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Geothermal Energy Potential for Power Generation in Palestine: A Case Study in Nablus

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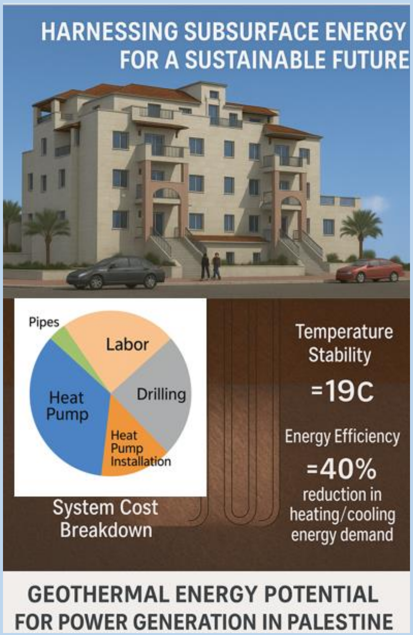
Abstract: Palestinians now incur the highest energy expense rates in the area. The Palestinian population has increased, and therefore, the number of devices in use has multiplied many times compared to a decade ago. The country's circumstances previously did not necessitate air conditioners; however, they have now become essential due to climate change and the proliferation of factories and installations, leading to an excess of electrical energy. Therefore, it is imperative to utilize natural energy sources to mitigate the consumption of non-renewable energy and the environmental pollution caused by fossil fuels. A geothermal heating and cooling system is an excellent, environmentally friendly choice. Geothermal energy is environmentally advantageous, operates continuously, and has a prolonged lifespan. The system utilizes a vertical ground heat exchanger installed at a depth of 70 meters via water pipes, facilitating heat transfer from the soil. An economical duct system circulates both heated and cooled air throughout the building and has a fresh air inlet. This research will evaluate the advantages and disadvantages of geothermal energy in comparison to other energy sources, namely electricity, focusing on cost, maintenance, and efficiency in heating and air conditioning at Hardee's restaurant. It was found that the overall thermal resistance was 0.4 $m^2.^oC/W$ and the average ground temperature was 19 ^oC. Geothermal energy remains underused in Palestine, and thus addresses the question, "Has this conceptual project been implemented in any building previously?" Geothermal energy is underexploited in Palestine; hence, its use is imperative. Given these advantages, it is recommended to use geothermal energy in locations that operate daily for 12 hours, as well as in areas with sufficient space for drilling. Hardee's restaurant in Nablus was selected because of its operation seven days a week for twelve hours daily, resulting in a consistently short recovery time, which we estimate to be around 40 Months.



Keywords: Geothermal, Palestine, energy saving, Air conditioning, Vertical ground loop, Heat pump, Sustainability, Environment.

Introduction

Energy costs in Palestine are significantly elevated compared to other nations, and due to persistent high population growth, there are no indigenous energy resources in Palestine to satisfy the needs of this increase. The Palestinian populace relies on purchasing electricity from the Israeli occupation, which generates substantial economic returns for the occupiers, consistently yielding significant profits and contributing to their overall satisfaction (1, 2).

It is essential to explore alternatives for energy sources, and geothermal energy may be a viable option in Palestine, which will be examined in this research (3, 4).

Geothermal heat pump (GHP) systems are categorized into closed-loop and open-loop combinations, each possessing distinct benefits. Closed-loop systems consist of horizontal loops, which are economical but necessitate more land area, and vertical loops, which are space-efficient but incur higher costs owing to extensive drilling. Pond/lake loops provide economical installation but need proximity to a water feature. Open-loop systems, utilizing groundwater directly, offer optimal efficiency but are contingent upon the availability and quality of water. Hybrid systems integrate geothermal energy with alternative heating and cooling technologies to enhance efficiency. The selection of a system is contingent upon land availability, water accessibility, efficiency requirements, and financial limitations. Table 1 summarizes the principal distinctions among various Geothermal Heat Pump (GHP) systems.

