consumption (kWh)
Without Geothermal	9617	78949.82
With Geothermal	8548.86	52388.05
Saving in Energy (kWh)	1068.14	26561.77
Saving %	11	34

Table 6

Heating and cooling loads/year for individual uses in both systems for South-Hebron city

South Hebron city - State of Palestine (Represent hot summer and Moderate winter climate)		
	Heating Consumption (kWh)	Cooling Consumption (kWh)
Without Geothermal	9674.61	99972.96
With Geothermal	8691.85	56703.87
Saving in Energy (kWh)	982.76	43269.09
Saving %	10	43

Table 7

Heating and cooling loads/year for individual uses in both systems for Gaza city

Gaza City - State of Palestine (Represent Moderate winter and hot and humidity summer climate)		
	Heating Consumption (kWh)	Cooling Consumption (kWh)
Without Geothermal	9091.35	89287.08
With Geothermal	8284.68	50466.91
Saving in Energy (kWh)	806.67	38820.17
Saving %	9	43

Based on the above simulation results, Jericho city has the highest saving amout of energy for cooling with 122.926 kWh (58.8%), and the lowest saving amout of heating 9.5 kWh (0.4%), and this is due to hot climate in summer and warm climate in winter. The next city is South-Hebron and Gaza with 43,269.09 kWh and 38,820.17 kWh (43%) saving in cooling and 982.76 kWh (10%) and 806.67 kWh (9%) saving in heating respectively. This because these two cities have hot summer climate and moderate winter climate. After that come Tul-Karim city, with 26,561.77 kWh (34%) saving in cooling and 1068.14 kWh (11%) saving in heating. The reason is Tul-Karim has hot and humid summer and warm winter. Last city is Jerusalem, with highest amout of saving in heating 13,404.57 kWh (42%) and lowset amout of saving in cooling 14,085.59 kWh (27%). And this is due to the cold climate in winter and moderate climate in summer.

Table 8

The effect of extremist climate (when ΔT value is high) on saving in cooling loads/year for five cities

City Name (120 boreholes-75m depth)	Underground temperature in C	Summer Average outdoor temperature in C	ΔT (Average temperature - Under Ground temperature) in C	Saving in Cooling (kWh)
Jericho	17	30.5	13.5	122926.5
South-Hebron	16	26.4	10.4	43269.09
Gaza	15	27	12	38820.17
Tul-Karim	15	28.5	13.5	26561.77
Jerusalem	14	24	10	14085.59

Table 9

The effect of extremist climate (when ΔT value is high) on saving in heating loads/year for five cities

City Name (120 boreholes-75m depth)	Underground temperature in C	Winter Average outdoor temperature in C	ΔT (Average temperature - Underground temperature) in C	Saving in Heating (kWh)
Jerusalem	14	8.9	-5.1	13404.6
Tul-Karim	15	14.5	-0.5	1068.14
South-Hebron	16	11.1	-4.9	982.76
Gaza	15	13.1	-1.9	806.67
Jericho	17	15	-2	9.5

Table 8 and 9 shows how that the extremist climate (when ΔT value is high) will lead to a great amount of energy saving in both cooling and heating. Cities are ranked in descending order in terms of energy savings in cooing, highest to lowest.

Chapter Five
Simulation Results and Analysis

5.1 Earth Tubes System

This chapter will cover the simulation work of using earth tubes system for ventilation purpose in building for five cities in Palestine. For each city two simulations are carried out on it, one simulation involved their basic HVAC system in A school building, and the second simulation involved the improvements when use the earth tubes system.

The reason behind chosen a school building in this research, is due to the big number of students in each class, the internal heat gain from student is high, so it's very important to provide an efficient ventilation system to save energy and provide a healthy environment for students in all classes.

Firstly, I will discuss and analyse the simulation results for Jerusalem city only, then the simulation results for the other four cities will be discussed.

5.2 Earth Tube for School building

To study the effect of using earth tubes in saving energy in the mechanical ventilation systems inside building, a school building with two floors has chosen. Building area 1519 m2, it has 17 class rooms, two laboratories, one computer lab, two offices and two toilets. The idea behind choosing a school building is because of the big amount of energy consumption needed to provide healthy ventilation environment for students (10 Litre / second / person). Building has multiple class rooms, multiple students per room, one laboratory, one computer lab, one store and two offices. As there are many students in the building. It therefore means that its energy requirements are significant. Its design is as shown on the next page.

The HVAC system selected for this building is a relatively simple split units' system.

In this thesis, the effect of insulation on the school building to save energy has been studied, two simulations have been carried out, first when the building in insulated and then when the building is not insulated, the result has been discussed in the conclusion. The school building walls, doors and ceiling were insulated with 0.7mm in thickness extruded polystyrene (XPS) boards to provide a good insulation in building envelope.

The simulation results proof how efficient is the insulation in saving energy and reducing heat and cool design capacity.

Design Builder software will be used to find out the efficiency of using earth tubes in saving energy when used in the ventilation process in buildings.
The HVAC system selected for this building is a relatively simple split units' system.

5.3 Methodology

As mentioned before, the idea behind using earth tubes in ventilation, is to take advantage of the constant underground temperature to save energy, instead of entering a cold air in winter i.e. 5 C degree directly to a building and then consume a lot of energy to increase this air temperature to 22 C degree (17 C degree difference), This cold air can be drawn from outside to inside through earth tubes so it will enter the building with 16 C degree instead of 5 C (6 C degree difference only) so raising the air temperature by HVAC system from 16 to 22 instead of 5 to 22 C degree will save a lot of energy. And the same thing for summer season.

To get an occurrent and correct results, too many simulations had been carried out with the help of DesignBuilder software to examine how different factors affect the performance of earth tubes. These parameters include the length, diameter, depth, and the conductivity of the earth tubes and the underground temperature. In this study several cities in Palestine are considered. Each city represents different climate. Jerusalem city (The capital Of Palestine) represent mild climate in summer and cold in winter, Gaza represent the coastal climate, were Jericho represents a hot and dry weather in summer and a warm weather in winter, whereas South-Hebron has a hot climate in summer and a moderate weather in winter, and Tulkarim represents a humid hot weather during summertime and a moderate climate in cold season. Also, the effect of insulation in building on energy saving will be studied.

5.4 Parametric Study and Simulation Results for Jerusalem City

All simulation results done in this research using DesignBuilder software, shows that using the earth tubes system for ventilation save a great amount of energy compare to the traditional mechanical ventilation system. Figure. (35, c) shows that replacing the mechanical ventilation with earth tubes gives 28.44% energy saving in total site energy, 35.71% energy saving in cooling and 34.67% energy saving in heating. But we need to make a detailed and accurate study for all parameters that affect the efficiency of using earth tubes system, then analyse and discuss the simulation results for each parameter to reach the best result. Each time one parameter is variable and the others are fixed, these elements are listed below.

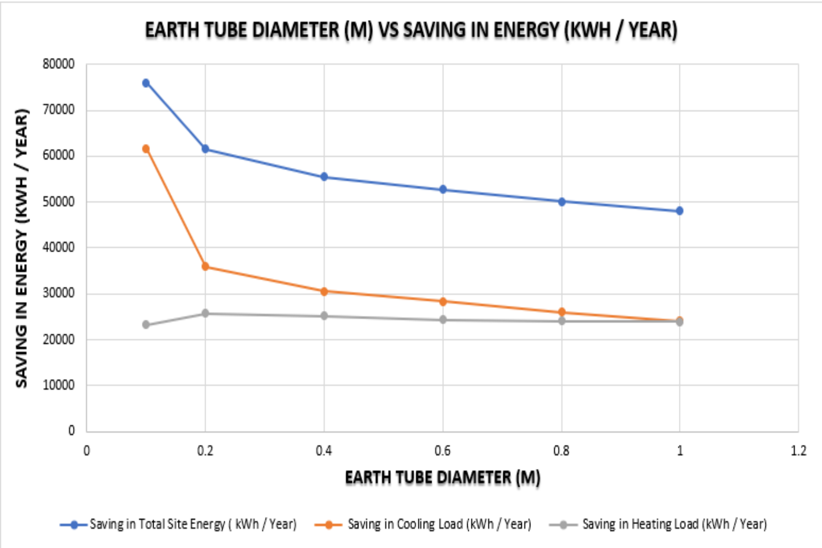
1. Earth Tubes Diameter

The below line chart in (figure.35) displays how earth tubes diameter affects the amount of energy saved. Simulation results on DesignBuilder software show that the greater the size of the tubes diameter, the energy saving becomes less (an inverse relationship). The reason for this is that the greater the diameter of the tubes, the area of tubes increases and therefore the friction between the air passing inside the tubes become less with the ground. Therefore, the temperature of the air exiting the earth tubes and entering the building will remain close to the outside air temperature, and the saving in energy in HVAC system will be much less.

The optimum value is after using 0.1m diameter earth tubes, the total site energy saving is 76,119.64 kWh/year, energy saving in cooling is 61,706.91 kWh/year and the energy saving in heating is 23,211.2 kWh / year. This good amount of saving in energy is due to the high friction between air inside earth tubes and ground because the pipe diameter is small. Were the worst amount of saving in energy is when 1m in diameter earth tubes used, the reason behind this is because the more the diameter size is the less the heat exchange between the air in the middle of tube with the ground is. the total site energy saving is 48000 kWh/year, energy saving in cooling is 24,117.6 kWh/year and energy saving in heating is 23,882.4 kWh/year. That’s mean when using an earth tube with a diameter of 0.1m gave me 10.5% more saving in total site energy, 21.75% more saving in cooling and 1% more saving in heating than an earth tubes with a diameter of 1m.

Figure 4

Earth tubes diameter vs Saving in Energy/year in HVAC system



	0.1	0.2	0.4	0.6	0.8	1
Series1	76119.64	61548.85	55551.95	52762.5	50108.83	48000.07
Series2	61706.91	35922.92	30541.26	28411.37	26022.02	24117.62
Series3	23211.2	25733.83	25118.58	24351.13	24086.8	23882.44

- Saving in Total Site Energy (kWh / Year)
- Saving in Cooling Energy (kWh / Year)
- Saving in Heating Energy (kWh / Year)

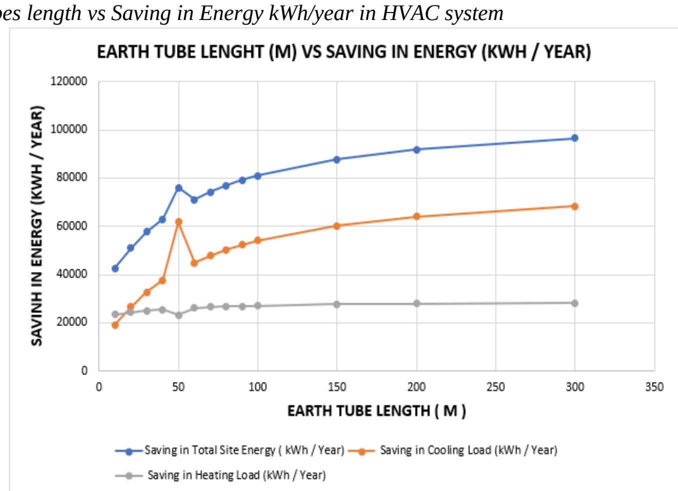
2. Earth Tubes Length

The below line chart in (figure.36) displays how earth tubes length affects the amount of energy saved. Simulation results on DesignBuilder software show that the greater the length of the tubes, the energy saving becomes more (positive relationship). The reason for this is that the greater the length of the tubes, the friction between the air passing inside the tubes become more with ground. Therefore, the temperature of the air exiting the earth tubes and entering the building will be close to the underground temperature (16 C degree), and the saving in energy in HVAC system will be much more.

The optimum value is after using 300m in length earth tubes system, the total site energy saving is 96,483.75 kWh/year, energy saving in cooling is 68,301.64 kWh/year and the energy saving in heating is 28,182.1 kWh / year. This good amount of saving in energy is due to the high friction between air inside earth tubes and ground because the pipe length is long. Were the worst amount of saving in energy is when 10m in length earth tubes is used, the total site energy saving is 42,559.17 kWh/year, energy saving in cooling is 19,056.44 kWh/year and energy saving in heating is 23,502.72 kWh/year. That's mean when using an earth tube with a length of 300m it gave me 20.15% more saving in total site energy, 28.5% more saving in cooling and 7% more saving in heating than an earth tubes with a length of 10m.