In 2024, a considerable increase in installed power production capacity is predicted, with substantial projects expected to enter operations in Kenya, Indonesia, the Philippines, and New Zealand. In North America, development persists, characterized by increased interest in recent geothermal license auctions, progress by new entrepreneurs

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employing novel technology, and ongoing development initiatives, leading to a consistent rise in figures. In Europe, the predominant emphasis remains on geothermal development for heating, whilst power generation initiatives are constrained, with Turkey seeing a somewhat sluggish market owing to existing conditions [10].

A geothermal system in Palestine decreased yearly heating and cooling expenses from $3,000 to $850, signifying a reduction of 70% (11). Moreover, geothermal systems can decrease energy usage by 30% to 70% during heating and by 20% to 50% during cooling (12). The horizontal ground loop heat pump system has an approximate simple payback period of four years, rendering it economically viable. A geothermal home system in Palestine has a straightforward payback time of 5.4 years (11). In contrast to conventional heating and cooling heat pumps, a geothermal heat pump exhibits a straightforward payback period of 1.5 to 3.2 years, notwithstanding the elevated initial expenses associated with excavation and installation (13). Geothermal systems are engineered to get a high coefficient of performance (COP). A system implemented in Ramallah is engineered to attain a minimum COP of 4.5 throughout the year, in contrast to a standard system with a COP of around 2.3 (11). The coefficient of performance (COP) of a traditional electric heat pump rose from 3.5-4 to 7 in cooling mode (13).

Table (1): The primary differences among various Geothermal Heat Pump (GHP) systems.

System Type	Configuration	Efficiency	Installation Cost	Ideal Applications	Pros	Cons
Closed-Loop Horizontal (5-8)	Coiled or straight pipes buried 1.5–2m (5–6.5 ft) underground	High (COP ~3–5)	Moderate	Residential, small commercial with land availability	Lower installation cost than vertical; good efficiency	Requires more land; performance affected by soil conditions
Closed-Loop Vertical (6, 9)	Pipes drilled 50–150m (165–500 ft) deep	High (COP ~3.5–5)	Higher	Large commercial buildings, areas with limited land space	Requires less land area; stable year-round temperatures	More expensive installation; requires deep drilling
Closed-Loop Pond/Lake (5, 6)	Coiled pipes submerged in a body of water	High (COP ~3.5–5)	Lower	Homes near a water source	Low installation cost; efficient heat transfer	Requires a nearby water source; potential environmental regulations
Open-Loop (5, 6, 9)	Uses groundwater from a well, then discharges it	Very High (COP ~4–6)	Lower	Areas with abundant groundwater	Most efficient; lower installation cost	Water quality and availability issues; potential environmental concerns
Hybrid Systems (5, 6)	Combination of geothermal and other heating/cooling systems	Variable	Variable	Large buildings, areas with fluctuating demand	Optimized efficiency and flexibility	More complex design and controls

To harvest geothermal energy, it is important to keep track of important information, such as geological surveys and measurements of temperature gradients. The process of geological surveys involves conducting investigations into the crust of the Earth at certain depths, assessing the composition of rocks, their ages, and the features of groundwater. For the purpose of determining the thermal conductivity of rocks, thermal gradient measurements require drilling to depths ranging from fifty to one hundred meters, collecting temperatures at a variety of levels, and using the data collected (14).

When it comes to deep exploration, drilling and testing are very necessary, and the choice of system to install is influenced by different elements. The meteorological conditions at the site, the qualities and composition of the soil, the initial cost of drilling, and the amount of space that is accessible inside the system are some of these, according to (14). When these factors were taken into consideration, the vertical ring system was chosen to be implemented at Hardee's restaurant, which is the primary subject of this investigation.

Customers come from all walks of life to dine at Hardee's Restaurant, which is a unique establishment that serves burgers prepared in the American way. At latitude 32.2 and longitude 35.2, Hardee's Restaurant is located on the southwest side of Nablus, directly across from An-Najah National University's new campus. HR consists of three stories, which are the basement, ground, first, and second floors. Each of these floors has a gross size of 495 m^2 and a height of 3.98 m. Figure 1 shows Hardee's Restaurant located in Nablus.