Figure 5

Earth tubes length vs Saving in Energy kWh/year in HVAC system



0	10	20	30	40	50	60	70	80	90	100	150	200	300
Series1	42559.2	50980.4	57631	63019.3	76119.6	71133.4	74246.4	76900.2	79157.9	81111.1	87892.8	91846.7	96483.8
Series2	19056.4	26650.8	32667.8	37554.5	61706.9	44938.6	47782.3	50210.7	52279.4	54071	60310	63966.2	68301.6
Series3	23502.7	24329.6	24963.2	25464.8	23211.2	26194.8	26464.1	26689.4	26878.5	27040.1	27582.8	27880.5	28182.1

- Saving in Total Site Energy (kWh / Year)
- Saving in Cooling Energy (kWh / Year)
- Saving in Heating Energy (kWh / Year)

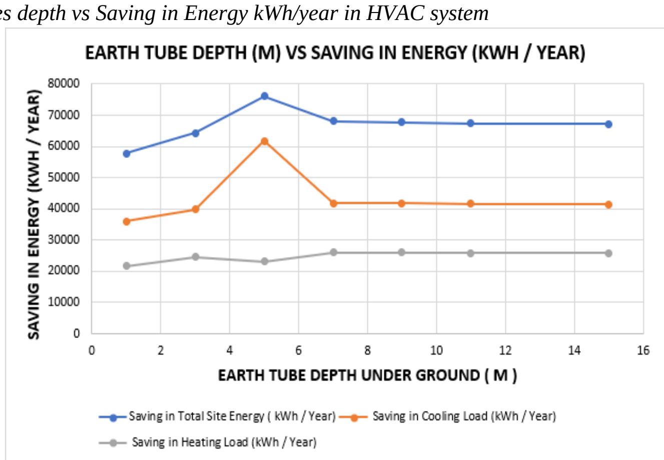
3. Earth Tubes Depth

The below line chart in (figure.37) display the effect of earth tubes depth underground on the amount of saving in energy achieved. The simulation results on DesignBuilder software shows increase in saving for total site, cooling and heating energy when the depth is between 1m to 3m, and when the depth was 5m the saving in total site and cooling energy keep increases to be 76,119.6 kWh and 61,706.9 kWh, while the saving in heating energy decrease a little bit to the value of 23,211.2 kWh. At 7m depth, the saving in total site and cooling energy decreases to the value of 68,016.8 kWh and 41,896.67 kWh respectively, while saving in heating increases to 26,120 kWh, then below 7m in depth, the saving in energy for total sit, cooling and heating almost remain constant.

A depth of 5 meter was chosen because it obtains the best result in energy saving and also because the cost of drilling at this depth is less expensive than the deeper depth.

Figure 6

Earth tubes depth vs Saving in Energy kWh/year in HVAC system



	1	3	5	7	9	11	15
Series1	57716.96	64380.76	76119.64	68016.78	67733.92	67432.52	67275.97
Series2	35958.52	39820.03	61706.91	41896.67	41728.74	41553.56	41464.9
Series3	21758.43	24560.73	23211.2	26120.11	26005.18	25878.95	25811.07

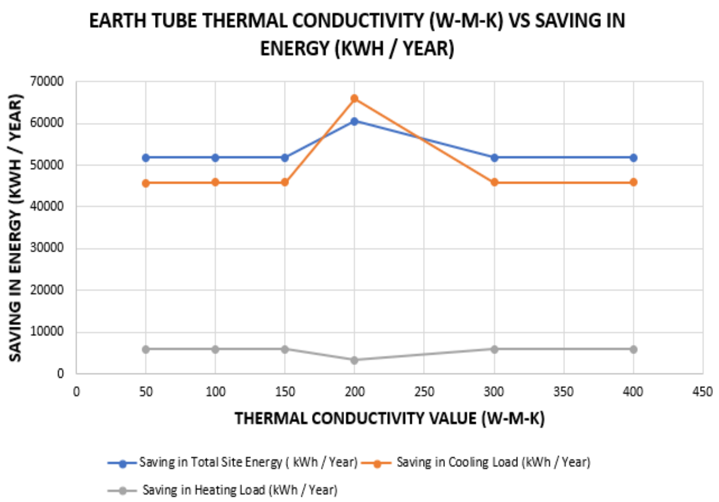
■ Saving in Total Site Energy (kWh / Year)
■ Saving in Cooling Energy (kWh / Year)
■ Saving in Heating Energy (kWh / Year)

4. Earth Tubes Thermal Conductivity

Several simulations have been done to study the effect of earth tube conductivity on saving energy, Figure.38 display a line chart for the result of this simulation. It is noted that when the value of conductivity was 200 Watt per Meter-Kelvin (W-M-K) the optimum value, we got the best energy saving value for total site and cooling energy 60,533.77 kWh and 65,973.47 kWh respectively, but for heating the result showed the lowest energy saving value of 3250.88 kWh 6.92% While for other conductivity values, the result showed less energy saving for total site and cooling energy and best saving for heating energy with value of 5906 kWh. Figure.38c shows the percentage of energy saving for different conductivity values, as mentioned above, at 200 W-M-K best energy saving was obtained for total site and cooling energy, 24% and 37.3% respectively.

Figure 7

Earth tubes Thermal Conductivity vs Saving in Energy kWh/year in HVAC system



0	50	100	150	200	300	400
Series1	51800.06	51832.44	51843.24	60533.77	51854.09	51856.8
Series2	45790.7	45820.31	45830.19	65973.47	45840.12	45842.6
Series3	5901.47	5904.23	5905.15	3250.88	5906.07	5906.3

- Saving in Total Site Energy (kWh / Year)
- Saving in Cooling Energy (kWh / Year)
- Saving in Heating Energy (kWh / Year)

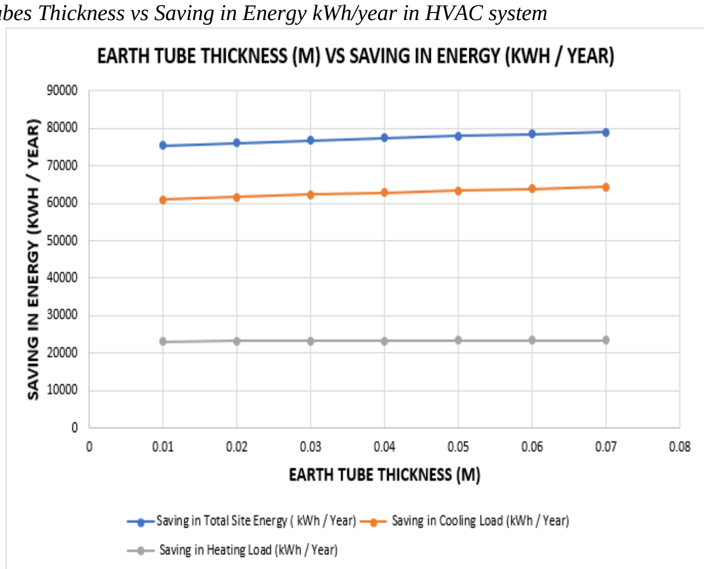
5. Earth Tubes Thickness

The last parameter that was studied is the thickness of the earth tubes, and the simulation results came as shown in figure.39. The greater the thickness of the tube is, the better the amount of energy savings, it's a direct relationship, and this is a logical result, since friction with ground increases with tube thickness, air flowing inside an earth tube will always be at the proper temperature underground.

The thickness of the tube slightly effects the energy saving, Figure.39a. Therefore, the tube with 0.02 m in thickness will be chosen for application in the upcoming simulation works due to economical purposes.

Figure 8

Earth tubes Thickness vs Saving in Energy kWh/year in HVAC system



0	0.01	0.02	0.03	0.04	0.05	0.06	0.07
Series1	75410.08	76119.64	76780.97	77399.72	77982.73	78532.23	79050.4
Series2	61050.66	61706.91	62320.61	62892.53	63432.05	63941.05	64422.04
Series3	23157.89	23211.2	23258.83	23305.66	23349.15	23389.65	23426.84

Saving in Total Site Energy (kWh / Year)

Saving in Cooling Energy (kWh / Year)

Saving in Heating Energy (kWh / Year)

The optimised values of the Earth tube diameter, length, depth, conductivity and thickness obtained from above simulation results will be applied on the other Palestinian cities (Jerusalem, Tulkarim, Jericho, South Hebron and Gaza).

5.5 Simulation Results for Jerusalem City

The city of Jerusalem is the capital of the State of Palestine. It's located in the heart of Palestine (coordinate 31.76667˚N 35.25˚E), Jerusalem rises about 750 m above the surface of the Mediterranean Sea, and about 1150 m from the surface of the Dead Sea. The climate of the city is moderately hot, dry during summertime and chilly, rainy during cold season. School building simulation in the city of Jerusalem was carried out on 3 stages. The first simulation done when using mechanical ventilation for the building without insulation, the second simulation work when replacing the mechanical ventilation system with the earth tubes system for the building without insulation, and the third simulation when using the earth tubes system for same building but with insulation. The purpose of this study, is finding out how much energy is saved when replacing the mechanical ventilation system with earth tubes, as well as to know the amount of energy savings when using these earth tubes in an isolated building compared to using them in a non-insulated building. The simulation result in showed the amount of yearly energy consumption for the school building, when using the automatic system of ventilation in an uninsulated structure the yearly energy consumption was estimated at 267,672.04 kWh for total site energy, 172,795.63 kWh for cooling and 66,939.39 kWh for heating. and when we replace the mechanical ventilation with earth tubes in an uninsulated building, the amount of yearly energy consumption reduced to be, 247,067.17 kWh for total site energy, 155,120.88 kWh for cooling and 64,009.28 for heating. But the lowest energy consumption per year was achieved when we use earth tubes in an insulated building, the yearly energy consumption reduced to the minimum with a value of 191,552.4 kWh for total site energy, 111,088.72 kWh for cooling and 43,728.19 kWh for heating. And this showed how effective is using earth tubes system when the building is insulated compare to the amount of energy saving when the building is an uninsulated. The simulation results in fig.40d, proved the effectiveness of using earth tubes in saving energy rather than using the mechanical ventilation systems, and also proved the effectiveness of using these earth tubes when the building is well insulated. How much energy is saved annually when we replace the mechanical ventilation system with the earth tubes in an uninsulated building

7.7% for total site energy, 10.23% in cooling and 4.38% in heating. while when we used these earth tubes in an insulated building, yearly energy saving increased to be, 28.44% in total site energy, 35.71% in cooling and 34.67% in heating. and this is showing the importance of using insulation in buildings to save energy.

The same simulation work done for the other Palestinian cities in next pages to see results will vary with different climates in those cities.

5.6 Simulation Results for Tul-Karim City

Tul-Karim city of is situated in the State of Palestine in the northwest part of West Bank (coordinate 32˚18’40’’N 35˚01’51’’E), Tul-Karim is 15 km away from Mediterranean Sea and rises about 65 m westward to 600 m eastward above the surface of the Mediterranean Sea. The climate of the city is hot humid in summer and moderately cold winter. The simulation result in Fig.41a showed the amount of energy consumption per year for the school building, when using the automatic system of ventilation in an uninsulated structure the yearly energy consumption stood at 315,417.26 kWh for total site energy, 258,558.68 kWh for cooling and 28,154.11 kWh for heating. and when we replace the mechanical ventilation with earth tubes in an uninsulated building, the amount of energy consumption per year reduced to be, 274,740.25 kWh for total site energy, 218,037.72 kWh for cooling and 27,998.06 for heating. But the lowest energy consumption was achieved when we use earth tubes in an insulated building, the yearly energy consumption reduced to the minimum with a value of 247,445.9 kWh for total site energy, 191,329.94 kWh for cooling and 18,655.83 kWh for heating. And this showed how effective is using earth tubes system when the building is insulated compare to the amount of energy saving when the building is an uninsulated. The simulation results in fig.41d, proved the effectiveness of using earth tubes in saving energy rather than using the mechanical ventilation systems, and also proved the effectiveness of using these earth tubes when the building is well insulated. How much energy is saved per year when we replace mechanical ventilation system with the earth tubes in an uninsulated building 12.9% for total site energy, 15.67% in cooling and 0.55% in heating. while when we used these earth tubes in an insulated building, the amount of energy saving per year increased to be, 21.55% in total site energy, 26% in cooling and 33.74% in heating. and this is showing the importance of using insulation in buildings to save energy.

The same simulation work done for the other Palestinian cities in next pages to see results will vary with different climates in those cities.

5.7 Simulation Results for Jericho City

Jericho is a city in the State of Palestinian city. It is situated in the Jordan Valley in the West Bank with Jerusalem to the west and the Jordan River to the east (coordinates 31°52′16″N 35°26′39″E), Jericho is about −258 m below sea level. The climate of the city is during summer season is hot and dry, while warm in winter. The simulation result in Fig.42a showed the amount of yearly energy consumption for the school building, when using the automatic system of ventilation in an uninsulated structure the yearly energy consumption totalled 399,421.8 kWh for total site energy, 361,782.61 kWh for cooling and 9,144.54 kWh for heating. and when we replace the mechanical ventilation with earth tubes in an uninsulated building, the amount of yearly energy consumption reduced to be, 350,445.32 kWh for total site energy, 313,239.32 kWh for cooling and 8,711.34 for heating. But the lowest energy consumption was achieved when we use earth tubes in an insulated building, the yearly energy consumption reduced to the minimum with a value of 306,830.86 kWh for total site energy, 265,187.51 kWh for cooling and 4,565.37 kWh for heating. And this showed how effective is using earth tubes system when the building is insulated compare to the amount of energy saving when the building is an uninsulated. The simulation results in fig.42d, proved the effectiveness of using earth tubes in saving energy rather than using the mechanical ventilation systems, and also proved the effectiveness of using these earth tubes when the building is well insulated. The amount of yearly energy saving when we replace the mechanical ventilation system with the earth tubes in an uninsulated building 12.26% for total site energy, 13.42% in cooling and 4.74% in heating. while when we used these earth tubes in an insulated building, yearly energy saving increased to be, 23.18% in total site energy, 26.7% in cooling and 50.08% in heating. and this is showing the importance of using insulation in buildings to save energy.

The same simulation work done for the other Palestinian cities in next pages to see results will vary with different climates in those cities.