Geothermal systems that are vertical-loop and horizontal-loop are distinct from one another in terms of their design, land requirements, cost, efficiency, and suitability. Because vertical-loop systems need just a small amount of surface area and require digging deep boreholes (150–300 feet), they are well suited for use in urban or space-constrained settings. In contrast, horizontal-loop systems need more acreage and employ shallow ditches that are between four and six feet deep. These systems are best suited for wide rural areas. In general, vertical systems are more expensive than horizontal systems because they need more sophisticated deep drilling. Horizontal systems, on the other hand, are less expensive since they depend on simpler trenching methods. Vertical systems are more efficient and more stable than horizontal systems because deeper subsurface temperatures stay steady throughout the year. Horizontal systems, on the other hand, are more susceptible to the seasonal temperature swings that the ground experiences. Systems that are vertical are favored for places that have rocky or inappropriate soil conditions and limited space, while systems that are horizontal are better suited for regions that are big and open and have excellent soil characteristics. The decision is determined by site-specific considerations, as well as the requirements for cost and efficiency (1, 10).

The vertical-loop system is an excellent option for Hardee's Restaurant since it offers a number of benefits and is ideal for the restaurant's operational needs. When compared to horizontal systems, vertical loops are more effective since they depend on continuous ground temperatures that may be found at a depth of 6 m or greater. Additionally, vertical loops need less pipe than horizontal systems. The boreholes, which are normally between 13 and 18 centimeters in diameter and are located between 3 and 6 meters apart, make it possible to have a compact system that is suitable for places with limited space. Pipes with a diameter of two to three centimeters are introduced into each borehole, and this is followed by the installation of a U-bend at the bottom of the borehole. The connections are then established in a trench that is one to two meters below ground level. Due to the fact that pipe lengths can range from 91 to 183 m per ton of heat generated, proper design is very necessary in order to guarantee the best possible performance. Additionally, before installation, a test borehole may be dug in order to evaluate the soil conditions, check the design of the system, and determine the length of the loop. This further substantiates the system's feasible and effective use for this particular application (15-18).

For this particular investigation, the parallel system was selected because of its cost-effectiveness, its ability to make optimal use of space, and its conformity with the needs of the project. This method makes use of tubes with a smaller diameter, which are not only more cost-effective but also enable a more rapid flow according to the laws of fluid mechanics. The correct design guarantees that air is evacuated throughout the cleaning and maintenance activities, which assists in preserving the efficiency of the operation (4, 19).

The parallel system has a number of benefits, including cost-effectiveness as a result of the use of pipes with smaller diameters, which contribute to a considerable reduction in material charges; reduced freezing risk that needs less mitigation in comparison to other designs; and cheaper installation costs as a result of its simplicity. However, the system creates difficulties, such as the necessity to maintain balanced flow and speed across parallel routes within a tolerance of ±5%, which necessitates accurate design and regular monitoring. Additionally, the system requires special attention to guarantee that all air discharges are completed during maintenance (19, 10).

In terms of pipe selection, the International Association of Geothermal Pumps suggests that geothermal systems use PVC pipes that are constructed from polyethylene or polybutylene. The ASTM criteria are met by these materials, which guarantees their longevity and dependability (17, 18)

Figure (1): Hardee's Restaurant in Nablus.