5.8 Simulation Results for South-Hebron City

South-Hebron is a city in the south of West Bank, State of Palestine around 110 kilometres south of Jerusalem. (Coordinate 31°21'26.7"N 34°56'19.1"E), South-Hebron rises about 260 m above the surface of the Mediterranean Sea. The climate of the city is hot and dry during months of summer and mild during cold season. The simulation result in Fig.43a showed the amount of energy consumption per year for the school building, when using the automatic system of ventilation in an uninsulated structure the yearly energy consumption totalled 326,502.3 kWh for total site energy, 266,220.78 kWh for cooling and 31,875.54 kWh for heating. and when we replace the mechanical ventilation with earth tubes in an uninsulated building, the amount of energy consumption per year reduced to be, 284,239.28 kWh for total site energy, 226,179.51 kWh for cooling and 29,653.8 for heating. But the lowest energy consumption was achieved when we use earth tubes in an insulated building, the yearly energy consumption reduced to the minimum with a value of 251,321.7 kWh for total site energy, 194,313.78 kWh for cooling and 19,982.2 kWh for heating. And this showed how effective is using earth tubes system when the building is insulated compare to the amount of energy saving when the building is an uninsulated. The simulation results in fig.43d, proved the effectiveness of using earth tubes in saving energy rather than using the mechanical ventilation systems, and also proved the effectiveness of using these earth tubes when the building is well insulated. How much energy is saved per year when we replace the mechanical ventilation system with the earth tubes in an uninsulated building 12.94% for total site energy, 15.04% in cooling and 6.97% in heating. while when we used these earth tubes in an insulated building, the amount of energy saving per year increased to be, 23.03% in total site energy, 27.01% in cooling and 37.31% in heating. and this is showing the importance of using insulation in buildings to save energy.

The same simulation work done for the other Palestinian cities in next pages to see results will vary with different climates in those cities.

5.9 Simulation Results for Gaza City

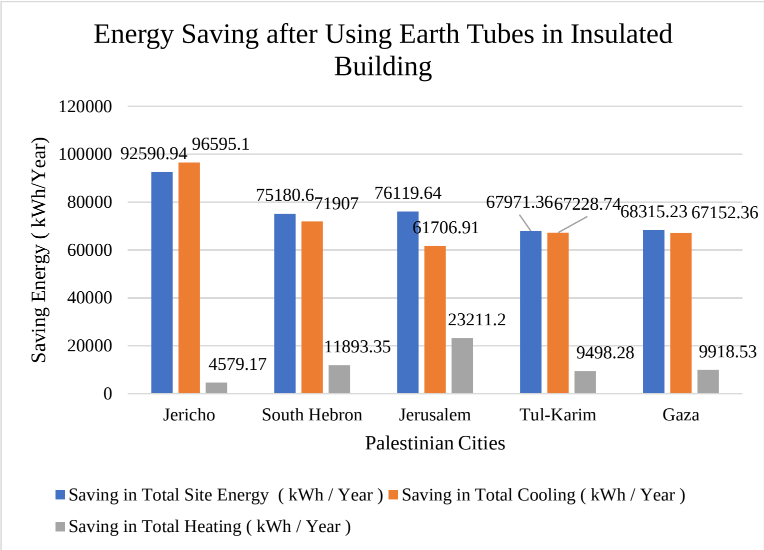
Gaza is a coastal city east of the Mediterranean Sea in the State of Palestine. It has an 11-kilometer southwest border with Egypt, and around 78 kilometres south west of Jerusalem. (Coordinate 31°31′N 34°27′E), Gaza rises about 14 m above the surface of the Mediterranean Sea. The climate of the city is hot and humid during summertime and moderate in cold season. Simulation result in Fig.44a showed how much energy was consumed per year for school premises, when using Mechanical ventilation system in an uninsulated building the energy consumption per year was 315,376.43 kWh for total site energy, 258,563.58 kWh for cooling and 28,108.38 kWh for heating. and when we replace the mechanical ventilation with earth tubes in an uninsulated building, the amount of energy consumption per year reduced to be, 274,199.28 kWh for total site energy, 218,124.25 kWh for cooling and 27,370.56 for heating. But the lowest energy consumption was achieved when we use earth tubes in an insulated building, the energy consumption per year reduced to the minimum with a value of 247,061.2 kWh for total site energy, 191,411.22 kWh for cooling and 18,189.85 kWh for heating. And this showed how effective is using earth tubes system when the building is insulated compare to the amount of energy saving when the building is an uninsulated. The simulation results in fig.44d, proved the effectiveness of using earth tubes in saving energy rather than using the mechanical ventilation systems, and also proved the effectiveness of using these earth tubes when the building is well insulated. How much energy is saved per year when we replace the mechanical ventilation system with the earth tubes in an uninsulated building 13.06% for total site energy, 15.64% in cooling and 2.62% in heating. while when we used these earth tubes in an insulated building, the amount of energy saving per year increased to be, 21.66% in total site energy, 25.97% in cooling and 35.29% in heating. and this is showing the importance of using insulation in buildings to save energy.

The same simulation work done for the other Palestinian cities in next pages to see results will vary with different climates in those cities.

A comparison in regards to energy saving for the five cites in Palestine using earth tubes in insulated school building is shown in fig.45 below. Jericho City had the biggest energy savings for cooling and the lowest for heating because of the city's warm summer and pleasant winter climates. while it was the opposite for Jerusalem city due to the mild summer and cold winter climate. Regards to Gaza and Tul-Karim in spite of hot summer climate, it was found that the energy saving in cooling it not as good as Jericho, and this is due to the high humidity climate in summer.

Figure 9

Energy saving per Year when using Earth Tubes for ventilation in Insulated building for the five Palestinian cities



5.10 Heating Design Calculation

To calculate the size of heating equipment needed to meet the coldest winter design climate conditions expected to be experienced at the site location, heating design calculations are carried out. Using DesignBuilder software, two simulations has been carried out for each city to compare the results when using Mechanical ventilation system verses using Earth Tubes. This simulation has been applied for five Palestinian cities with different climate conditions.

The simulation results in figure 46 below, shows a great amount of saving in Heating capacity when using earth tubes for all Palestinian cities, for example in Jerusalem city, the heating design capacity found to be 244 kW when using Mechanical ventilation system, while when this system replaced by Earth Tubes the heating design capacity drop to be 55.3 kW only, that means 77.34% saving in heating capacity has been achieved. And as a result, the size of heating equipment needed to handle the coldest environment will be decreased. In other words, when using Earth Tunes, we have achieved savings in three things, lower price of the heating equipment, less energy consumption, and also less space for that equipment's place.

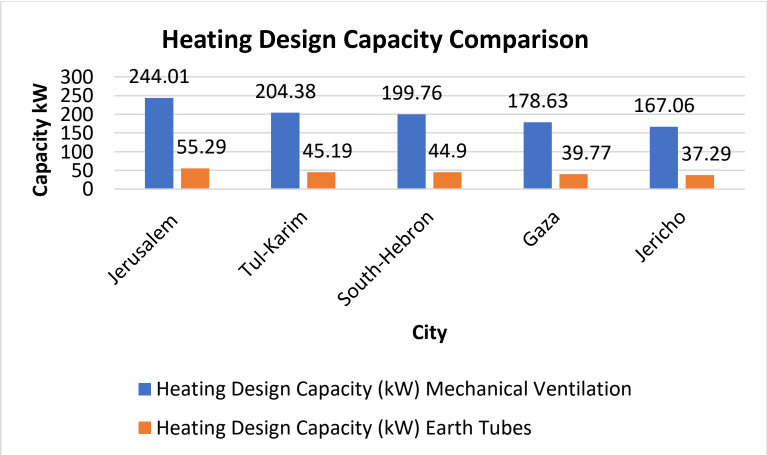
5.11 Cooling Design Calculation

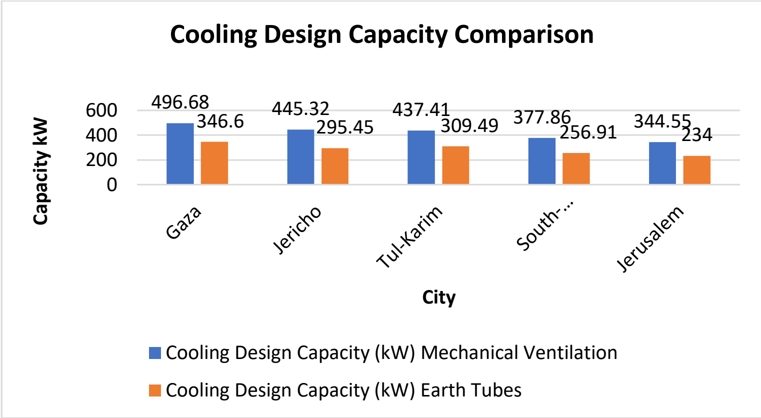
To estimate the capacity of mechanical cooling equipment needed to meet the warmest summer design weather patterns expected to be experienced at the selected site, cooling design calculations are conducted out. If these settings are chosen on the zone HVAC tab, free-floating temperatures in zones that are not mechanically cooled are computed along with the effects of natural or mechanical ventilation.

The simulation results in figure 46, below, shows a great amount of saving in cooling capacity when using earth tubes for all Palestinian cities, for example in Gaza city, the cooling design capacity found to be 496.7 kW when using Mechanical ventilation system, while when this system replaced by Earth Tubes the heating design capacity drop to be 346.6 kW only, that means 30% saving in cooling capacity has been achieved. And as a result, the size of cooling equipment needed to handle the coldest environment will be reduced. In other words, when using Earth Tunes, we have achieved savings in three things, lower price of the cooling equipment, less energy consumption, and also less space for that equipment's place.

Figure 10

Heating / Cooling design capacity, Mechanical ventilation Vs Earth Tubes




Cooling Design Capacity Comparison
Capacity kW
600
400
200
0
496.68
346.6
445.32
295.45
437.41
309.49
377.86
256.91
344.55
234
Gaza
Jericho
Tul-Karim
South-...
Jerusalem
City
Cooling Design Capacity (kW) Mechanical Ventilation
Cooling Design Capacity (kW) Earth Tubes

Chapter Six
Feasibility Study

6.1 Introduction

6.2 Geothermal Heat Exchange system

The purpose of feasibility research is to identify whether or not the proposed geothermal heat exchange system is likely to be successful. The cities that have the highest amount for energy saving were selected to conduct the feasibility study. These cities are Jericho, with 122,936 kWh/yeas energy saving, then South-Hebron, with 44,252 kWh/year energy saving.

6.2.1 Feasibility study result for Jericho City

The detailed work of the feasibility study and the cumulative cash flow chart will be found in the Appendix (Copy of Excel file).

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jericho City	122,936	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investment cost (TIC)=	633,860	NIS
Simple payback period (SPP)	8.3	Years
Feasibility Study Result	Feasible	

6.2.2 Feasibility study result for South-Hebron City

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for South-Hebron City	44,252	kWh/Year
3.Price are in (NIS)		
4.Study period 30 years		
(Without bank interest):		
Total investment cost (TIC)=	633,860	NIS
Simple payback period (SPP)	25.1	Years
Feasibility Study Result	Not Feasible!	

6.2.3 Conclusion

The feasibility study showed that using GAHP system was accepted for Jericho city, the system will pay back the investment cost within 8.3 year, the long payback period is due to the high investment cost. But this saving in energy after 8 years payback period is considered as a profit, the system will keep save energy for the rest 22 years and this because GAHP system save a lot of energy in cooling for Jericho city. While for South-Hebron city, installing GAHP system found to be not feasible, although it succeeds to pay back the investment after 25.1 years, but it's still very long time period to bring back the investment, and this due to the small cooling energy saving amount/year and high investment cost.

6.3 Earth Tubes System

Same study obtained for GAHP will also apply for Earth Tube system to proof the successful of using it. The feasibility study for installing Earth Tube system will be applied on all cities, and the insulated school building is considered in the study.

6.3.1 Feasibility study result for Jericho city

The detailed work of the feasibility study will be found in the Appendix (Copy of Excel file).

Note:

1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jericho City Insulated building	101,174	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		

(Without bank interest):

Total investment cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.2	Years
Feasibility Study Result	Feasible	

6.3.2 Feasibility study result for South-Hebron city

The detailed work of the feasibility study and the cumulative cash flow chart will be found in the Appendix (Copy of Excel file).

Note:

1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for South-Hebron City Insulated Building	83,800	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		

(Without bank interest):

Total investment cost (TIC)=	66,180	NIS

Simple payback period (SPP)	1.4	Years
Feasibility Study Result	Feasible	

6.3.3 Feasibility study result for Jerusalem city

The detailed work of the feasibility study and the cumulative cash flow chart will be found in the Appendix (Copy of Excel file).

Note:

1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jerusalem City Insulated Building	84,918	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		

(Without bank interest):		
Total investment cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.4	Years
Feasibility Study Result	Feasible	

6.3.4 Feasibility study result for Tul-Karim city

The detailed work of the feasibility study and the cumulative cash flow chart will be found in the Appendix (Copy of Excel file).

Note:

1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Tul-Karim City Insulated Building	76,727	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		

(Without bank interest):

Total investment cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.6	Years
Feasibility Study Result	Feasible	

6.3.5 Feasibility study result for Gaza city

The detailed work of the feasibility study and the cumulative cash flow chart will be found in the Appendix (Copy of Excel file).

Note:

1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Gaza City Insulated Building	77,071	kWh/Year
3.Price are in (NIS)		
4.Study Period 30 years		

(Without bank interest):

Total investment cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.6	Years
Feasibility Study Result	Feasible	

6.3.6 Conclusion

The feasibility study showed that using Earth Tube system in an insulated school building was accepted for all cities in Palestine, the payback period ranges between 1.2 to 1.6 year, and will keep save energy for the rest 28 years, and this saving in energy is consider as a profit, the success of this system in all deferent climates/cites is due to the high saving in energy and low system investment cost.

Chapter Seven
Conclusion and Recommendation

7.1 Conclusion

This research represents analyses of two highly recommended technologies that utilize the geothermal energy of the ground “GAHP Technology and “ET Technology”. These two systems are used as an energy retrofit strategy for the air conditioning system in a residential building and school building. A parametric study was performed for the two systems and the related buildings. The simulation is carried out using the DesignBuilder software. The study is applied on five Palestinian cities, each city represents a different climate zone in Palestine. The results show that energy consumption for heating and cooling can be decreased when using GAHP by (42% in heating to 58.8% in cooling). For ET, this reduction ranges between (33.7% to 50.1% in heating, and 26% to 35.7% in cooling%). Moreover, this reduction in energy consumption led to reduction in CO2 emission, using this type of renewable energy considered as an environmentally friendly solution than that of a traditional air conditioning system.

The economic study in this master thesis also proved that the two proposed systems are economically feasible, the payback period for the GAHP was longer than the ET ones due to the high cost of borehole drilling and the cost of geothermal heat exchange pipes. From the other side, based on different climate conditions for the five cities in Palestine, the best results in energy saving for cooling were for the city of Jericho, as the city of Jericho is one of the hottest cities in the summer, while the best results in energy saving for heating were for the city of Jerusalem because it is one of the coldest cities in the winter. The study also showed the importance of insulation on buildings envelope in energy saving. Simulation results showed that the amount of savings in cooling for Jericho city in an insulated building was 26.7%, while the amount of savings in cooling for the same building but without insulation was 13.4%. And the amount of savings in heating for Jerusalem city in an insulated building was 34.7%, while the amount of savings in heating for the same building but without insulation was 4.4% only.

7.2 Recommendation and Future Work

1- Performing Pilot project with real data about GAHP and ET in Palestinian cities.

2- More studies are recommended for other applications of geothermal energy.

List of Abbreviations

Abbreviation	Meaning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASHP	Air Source Heat Pumps
BTU	British Thermal Unit
BHE	Borehole Heat Exchanger
BS EN	British Standard and European regulatory standard
BIM	Building Information Modelling
CO2	Carbon Dioxide
CFCs	Chlorofluorocarbons
COP	Coefficient Of Performance
COPHP	Coefficient Of Performances of the two ground-source Heat Pumps
COPsys	overall Coefficient Of Performances of system
Cp	Thermal Capacity
CFD	Computational Fluid Dynamics
C˚	Celsiusd degree
DOAS	Dedicated Outdoor Air System
ET	Earth Tube Technology
ft^2	Square Feet
Fº	Fahrenheit
GAHP	Ground Heat Assisted Heat Pump Technology
GEP	Geothermal Energy Piles
GHE	Ground Heat Exchange
GHX	Ground Heat Exchangers
GHG	Green House Gas emissions
GLHEPRO	Ground Loop Heat Exchanger Design Software
GWHP	Ground-Water Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning system
hr	Hour
HTF	Heat Transfer Fluid

HP	Heat Pump
IDA ICE	Indoor Climate and Energy software simulation tool
kWh	Kilo Watt Hour
NIS	New Israeli Shekel
NOx	Nitrogen Oxides
PCM	Phase Change Material
SCW	Standing Column Well
SPP	Simple Payback Period
SWHP	Surface Water Heat Pump
TIC	Total Investment Cost
TL	External Air Temperature
TRNSYS	Transient System Simulation Software
VRF	Variable Refrigerant Flow
W-M-K	Thermal Conductivity unit Watt per Meter-Kelvin
WSHP	Water Source Heat Pumps
XPS	Extruded Polystyrene boards
λ	Thermal Conductivity
ΔT	Average temperature - Underground temperature
ρ	Density
$\rho\ \lambda\ \alpha\ Cp$	Thermal Diffusivity

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Appendices

Appendix A

Simulation Result Figures

Figure 1

The total saving in cooling loads/year vs ΔT for five cities

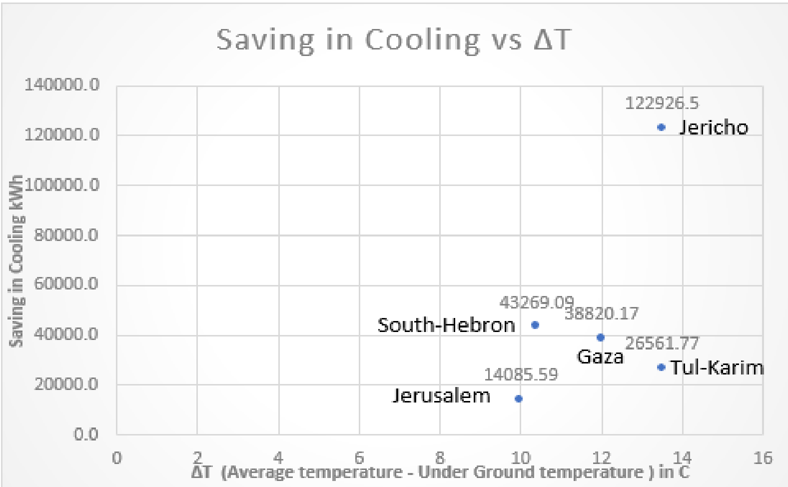


Figure 2

Total saving in heating loads/year vs ΔT for five cities

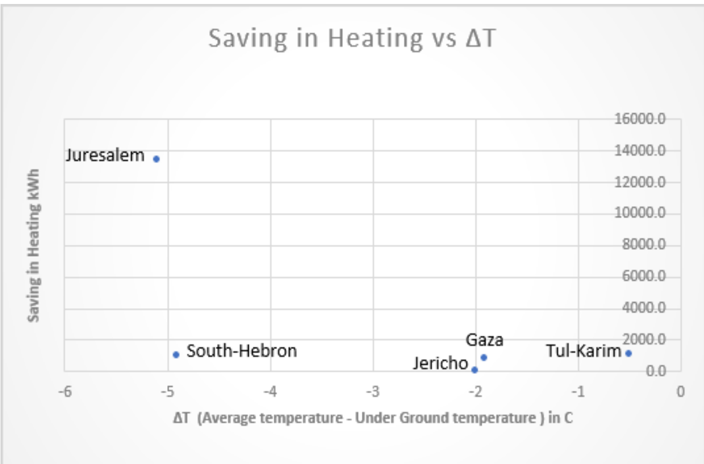


Figure 3

Comparison of Energy consumption kWh/m2 per Year between Mechanical and Earth Tubes Ventilation systems in Insulated and Uninsulated building in Jerusalem city

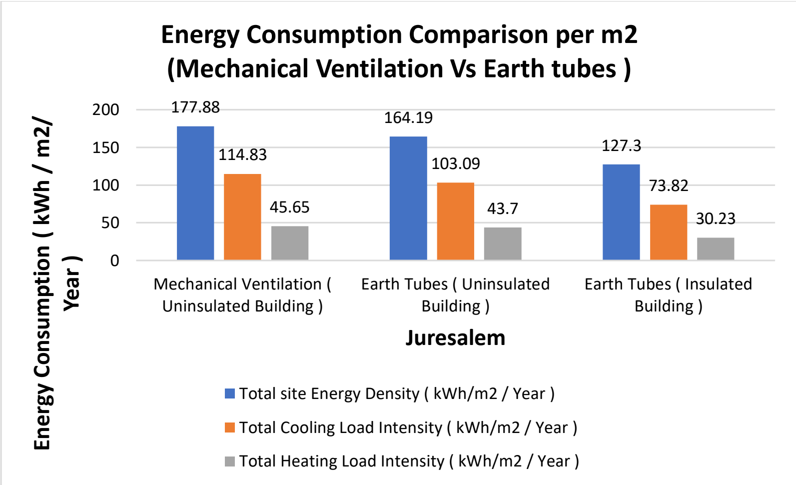


Figure 4

Energy saving kWh per Year when using Earth Tubes for ventilation in Insulated and Uninsulated building in Jerusalem city

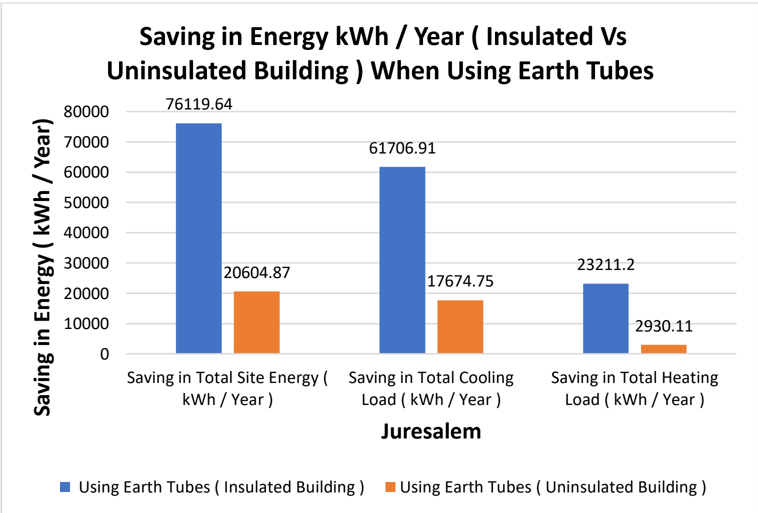


Figure 5

Comparison of Energy consumption kWh/m2 per Year between Mechanical and Earth Tubes Ventilation systems in Insulated and Uninsulated building in Tul-Karim city

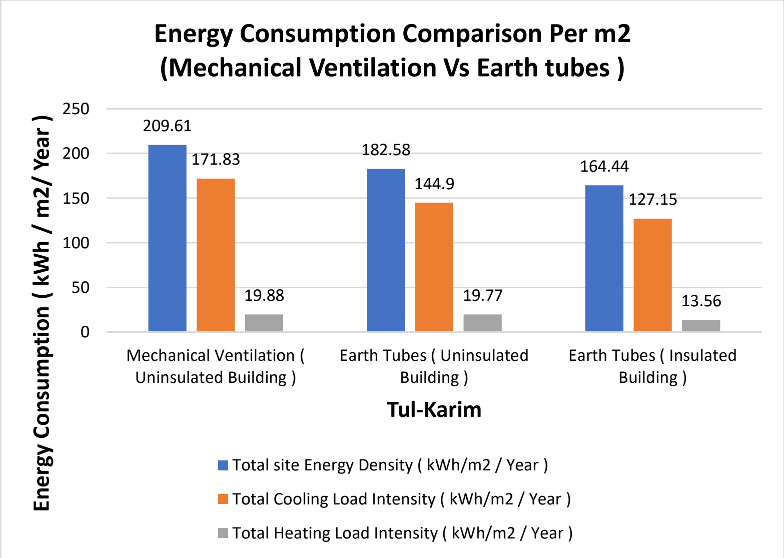


Figure 6

Energy saving kWh per Year when using Earth Tubes for ventilation in Insulated and Uninsulated building in Tul-Karim city

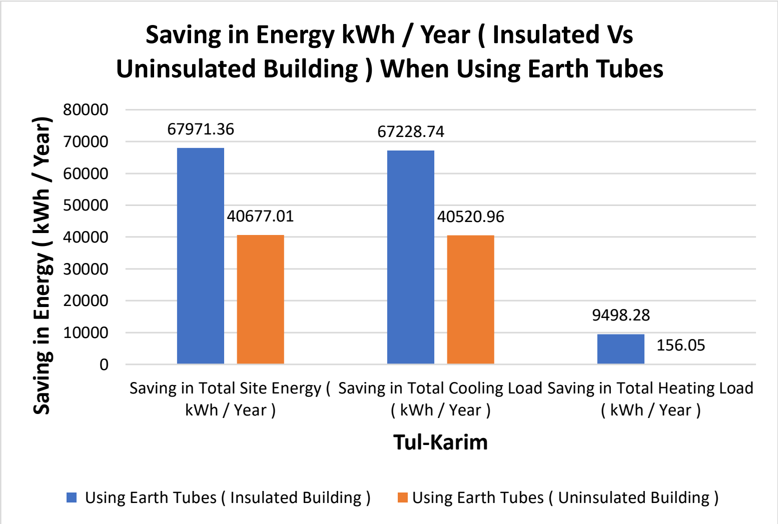


Figure 7

Comparison of Energy consumption kWh/m2 per Year between Mechanical and Earth Tubes Ventilation systems in Insulated and Uninsulated building in Jericho city