This study assesses geothermal energy as a sustainable and economical solution for heating and cooling applications in Palestine. The assessment is predicated on energy consumption, expenses, and return on investment terms. This case study examines the feasibility and advantages of establishing a geothermal power plant at Hardee's Restaurant in Nablus, Palestine. The results indicate that the anticipated payback period is around 3.4 years, ensuring a rapid return on investment and sustained energy savings. This study offers insights into the feasibility of using geothermal energy in Palestine. This work is essential since it addresses the escalating energy challenges in Palestine, where energy costs are significantly higher than in many other countries. This is intensified by Palestine's deficiency in native energy resources to meet the escalating demands of its rapidly growing population. The Palestinian population is heavily reliant on energy imports from neighboring countries, hence increasing their vulnerability to fluctuations and shortages in international energy prices. The research assesses geothermal energy as a viable and economical solution for heating and cooling purposes. The study advocates for the establishment of a geothermal power facility at Hardee's Restaurant in Nablus to reduce reliance on imported energy, presenting an environmentally friendly and economically viable alternative. The assessment of cooling and heating loads, including cost analysis and payback period, will provide essential insights into the feasibility of implementing geothermal energy as a sustainable option, potentially reducing future energy costs and promoting energy independence for Palestine.

Materials and Methods

Polyethylene must be in compliance with ASTM 3350 and have ratings of either PE355434C or PE345434C that are acceptable. Produced in accordance with the specifications of ASTM D-2581 for polybutylene (17, 18).

For the purpose of lowering pressure, parallel installations make use of pipes with a smaller diameter (usually 1-1/2 inches), Each unit ton (12,000 BTU/hour) of heat pump capacity is represented by a single loop. Considering the data that the International Ground Source Heat Pump Association (IGSHPA) supplied, the following are the system dimensions:

1. Pipe diameters range from 3/8 inch to 1 inch.
2. Lengths of the bore range from 100 to 200 feet per ton.
3. For each ton, pipe lengths range from 200 to 400 feet.
4. The distance between each loop should be between 10 and 15 feet (17-19).

The parallel system is able to successfully satisfy the study's aims of being affordable, efficient, and suitable for the area that is available since it incorporates these elements and adheres to these rules.

A chiller is a component of the traditional heating, ventilation, and air conditioning (HVAC) system utilized at Hardee's Restaurant in Nablus. This chiller possesses a capacity of 140 kilowatts, elucidating the high cost of the system. In addition, the system is comprised of one boiler that has a capacity of 160 kilowatts. In order to save expenses, the Hardee's Restaurant in Nablus has implemented a geothermal system. This is because the restaurant's operational costs are rather expensive. Figure 2 illustrates the vertical loop arrangement of the geothermal system.

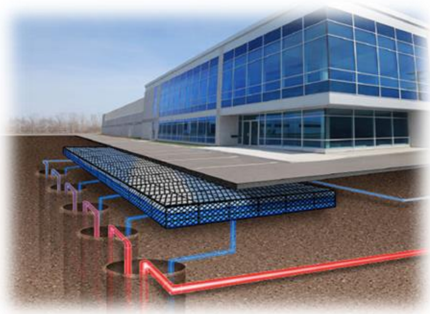

Figure (2): vertical loop system.

Prior to starting the installation of an underground thermal energy storage (UTES) or ground source heat pump (GSHP) borehole heat exchanger (BHE), it is very necessary to have a thorough understanding of the thermal characteristics that are present in the subterranean environment. The thermal conductivity testing of bigger plants, such as commercial GSHP or UTES, must be carried out on-site whenever it is feasible to do so. Within the parameters of this situation, the reaction test is an ideal tool to use. A certain heat load is injected into BHE, and it is exposed to the injection. For the aim of conducting a thermal response test, the fluid's subsequent temperature changes are then tracked. Thermal response developed with time (15, 19):

$$K = \frac{Q}{4\pi H\lambda_{eff}} \qquad (1)$$

In order to do the calculation for thermal conductivity, the formula has to be changed:

$$\lambda_{eff} = \frac{Q}{4\pi HK} \qquad (2)$$

For the purpose of calculating the pipe thermal resistance of the borehole, the following formula may be used (R_b) (16-18):

$$R_b = H(T_f - T_o) - \frac{1}{4\pi\lambda}\left[Ln(t) + Ln\frac{4\alpha}{r_o} - 0.5772\right] \qquad (3)$$

The different components of (for example, the grout's thermal conductivity) are often found and may be ascertained when using parameter estimation methodologies. The overall Thermal resistance was established to be 0.4 m^2.°C/W by the test that was conducted for this study (this number was obtained from a prior test that was conducted in West bank). It was found that the average temperature of the earth was 19 °C, and the test had a hole depth of one hundred meters (4).