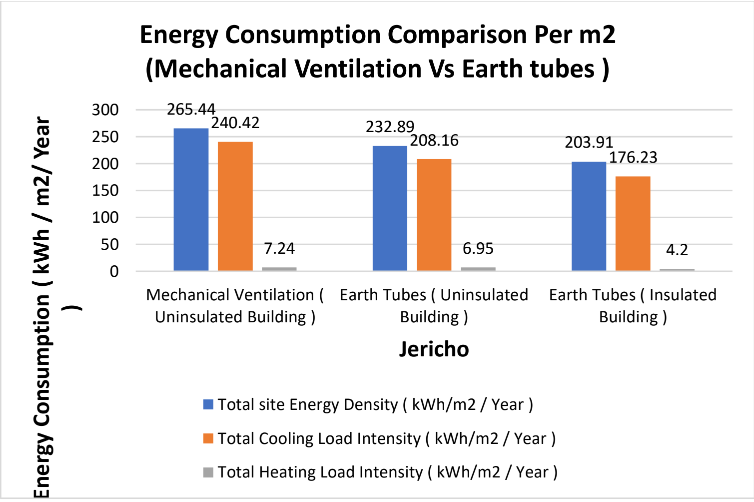


Figure 8

Energy saving kWh per Year when using Earth Tubes for ventilation in Insulated and Uninsulated building in Jericho city

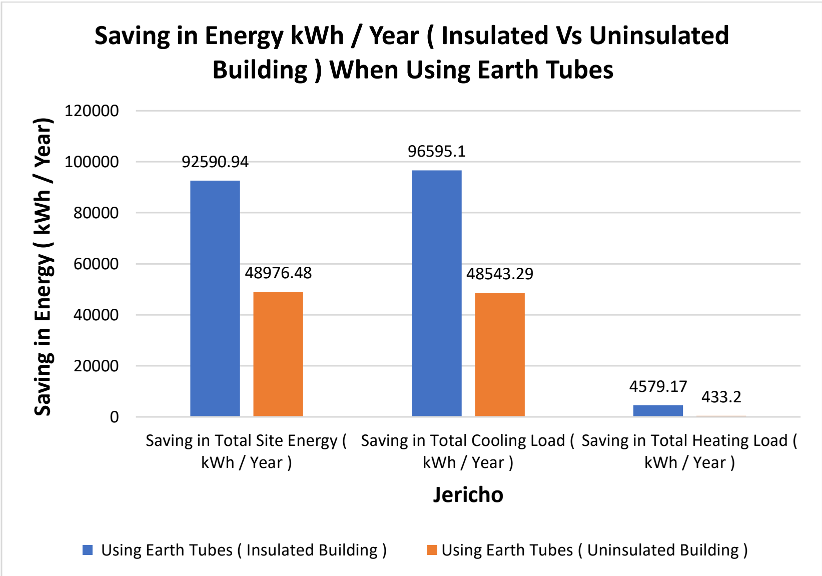


Figure 9

Comparison of Energy consumption kWh/m2 per Year between Mechanical and Earth Tubes Ventilation systems in Insulated and Uninsulated building in South-Hebron city

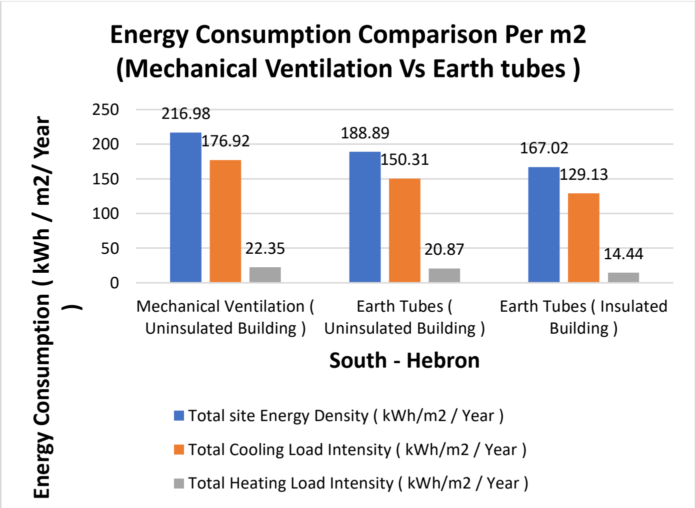


Figure 10

Energy saving kWh per Year when using Earth Tubes for ventilation in Insulated and Uninsulated building in South-Hebron city

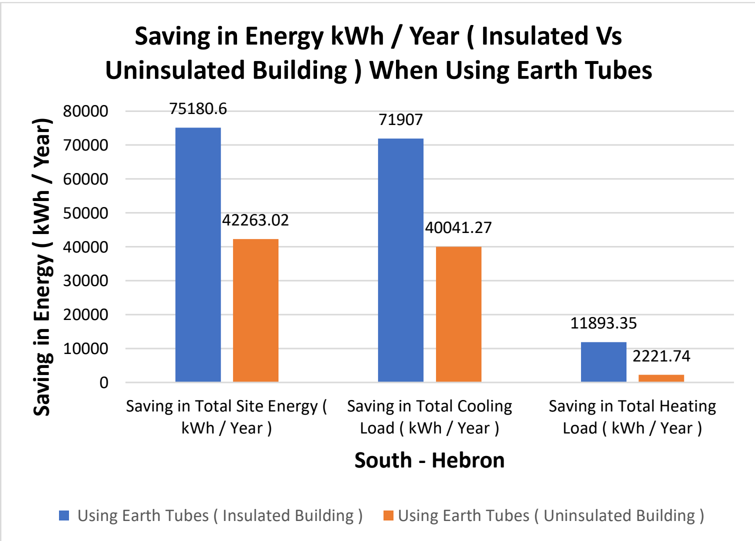


Figure 11

Comparison of Energy consumption kWh/m2 per Year between Mechanical and Earth Tubes Ventilation systems in Insulated and Uninsulated building in Gaza City

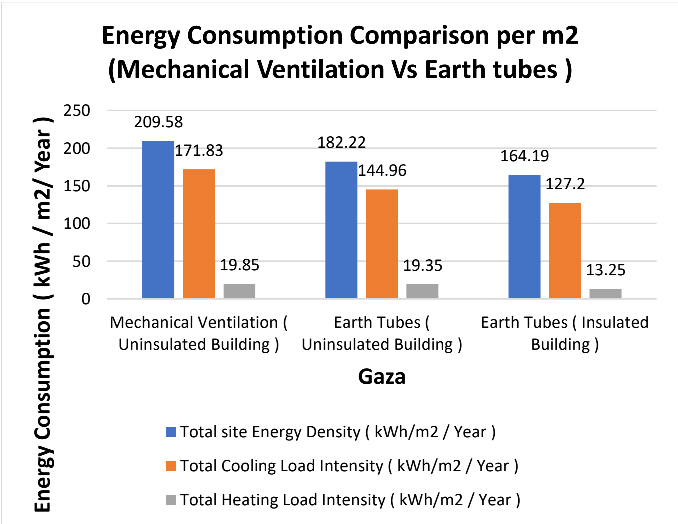


Figure 12

Energy saving kWh per Year when using Earth Tubes for ventilation in Insulated and uninsulated building in Gaza City

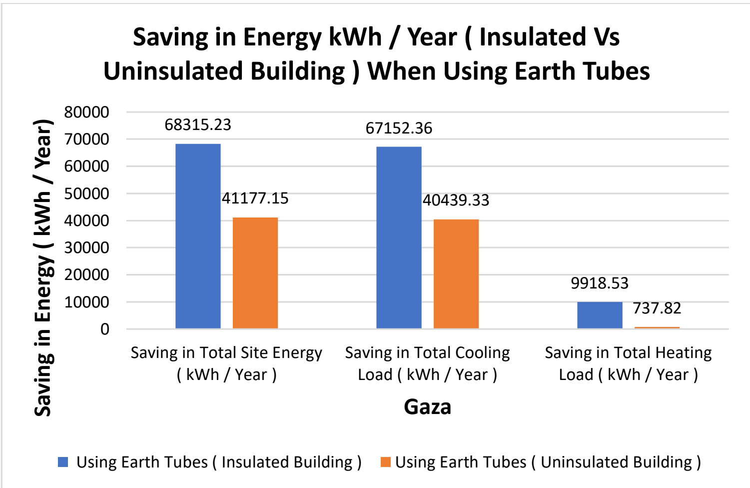


Figure 13

Percentage (%) of Energy saving per Year when using Earth Tubes ventilation instead of Mechanical ventilation in Insulated and uninsulated building for the five Palestinian cities

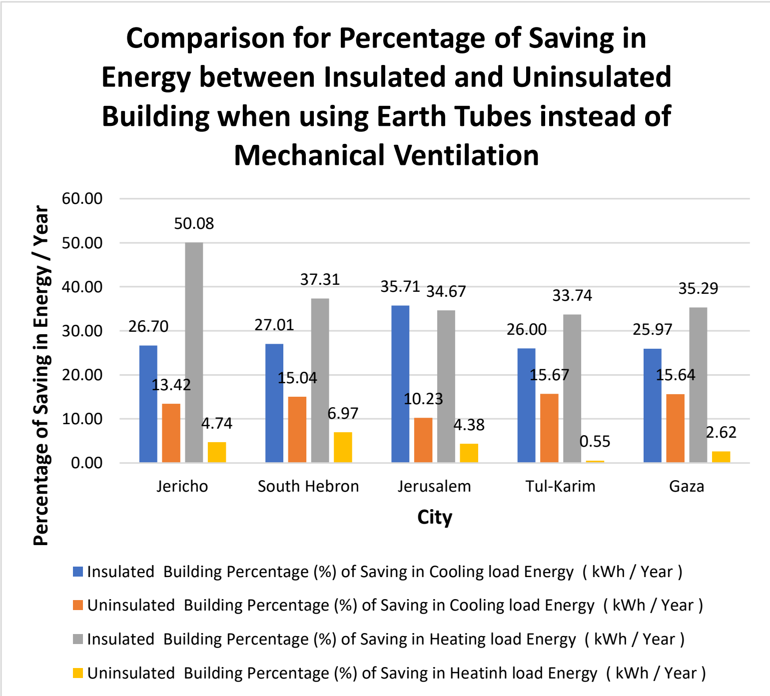
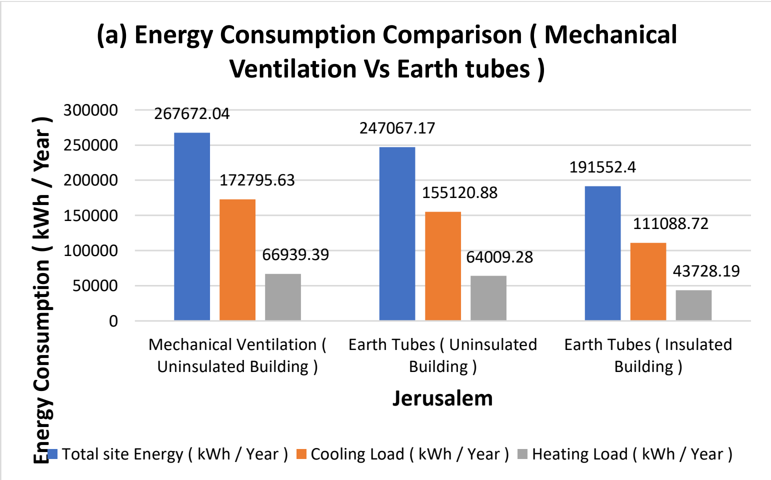


Figure 14

a. Energy consumption kWh per Year between Mechanical and Earth Tubes Ventilation systems

b. Percentage of Energy saving per Year when using Earth Tubes for ventilation for Insulated and uninsulated building in Jerusalem city



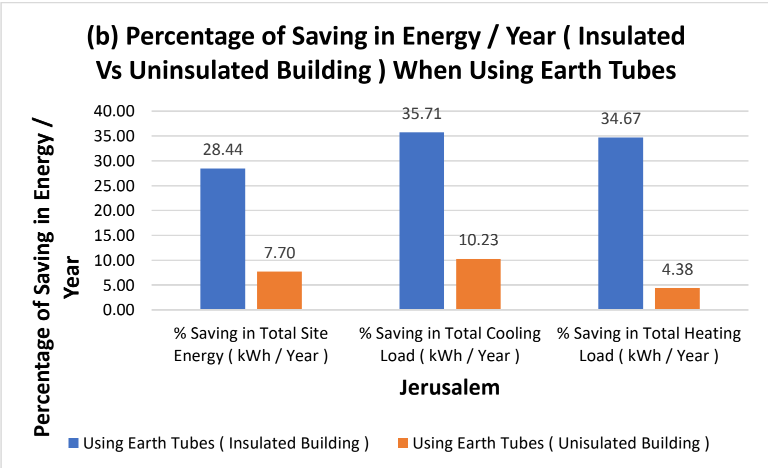


Figure 15

a. Energy consumption kWh per Year between Mechanical and Earth Tubes Ventilation systems

b. Percentage of Energy saving per Year when using Earth Tubes for ventilation for Insulated and uninsulated building in Tul-Karim city

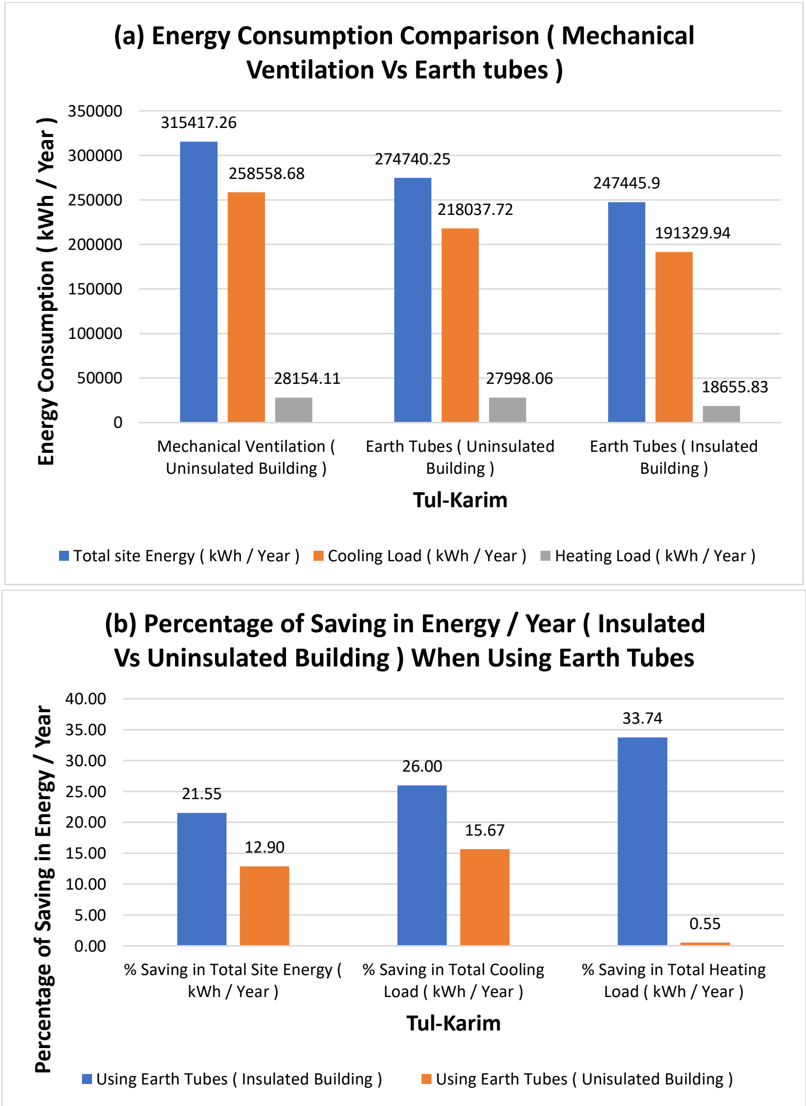
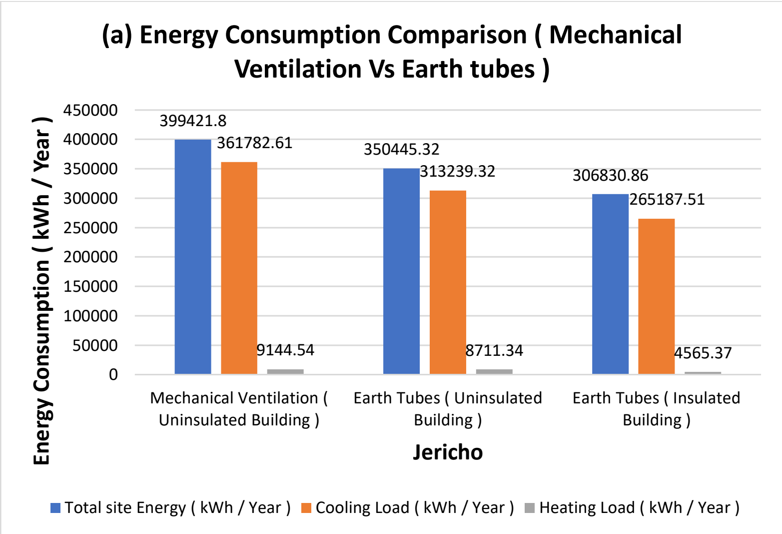


Figure 16

a. Energy consumption kWh per Year between Mechanical and Earth Tubes Ventilation systems

b. Percentage of Energy saving per Year when using Earth Tubes for ventilation for Insulated and uninsulated building in Jericho city



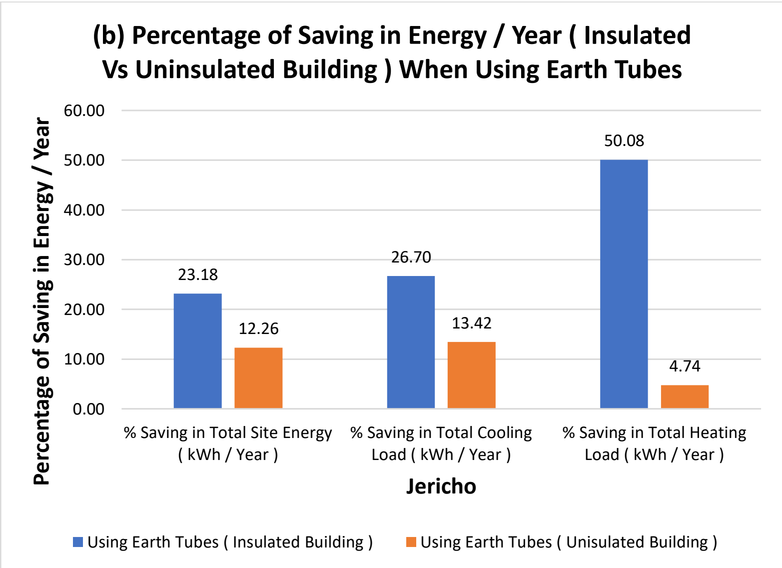
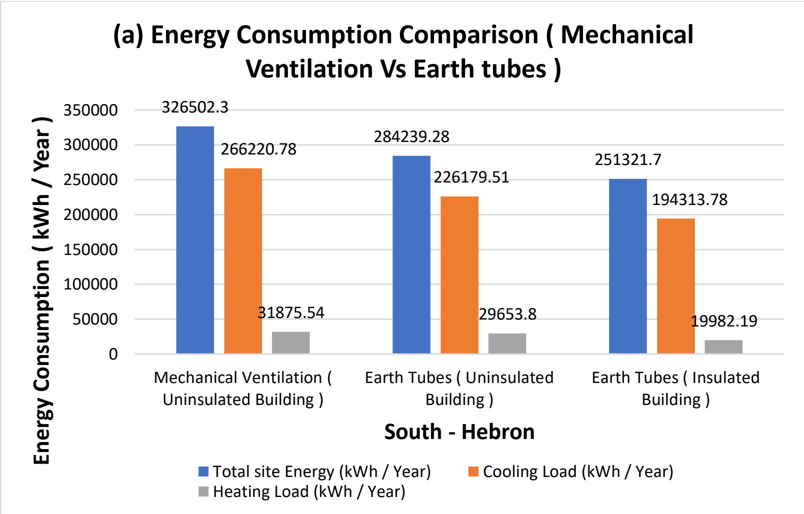


Figure 17

a. Energy consumption kWh per Year between Mechanical and Earth Tubes Ventilation systems

b. Percentage of Energy saving per Year when using Earth Tubes for ventilation for Insulated and uninsulated building in South-Hebron city



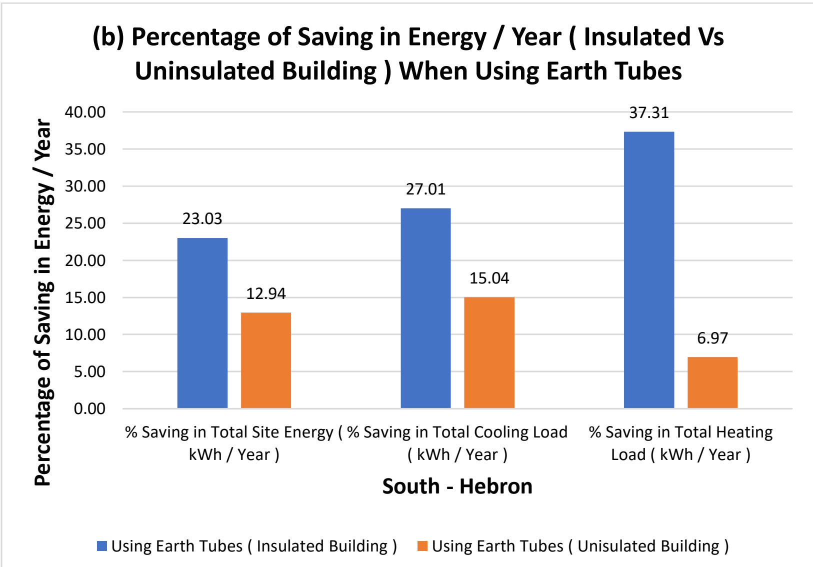
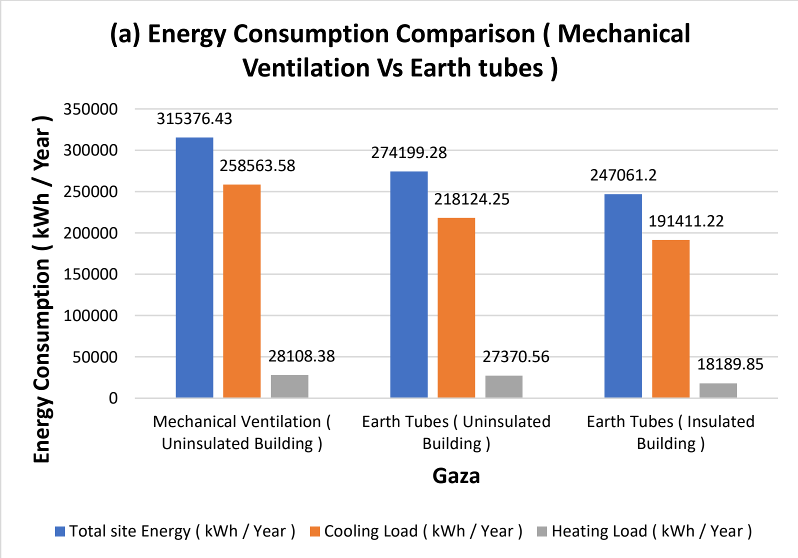
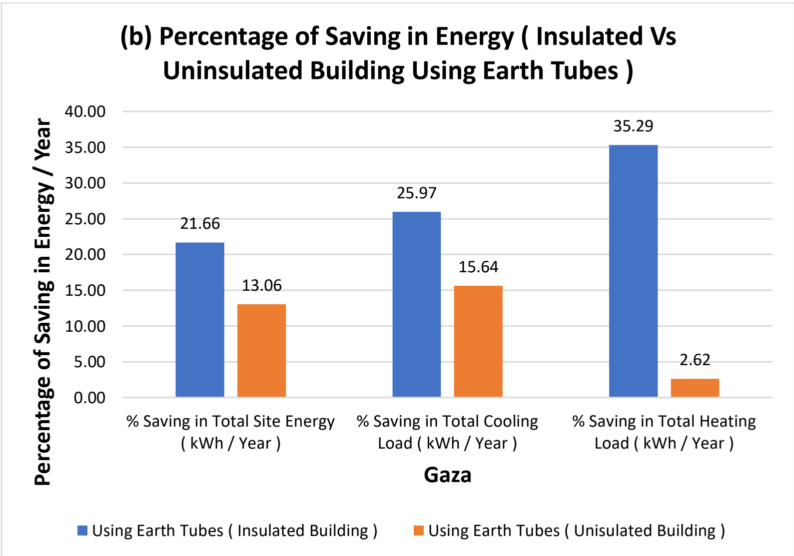


Figure 18

a. Energy consumption kWh per Year between Mechanical and Earth Tubes Ventilation systems

b. Percentage of Energy saving per Year when using Earth Tubes for ventilation for Insulated and uninsulated building in Gaza city





Appendix B

Economical Study Figures

Figure 1

Cumulative Cash flow chart for Jericho city (GAHP system)

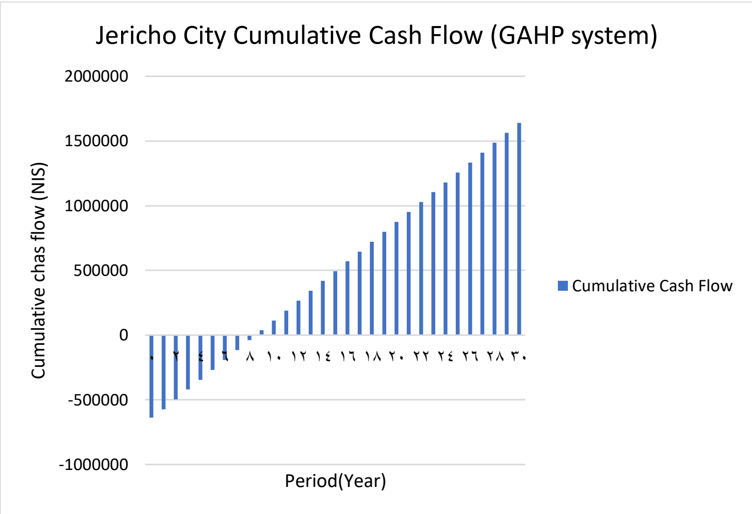


Figure 2

Cumulative Cash flow chart for South-Hebron city (GAHP system)

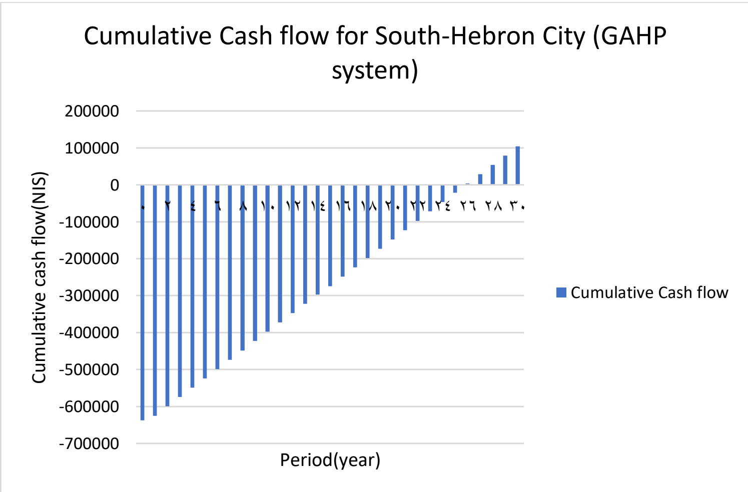


Figure 3

Cumulative Cash flow chart for Jericho city (Earth tube system)