When evaluating the ground heat exchanger's size, the main factor to take into account is its length. According to the heating requirement, the necessary GHX length (L_h) is (16-18):

$$Lh = q_{heat} \times \frac{\frac{COP_h - 1}{COP_h} \times (R_p + R_{sFh})}{T_{g.min} - T_{ewt.min}} \qquad (4)$$

Where:

The necessary GHX length (Lc) depending on cooling needs may be determined using a similar formula (16-18):

$$Lc = q_{cooling} \times \frac{\frac{COP_c - 1}{COP_c} \times (R_p + R_sF_h)}{T_{g.min} - T_{ewt.min}} \qquad (5)$$

The following conclusions may be drawn for both horizontal and vertical systems based on the previously mentioned equations and Palestine's environmental features and conditions:

The length (L) of vertical systems is 21 meters per kilowatt (73 meters per ton), regardless of the design of the system you are using. When it comes to horizontal systems, the length varies depending on the pipe configuration. For single-pipe configurations, the length is 37 meters per kilowatt, which is equivalent to 130 meters per ton. For two-pipe configurations, the length is 44 meters per kilowatt, which is equivalent to 155.5 meters per ton. For four-pipe configurations, the length is 54 meters per kilowatt, the length is 180.5 meters per ton.

When calculating the GHX length, it is necessary to determine the GHX component load factor. This is because the calculations that came before these need it. The ratio of equivalent full load hours in the design month to the total load hours for that month is termed the component load factor (F), and it is shown on the GHX. This is one possible method of calculation (4):

$$F = \frac{q_{avg}}{q_{max}} \qquad (6)$$

Where:

q_{avg}: monthly average load.

q_{max}: monthly peak load.

The component load factor (F) is calculated for the design cooling and heating months, generally July and January in the northern hemisphere. The numbers that are obtained from this calculation are then employed in equations. When peak load calculations are used, the section load is equal to one, which represents the maximum load.

Estimation of the length of the pipe:

Table 2 shows the findings obtained as a consequence of the thermal test performed (4):

Table (2): Thermal Parameters and Surface Resistances for Geothermal System.

Parameter	Value	Units
T_g	19	°C
$T_{ewt, min}$	- 6.7	°C
$T_{ewt.max}$	92.2	°C
R_p	0.4	m^2.°C/W
Rs	Rs	m^2.°C/W

According to the heat pump cataloging Table 3 summarizes the eat pump specifications:

Table (3): Performance Parameters for Geothermal Heat Pump System.

Mode	COP	Flow Rate	Units
Heating	4.9	4.3	L/s
Cooling	5.4	5.7	L/s

The design of the heating load (160 kw).

L_c= 21(m/KW) ×160=(KW) =3360 m.

Thus the Number of holes: depth/length =3360/100 =34 holes.

This paper recommends the building of a geothermal power plant due to the expected high running expenses of traditional heating and cooling systems, so Hardee's Restaurant in Nablus is selected for the calculation of cooling and heating loads. The cost of the new system is assessed, together with the duration required to recoup the capital expenditure.

Results and Discussion

The primary factor to consider is the expense associated with heating and cooling (the cost of materials). The expense for the mechanical room, encompassing the boiler and pumps required for heating the Hardee's Restaurant in Nablus, amounts to 6000 dollars. Additionally, the chiller that is necessary for cooling comes at the same price. In addition to the cost of installation, the total cost totals 14000 dollars. So, the initial cost is ten thousand dollars.

The building's operational cost encompasses both the fuel used for winter heating and the energy utilized for summer chiller operation. Both of these amounts are included in the building's operating cost. The degree-day approach is used in order to accomplish the task of accurately computing the operating cost.