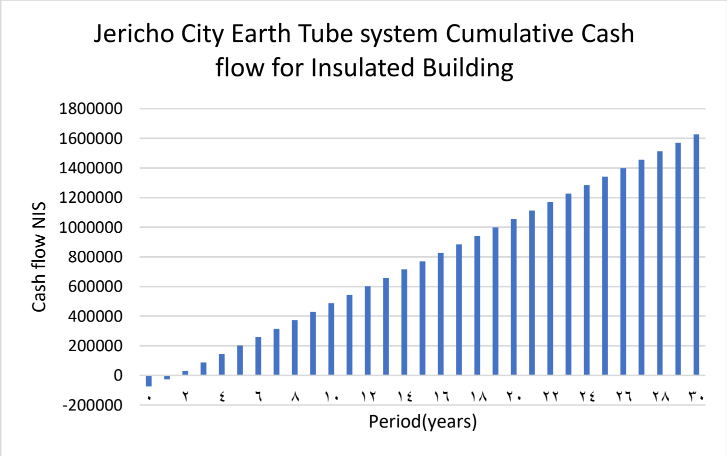


Figure 4

Cumulative city Cash flow chart for South-Hebron (Earth tube system)

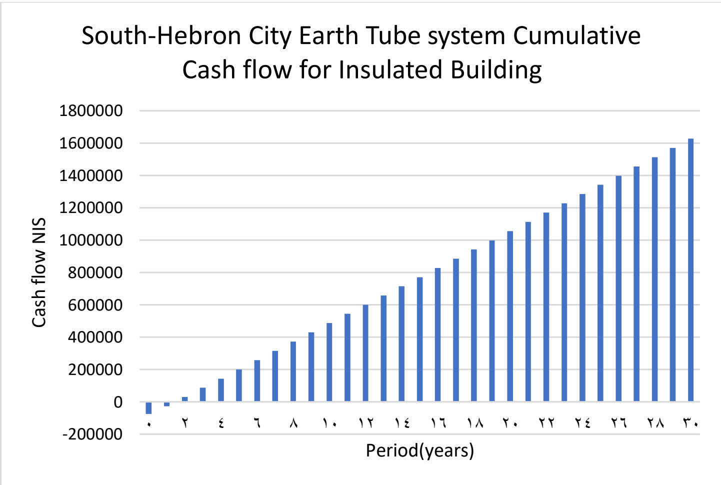


Figure 5

Cumulative Cash flow chart for Jerusalem city (Earth tube system)

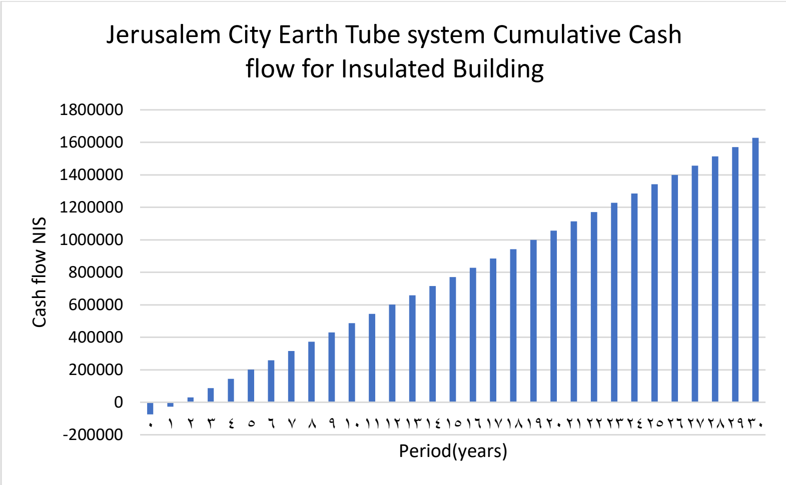


Figure 6

Cumulative Cash flow chart for Tul-Karim city (Earth tube system)

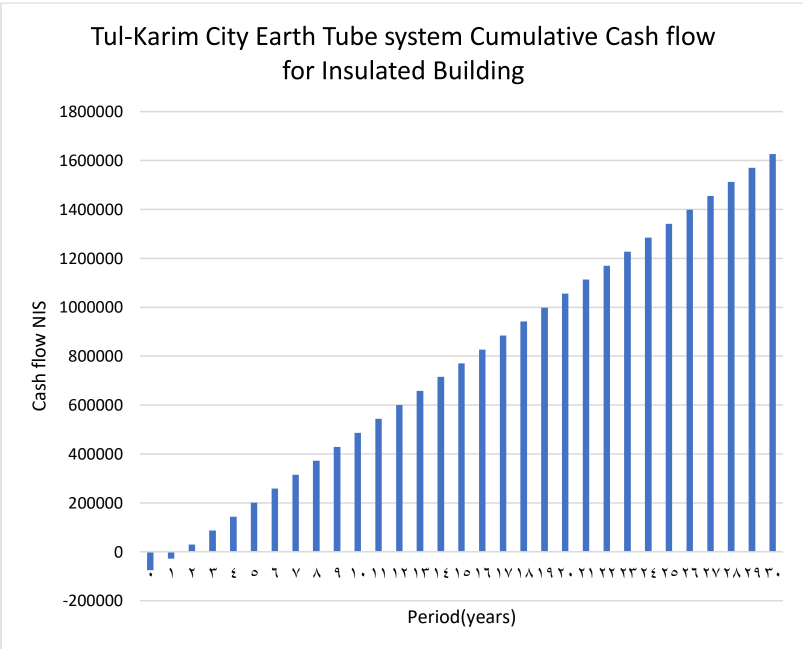


Figure 7

Cumulative Cash flow chart for Gaza city (Earth tube system)

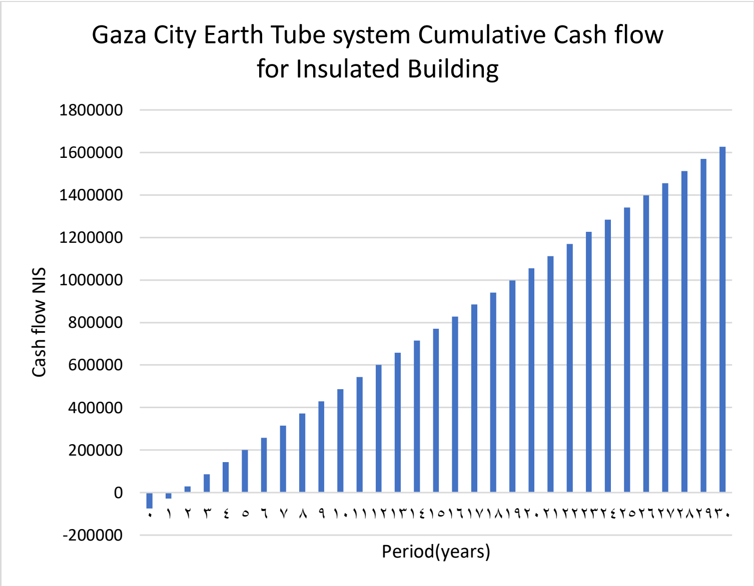


Figure 8

Feasibility study for Jericho City (GAHP system)

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works (Drilling And Fillig)		380,000					
Supply and Installation the GHX and Heat Pump System for one time.		137,760					
Cost of Insulation the school building (material+Instalation cost)		116,100					
Heat Pump Replacement		0					
Total Investment Cost		633,860	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			13,000	0	0	0	0
Operation Cost							
Regular Maintenance			150	150	150	150	150
Heat Pump Electricity consumption cost		3,370	3,370	3,370	3,370	3,370	3,370
Total Operation Cost		3,370	3,520	3,520	3,520	3,520	3,520
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	122936*0.65		79,908	79,908	79,908	79,908	79,908
Electricity Saved							
Total		0	63,389	76,388	76,388	76,388	76,388
Cash Flow		-63 7,230	63,389	76,388	76,388	76,388	76,388
Cumulative Cash Flow		-63 7,230	-57 3,841	-49 7,452	-42 1,064	-34 4,676	-26 8,287

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,500		
0	0	0	0	0	0	0	0	0	2,500	0	0
0	0	0	0	0	0	0	0	0	0	0	0
150	150	150	150	150	150	150	150	150	150	150	150
3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370
3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520
0	0	0	0	0	0	0	0	0	0	0	0
79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908
76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	73,888	76,388	76,388
76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	73,888	76,388	76,388
-19 1,899	-11 5,510	-3 9,122	37,266	11 3,655	19 0,043	26 6,432	34 2,820	41 9,208	49 3,097	56 9,485	64 5,874

2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	150	150	150	150	150	150	150	150	150	150	150	150	150
3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370
3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520
0	0	0	0	0	0	0	0	0	0	0	0	0	0
79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908	79,908
76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388
76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388	76,388
64 5,874	72 2,262	79 8,650	87 5,039	95 1,427	1,02 7,816	1,10 4,204	1,18 0,592	1,25 6,981	1,33 3,369	1,40 9,758	1,48 6,146	1,56 2,534	1,63 8,923

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jericho City	122,936	kWh/Year
3.Price are in Shekel (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investment cost (TIC)=	633,860	NIS
Simple payback period (SPP)	8.3	Years
Feasibility Study Result	Feasible	

Figure 9

Feasibility study for South-Hebron City (GAHP system)

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works (Drilling And Fillig)		380,000					
Supply and Installation the GHX and Heat Pump System for one time.		137,760					
Cost of Insulation the school building (material+Instalation cost)		116,100					
Heat Pump Replacement		0					
Total Investment Cost		633,860	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			13,000	0	0	0	0
Operation Cost							
Regular Maintenance			150	150	150	150	150
Heat Pump Electricity consumption cost		3,370	3,370	3,370	3,370	3,370	3,370
Total Operation Cost		3,370	3,520	3,520	3,520	3,520	3,520
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	44252*0.65		28,764	28,764	28,764	28,764	28,764
Electricity Saved							
Total		0	1 2,244	25,244	25,244	25,244	25,244
Cash Flow		-63 7,230	1 2,244	25,244	25,244	25,244	25,244
Cumulative Cash Flow		-63 7,230	-62 4,985	-59 9,741	-57 4,497	-54 9,253	-52 4,009

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,500		
0	0	0	0	0	0	0	0	0	2,500	0	0
0	0	0	0	0	0	0	0	0	0	0	0
150	150	150	150	150	150	150	150	150	150	150	150
3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370
3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520
0	0	0	0	0	0	0	0	0	0	0	0
28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764
25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	22,744	25,244	25,244
25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	22,744	25,244	25,244
-49 8,764	-47 3,520	-44 8,276	-423,032	-39 7,788	-37 2,543	-34 7,299	-32 2,055	-29 6,811	-27 4,067	-24 8,822	-22 3,578

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
150	150	150	150	150	150	150	150	150	150	150	150	150
3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370	3,370
3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520	3,520
0	0	0	0	0	0	0	0	0	0	0	0	0
28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764	28,764
25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244
25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244	25,244
-19 8,334	-17 3,090	-14 7,846	-12 2,601	-9 7,357	-7 2,113	-4 6,869	-2 1,625	0 3,620	2 8,864	5 4,108	7 9,352	10 4,596

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for South-Hebron City	44,252	kWh/Year
3.Price are in Shekel (NIS)		
4.Study period 30 years		
(Without bank interest):		
Total investmrnt cost (TIC)=	633,860	NIS
Simple payback period (SPP)	25.1	Years
Feasibility Study Resut	Not Feasible	

Figure 10

Jericho city insulated school building cash flow (Earth Tubes system)

Year		2022	2023	2024	2025
Period		0	1	2	3
Investment Cost					
Civil Works(excavations and fillig) + Installation work		8,850			
Materialcost for Earth Tube system for one time.		3,180			
Cost of Insulation the school building (material+Instalation cost)		63,000			
Fan Replacement		0			
Total Investment Cost		66,180	0	0	0
Engineering Services (Design, Studies and Supervision)			10,000	0	0
Operation Cost					
Regular Maintenance			100	100	100
Fan Electricity consumption cost		8,541	8,541	8,541	8,541
Total Operation Cost		8,541	8,641	8,641	8,641
Salvage Value of All System			0	0	0
Income Cost (Saving Cost)	101174.27*0.65		65,763	65,763	65,763
Electricity Saved					
Total		0	47,122	57,122	57,122
Cash Flow		-7 4,721	47,122	57,122	57,122
Cumulative Cash Flow		-7 4,721	-2 7,599	2 9,524	8 6,646

2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
4	5	6	7	8	9	10	11	12	13	14	15	16	17
											2,000		
0	0	0	0	0	0	0	0	0	0	0	2,000	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0	0
65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763
57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	55,122	57,122	57,122
57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	55,122	57,122	57,122
14 3,768	20 0,890	25 8,013	31 5,135	37 2,257	429,379	48 6,502	54 3,624	60 0,746	65 7,869	71 4,991	77 0,113	82 7,235	88 4,358

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0
65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763	65,763
57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122
57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122	57,122
94 1,480	99 8,602	1,05 5,725	1,11 2,847	1,16 9,969	1,22 7,091	1,28 4,214	1,34 1,336	1,39 8,458	1,45 5,580	1,51 2,703	1,56 9,825	1,62 6,947

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jericho City Insulated building	101,174	kWh/Year
3.Price are in Shekel (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investmrnt cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.2	Years
Feasibility Study Resut	Feasible	

Figure 11

South-Hebron city insulated school building cash flow

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works(excavations and fillig) + Installation work		8,850					
Materialcost for Earth Tube system for one time.		3,180					
Cost of Insulation the school building (material+Instalation cost)		63,000					
Fan Replacement		0					
Total Investment Cost		66,180	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			10,000	0	0	0	0
Operation Cost							
Regular Maintenance			100	100	100	100	100
Fan Electricity consumption cost		8,541	8,541	8,541	8,541	8,541	8,541
Total Operation Cost		8,541	8,641	8,641	8,641	8,641	8,641
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	83800*0.65		54,470	54,470	54,470	54,470	54,470
Electricity Saved							
Total		0	35,829	45,829	45,829	45,829	45,829
Cash Flow		-7 4,721	35,829	45,829	45,829	45,829	45,829
Cumulative Cash Flow		-7 4,721	-3 8,892	0 6,937	5 2,767	9 8,596	14 4,425

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,000		
0	0	0	0	0	0	0	0	0	2,000	0	0
0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0
54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470
45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	43,829	45,829	45,829
45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	43,829	45,829	45,829
19 0,254	23 6,084	28 1,913	327,742	37 3,571	41 9,401	46 5,230	51 1,059	55 6,888	60 0,717	64 6,547	69 2,376

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0
54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470	54,470
45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829
45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829	45,829
73 8,205	78 4,034	82 9,864	87 5,693	92 1,522	96 7,351	1,01 3,180	1,05 9,010	1,10 4,839	1,15 0,668	1,19 6,497	1,24 2,327	1,28 8,156

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for South-Hebron	83,800	kWh/Year
City InsulatedBuilding		
3.Price are in Shekel (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investmrnt cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.4	Years
Feasibility Study Resut	Feasible	

Figure 12

Jerusalem city insulated school building cash flow

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works(excavations and fillig) + Installation work		8,850					
Materialcost for Earth Tube system for one time.		3,180					
Cost of Insulation the school building (material+Instalation cost)		63,000					
Fan Replacement		0					
Total Investment Cost		66,180	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			10,000	0	0	0	0
Operation Cost							
Regular Maintenance			100	100	100	100	100
Fan Electricity consumption cost		8,541	8,541	8,541	8,541	8,541	8,541
Total Operation Cost		8,541	8,641	8,641	8,641	8,641	8,641
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	84918.11*0.65		55,197	55,197	55,197	55,197	55,197
Electricity Saved							
Total		0	36,556	46,556	46,556	46,556	46,556
Cash Flow		-7 4,721	36,556	46,556	46,556	46,556	46,556
Cumulative Cash Flow		-7 4,721	-3 8,165	0 8,391	5 4,946	10 1,502	14 8,058

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,000		
0	0	0	0	0	0	0	0	0	2,000	0	0
0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0
55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197
46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	44,556	46,556	46,556
46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	44,556	46,556	46,556
19 4,614	24 1,169	28 7,725	334,281	38 0,837	42 7,392	47 3,948	52 0,504	56 7,060	61 1,616	65 8,171	70 4,727

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0
55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197	55,197
46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556
46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556	46,556
75 1,283	79 7,839	84 4,394	89 0,950	93 7,506	98 4,062	1,03 0,618	1,07 7,173	1,12 3,729	1,17 0,285	1,21 6,841	1,26 3,396	1,30 9,952

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Jerusalem	84,918	kWh/Year
City InsulatedBuilding		
3.Price are in Shekel (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investmrnt cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.4	Years
Feasibility Study Resut	Feasible	

Figure 13

Tul-Karim city insulated school building cash flow

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works(excavations and fillig) + Installation work		8,850					
Materialcost for Earth Tube system for one time.		3,180					
Cost of Insulation the school building (material+Instalation cost)		63,000					
Fan Replacement		0					
Total Investment Cost		66,180	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			10,000	0	0	0	0
Operation Cost							
Regular Maintenance			100	100	100	100	100
Fan Electricity consumption cost		8,541	8,541	8,541	8,541	8,541	8,541
Total Operation Cost		8,541	8,641	8,641	8,641	8,641	8,641
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	76727*0.65		49,873	49,873	49,873	49,873	49,873
Electricity Saved							
Total		0	31,232	41,232	41,232	41,232	41,232
Cash Flow		-7 4,721	31,232	41,232	41,232	41,232	41,232
Cumulative Cash Flow		-7 4,721	-4 3,489	-0 2,258	3 8,974	8 0,205	12 1,437

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,000		
0	0	0	0	0	0	0	0	0	2,000	0	0
0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0
49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873
41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	39,232	41,232	41,232
41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	39,232	41,232	41,232
16 2,668	20 3,900	24 5,132	286,363	32 7,595	36 8,826	41 0,058	45 1,289	49 2,521	53 1,752	57 2,984	61 4,216

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0
49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873	49,873
41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232
41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232	41,232
65 5,447	69 6,679	73 7,910	77 9,142	82 0,373	86 1,605	90 2,837	94 4,068	98 5,300	1,02 6,531	1,06 7,763	1,10 8,994	1,15 0,226

Note:			
1. Electricity price =		0.65	NIS/kWh
2. Total Energy Saving for Tul-Karim City		76,727	kWh/Year
InsulatedBuilding			
3.Price are in Shekel (NIS)			
4.Study Period 30 years			
(Without bank interest):			
Total investmrnt cost (TIC)=		66,180	NIS
Simple payback period (SPP)		1.6	Years
Feasibility Study Resut		Feasible	

Figure 14

Gaza city insulated school building cash flow

Year		2022	2023	2024	2025	2026	2027
Period		0	1	2	3	4	5
Investment Cost							
Civil Works(excavations and fillig) + Installation work		8,850					
Materialcost for Earth Tube system for one time.		3,180					
Cost of Insulation the school building (material+Instalation cost)		63,000					
Fan Replacement		0					
Total Investment Cost		66,180	0	0	0	0	0
Engineering Services (Design, Studies and Supervision)			10,000	0	0	0	0
Operation Cost							
Regular Maintenance			100	100	100	100	100
Fan Electricity consumption cost		8,541	8,541	8,541	8,541	8,541	8,541
Total Operation Cost		8,541	8,641	8,641	8,641	8,641	8,641
Salvage Value of All System			0	0	0	0	0
Income Cost (Saving Cost)	77071*0.65		50,096	50,096	50,096	50,096	50,096
Electricity Saved							
Total		0	31,455	41,455	41,455	41,455	41,455
Cash Flow		-7 4,721	31,455	41,455	41,455	41,455	41,455
Cumulative Cash Flow		-7 4,721	-4 3,266	-0 1,811	3 9,644	8 1,099	12 2,554

2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
6	7	8	9	10	11	12	13	14	15	16	17
									2,000		
0	0	0	0	0	0	0	0	0	2,000	0	0
0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0
50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096
41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	39,455	41,455	41,455
41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	39,455	41,455	41,455
16 4,009	20 5,465	24 6,920	288,375	32 9,830	37 1,285	41 2,740	45 4,195	49 5,650	53 5,105	57 6,560	61 8,015

18	19	20	21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100	100
8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541	8,541
8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641
0	0	0	0	0	0	0	0	0	0	0	0	0
50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096	50,096
41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455
41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455	41,455
65 9,470	70 0,925	74 2,381	78 3,836	82 5,291	86 6,746	90 8,201	94 9,656	99 1,111	1,03 2,566	1,07 4,021	1,11 5,476	1,15 6,931

Note:		
1. Electricity price =	0.65	NIS/kWh
2. Total Energy Saving for Gaza City	77,071	kWh/Year
InsulatedBuilding		
3.Price are in Shekel (NIS)		
4.Study Period 30 years		
(Without bank interest):		
Total investment cost (TIC)=	66,180	NIS
Simple payback period (SPP)	1.6	Years
Feasibility Study Result	Feasible	

جـامعــة النجاح الوطنية
كليــة الدراســات العليــا

إمكانيات الطاقة الحرارية الجوفية لكفاءة استخدام الطاقة في المباني في فلسطين

إعداد
عارف رشاد عارف عبد الكريم

إشراف
د.معتصم بعباع

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الإستهلاك، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2023

إمكانيات الطاقة الحرارية الجوفية لكفاءة استخدام الطاقة في المباني في فلسطين

إعداد

عارف رشاد عارف عبد الكريم زكارنه

إشراف

د.معتصم بعباع

الملخص

يرتبط ٤٠٪ تقريبًا من استهلاك الطاقة في جميع أنحاء العالم بالمباني. وبالتالي ، فإن قطاعات البناء ضرورية لتحقيق أهداف الطاقة والبيئة لإزالة الكربون بحلول عام ٢٠٥٠. ومع ذلك ، فإن غالبية المباني في فلسطين مبنية بمعايير منخفضة الكفاءة بالطاقة مما ينتج عنه مبانٍ ذات استهلاك مرتفع الطاقة. في السنوات الأخيرة ، تم إجراء الكثير من الدراسات والتطبيقات حول إيجاد حلول موفرة للطاقة للمباني القائمة لمعالجة المشاكل المذكورة أعلاه بشكل صحيح في مختلف البلدان. الطاقة الحرارية الأرضية ، باعتبارها واحدة من أكثر تقنيات الطاقة المتجددة شيوعًا ، تم استخدامها واستكشافها للتقليل من اسهلاك الطاقة في عمليتي التدفئة و التبريد ولتقليل انبعثات الغازات الدفيئة الناتجة عن توليد الكهرباء من مصادر الطاقة الأحفورية كالنفط والغاز. نعني بالطاقة الحرارية الأرضية موارد الطاقة الحرارية الأرضية التي يقل عمقها عن ٢٠٠ متر ، والتي تُعرف أيضًا بأنها طاقة حرارية سطحية. هذه الطاقة ليست مقيدة جغرافيا ، وهذه الطاقة متوفرة بشكل مستمر وموثوق تقريبا في كل مكان في العالم حيث تتراوح درجة حرارتها بين ٥ – ٣٠ درجة مئوية. ومع ذلك ، فإن مصدر الطاقة المتجددة هذا في فلسطين لم يتم استكشافه على نطاق واسع مع القليل من الدراسات حول جدواه. ومع ذلك ، تختلف هذه التقنية عن تقنيات توفير الطاقة الشائعة (على سبيل المثال ، الألواح الشمسية الكهروضوئية) ، ويمكن للألواح الشمسية وطاقة الرياح إنتاج الكهرباء فقط في وقت النهار وعندما تكون هناك رياح ، يلزم أيضًا الحصول على موافقة وتوقيع عقود طويلة الأمد من السلطات لتثبيتها ، ولا تتوفر دائمًا مساحة كافية لتركيب هذه الأنظمة. ولكن في حالة الطاقة الحرارية الأرضية ، فإنها متوفرة

على مدار اليوم والأسبوع والسنة واستخدام مصدر الطاقة المتجددة هذا لا يتطلب أي عقد أو موافقات من السلطات، كما أنها متوفرة في كل مكان على الأرض والمساحة المطلوبة لتركيبها أقل ووقت وتكلفة صيانها أقل أيضا. كل هذه المزايا على الأنظمة المتجددة الأخرى تجعل الطاقة الحرارية الأرضية واحدة من أكثر الطاقات المتجددة الواعدة.

تم في هذا البحث دراسة نوعين من تطبيقات الطاقة الحرارية الأرضية ؛ "تكنولوجيا المضخات الحرارية بمساعدة الحرارة الأرضية (GAHP) و"تقنية ألأنابيب الأرضية (ET) "لمختلف المناطق المناخية في فلسطين، وهي صيف حار جاف وشتاء دافئ في مدينة أريحا، صيف حار وجاف وشتاء بارد في جنوب الخليل، جو رطب و حار صيفا ومعتدل شتاءا في غزة وطولكرم، وأخيراً صيف معتدل وشتاء بارد في مدينة القدس العاصمة الأبدية لدولة فلسطين، وجدنا أن استهلاك الطاقة للتدفئة والتبريد يمكن أن ينخفض بنسبة (٤٢٪ في التدفئة إلى ٥٨,٨٪ في التبريد) عند استخدام نظام GAHP، وعند استخدام نظام ET يتراوح هذا التخفيض باستهلاك الطاقة ما بين ٣٣,٧٪ إلى ٥٠,١٪ في التدفئة، و ٢٦٪ إلى ٣٥,٧٪ في التبريد). وهذا يثبت أن استخدام هذه الطاقة الدائمة والنظيفة أمر ممكن في فلسطين، ويمكن أن يقلل بشكل فعال من استهلاك الطاقة ، ويوفر راحة أفضل ويقلل من الأثر البيئي المترتب بسبب عملية التدفئة والتبريد في المباني.

الكلمات المفتاحية: الطاقة الحرارية الأرضية، الطاقة المتجددة، المضخة الحرارية، الأنابيب الأرضية.