The annual degree day (DD) for the heating season is 909, based on the heating load and the monthly average design temperature for Nablus. Consequently, it is possible to determine the fuel usage during the heating season:

$$m_f = \frac{160 \times 3600 \times 909 \times 12 \times 0.8}{(22 - 5.7) \times 39000 \times 0.8} = 9883.6\ kg\ of\ diesel$$

Utilizing the diesel density of 850 kg/m³, the volume of diesel required for the heating season may be computed as follows:

$$V_f = \frac{9883.6}{850} = 11600\ liter$$

When diesel is priced at $1.65 a liter, 11,600 liters will cost $19,140 in total (Cost = 11,600 × 1.65 = $19,140).

One chiller running at full load (140 kW) for 12 hours a day for six months is the basis for the estimated operating expenses for cooling at Hardee's Restaurant. 140 × 12 × 30 × 6 = 302,400 kWh of power are needed, and because each kWh costs $0.16, the total cost comes to $48,384 (Cost = 302,400 × 0.16 = $48,384).

The cost of completing a single borehole, including drilling, labor, and pipe installation, will amount to around $1500. The number of boreholes is shown (34 holes). Approximately 45,000 dollars is the cost of the water-to-air heat pump that is being installed at Hardee's Restaurant. The initial cost will be around $96,000, calculated as (45,000) + (1,500 × 34).

The operational expense of heating in a geothermal system with a coefficient of performance (COP) of 4.9 is assessed against a conventional system with a COP of 3.5, yielding a COP ratio of 1.4. The operational expense for heating amounts to $19,140 divided by 1.4, resulting in $13,671. In the same manner, a geothermal cooling system with a coefficient of performance (COP) of 5.4, in contrast to a conventional system's COP of 3.5, results in a ratio of 1.54. Consequently, the operational cost is calculated as $48,384 ÷ 1.54 = $31,418.

The geothermal system has a high initial cost of $96,000 compared to the $20,000 cost of a conventional system. However, the geothermal system's operating cost is significantly lower at $45,089, compared to $67,524 for the conventional system, representing a 33% reduction in operating expenses. The geothermal system requires 34 vertical holes, each 0.127 meters in diameter, spaced 2 meters apart (4), resulting in a total land requirement of approximately 70.3 m². Despite the higher upfront investment, the payback period for geothermal systems often spans from 3 to 7 years due to substantial long-term energy savings.

The payback period (PBP) for the geothermal system may be determined using the formula:

$$PBP = \frac{Initial\ cost\ difference}{\text{Annual savings in operating costs}} \quad (7)$$

The lifetime running cost of a typical heating and cooling project is projected to be around $67,524, comprising $19,140 for heating and $48,384 for cooling. The geothermal system presents considerably reduced running costs, totaling $45,089, which includes $13,671 for heating and $31,418 for cooling. This underscores the geothermal system's enhanced energy efficiency, leading to a significant decrease in operational expenses relative to the traditional system.

$$PBP = \frac{96000 - 20000}{67524 - 45089} = 3.4\ year$$

The supplementary investment in the geothermal system, relative to a conventional system, will be entirely recouped in around 3.4 years or nearly 40 months. After this payback time, the geothermal system will persist in delivering financial savings due to its reduced running expenses.

The considerable installation cost of geothermal systems may provide a challenge, particularly in areas with restricted financing and subsidies for renewable energy.

Figure 3 illustrates the cost comparison between a geothermal system and a conventional system, revealing a markedly greater initial cost for the geothermal system ($96,000 compared to $20,000). The geothermal system provides reduced operating expenses for heating ($13,671 compared to $19,140) and cooling ($31,418 compared to $43,384).

The reduced running expenses indicate that the geothermal system may prove to be more cost-effective over time, particularly if energy prices persist in escalating.

Palestine experiences hot summers and temperate winters. The reduced cooling expenses of the geothermal system are particularly pertinent, given the substantial cooling demand. Given the geopolitical problems impacting energy supply, investment in geothermal energy may diminish dependence on foreign fuels. Geothermal systems are ecologically sustainable, diminishing carbon emissions in contrast to traditional fossil fuel heating and cooling methods.

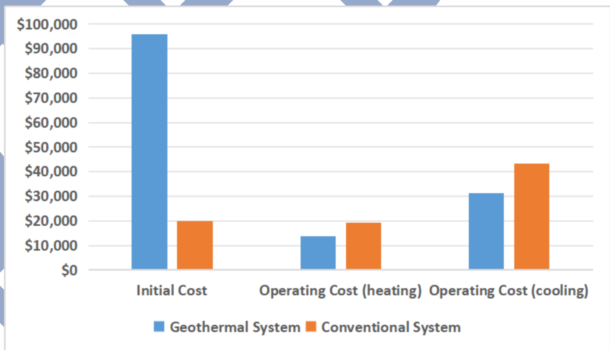

Figure (3): Initial and operating cost (heating and cooling) for the geothermal and conventional systems**.**

Figure 4 provides a comprehensive overview of the expenses, amalgamating heating and cooling into a unified running cost for both geothermal and conventional systems.

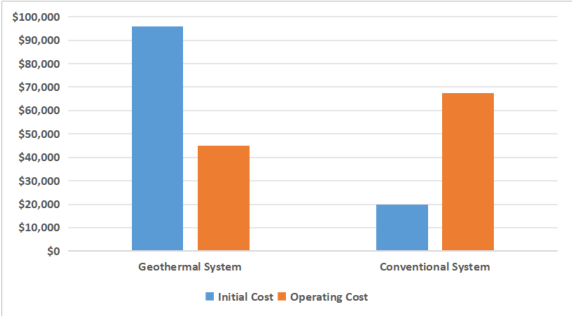

Figure (4): Initial and operating costs for the geothermal and conventional systems**.**

Table 4 and Figure 5 show the initial cost components and percentages of the geothermal system.

Heat Pump and Installation (about 47%). The heat pump constitutes the most costly individual component, accounting for approximately 35.4% of the overall expense.

The installation expense of 11,000 includes the setup of the unit, its integration with the system, and the assurance of operational performance.

Despite its high cost, the heat pump exhibits exceptional efficiency and decreases long-term operational expenses.

Table (4): The initial cost components of the geothermal system.

Component	Cost ($)
Heat Pump	34000
Heat Pump Installation	11000
Drilling	27000
Labor	16000
Pipes	8000

Drilling (~28.1%): A key cost determinant, encompassing borehole excavation or horizontal trenching. Expenses are contingent upon soil composition, depth, and drilling methodology. Palestine Encountering rocky terrain may elevate drilling expenses. Labor (~16.7%): Comprises skilled labor for excavation, system assembly, and commissioning. In certain areas, labor prices may vary based on the availability of skilled geothermal technicians. Pipes (~8.3%): Comprises high-density polyethylene (HDPE) pipes that facilitate the circulation of the heat transfer fluid. Expenses are contingent upon the length, diameter, and material quality of the pipe. Significant initial expenses may provide an obstacle in the absence of governmental incentives or funding alternatives. The local availability of trained labor and drilling equipment might influence expenses. The potential for sustained energy savings and less reliance on fossil fuels renders this a strategic investment.

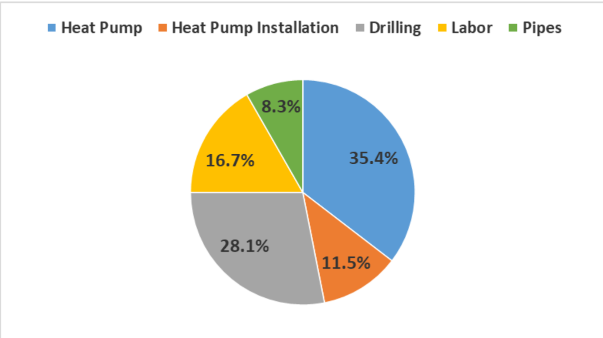

Figure (5): The initial cost components percentages of the geothermal system.

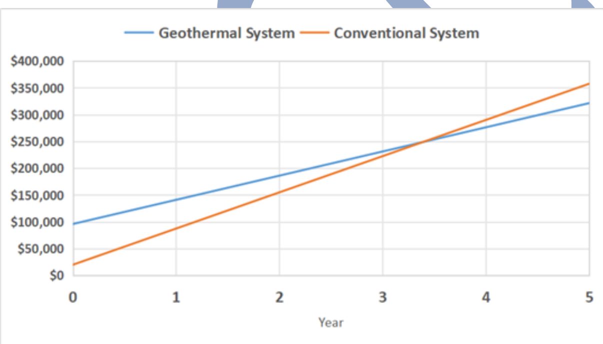

Figure (6): The break-even for the geothermal system.

Figure 6 shows the break-even for the geothermal system. The geothermal system will achieve cost parity in approximately 3.4 years, after which all savings will immediately contribute to cost reduction. The extended longevity of geothermal systems (exceeding 20 years) indicates significant long-term financial advantages.

Conclusion

Geothermal energy gives Palestinians an independent energy supply. Geothermal energy reduces air conditioning costs and ensures a pleasant environment by reducing fuel use. Geothermal operations emit harmless gases, making them environmentally sustainable. Given these benefits, geothermal energy should be used in permanent or long-term facilities with enough drilling space. Hospitals, universities, and shopping malls may improve geothermal system efficiency and cost.

Hardee's Restaurant in Nablus is a geothermal energy candidate. The restaurant's 12-hour operation and high energy needs make geothermal integration suitable. The system's projected payback period at this location is 3.4 years, ensuring a rapid ROI and long-term energy savings.

In conclusion, geothermal heating has pros and cons. The high installation costs and long payback period may seem frightening, but for those who can afford them, the benefits outweigh them. For sustainable energy solutions, geothermal systems offer higher thermal efficiency, longer lifespan, and lower maintenance costs than traditional heating and cooling methods.

Many important elements must be considered during design and implementation to ensure geothermal energy system efficiency and efficacy. Enough Land for Drilling: Geothermal well drilling requires sufficient area, which affects system design and efficiency. Geological and Environmental Factors: Soil composition and nearby environmental factors determine geothermal system feasibility and efficacy. Hardee's Restaurant in Nablus' 12-hour HVAC system is ideal for geothermal integration. The moderate length and daily operation shorten the payback period, making the geothermal system more efficient and economically viable.

Disclosure Data

- **Ethics approval and consent to participate:** Not applicable
- **Consent for publication:** Not applicable
- **Availability of data and materials:** The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.
- **Author's contribution:** The authors confirm their contribution to the paper as follows: study conception and design: Ramez Abdallah, theoretical calculations and modeling: Ramez Abdallah, Salameh Abdel-Fattah; data analysis and validation, Salameh Abdel-Fattah, Ramez Abdallah. draft manuscript preparation: Salameh Abdel-Fattah, Ramez Abdallah. All authors reviewed the results and approved the final version of the manuscript.

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List of Abbreviations

K: the slope of the curve showing the correlation between logarithmic time and temperature.

Q: The insertion and extraction of heat.

H: borehole heat exchanger length.

λ_{eff}: Efficient thermal conductivity.

T_0: the ground's starting temperature (ºC).

λ: conductivity.

α: thermal diffusivity.

r_0: radius of the borehole (m).

q_{heat}: the heating system's load liquid flow

COP_h: the heat pump system's COP, or design heating coefficient of performance.

R_p: the pipe thermal resistance.

R_s: the soil/field thermal resistance.

F_h: the heating load factor of the GHX component.

$T_{g.min}$: The lowest temperature of the undisturbed ground.

$T_{ewt.min}$: the heat pump's minimum design entering water temperature (EWT).

$q_{cooling}$: the cooling system's load liquid flow

COP_c: the heat pump system's COP, or design cooling coefficient of performance.

PBP: The payback period

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