First geothermal system in Palestine

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Abstract

Palestinians today are paying the highest energy prices in the entire Middle East and North Africa (MENA). In addition, Palestinians are experiencing population growth rates that are amongst the highest in the world, 3.99% in Gaza and 2.9% in the West Bank. Palestine has no sources of natural energy and is completely dependent on the Israeli occupation for supply. In search of a solution, the first geothermal heating and cooling system has been installed in Palestine with great success with the support of the European Union financed MED-ENEC project. This innovative 23 kW geothermal heating and cooling pilot system installed in Ramallah is designed to achieve a peak coefficient of performance (COP) of 4.2 in heating and 14.5 EER in cooling, giving the geothermal system worst-case scenario efficiency of 420%. This environmentally friendly system utilizes a vertical ground heat-exchanger installed at 70 meters deep. An economical duct system distributes both hot and cold air throughout the building and incorporates a fresh air in-take. Although geothermal system can provide 66% of the domestic hot water for free with a "desuperheater" option, locally manufactured solar water heaters were used. If operated all year long, the geothermal system is expected to reduce operating costs from 8,100 USD (5,818 Euro) per year to merely 2,700 USD (1,939 Euro) per year, which is 67 percent in savings, resulting in a simple payback period 4.2 years. The success of this pilot project has lead to the launch of a new Palestinian business, MENA Geothermal, dedicated to advancing geothermal in the entire Middle East and North Africa.

Introduction

As the economy of the Palestinian Territories continues to develop, the Palestinian people find themselves in dire need of an efficient and economical source of energy that can meet their energy requirements. With soaring global energy prices, Palestinians are paying 0.18 USD (0.13 Euro) per kWh of electricity and 1.98 USD (1.42 Euro) per litre of diesel fuel; moreover, Palestine experiences one of the world's highest population growth rates: 3.99 percent per year in Gaza and 2.99 percent per year in the West Bank. Palestine has no sources of natural energy and is completely dependent on the Israeli occupation for supply. With no energy-efficiency building codes, no minimum insulation standards, and the rampant use of conventional boilers for heating and air-source split units for cooling, Palestine is in dire need of alternative energy and efficient urban planning. In search of a solution and in an attempt to create a sustainable future for Palestine, MENA Geothermal, a newly formed Palestinian company, has installed the first geothermal heating and cooling system in the entire MENA region. It is MENA Geothermal's belief that in the absence of a government that enforces building standards, the private sector must take the initiative to maintain its own high standards and efficiency codes.

This first geothermal system was installed in a residential application in partnership with the MED-ENEC Project, a European Union Energy Initiative (EU-EI) designed to boost energy efficiency measures in the construction sectors of the Mediterranean.

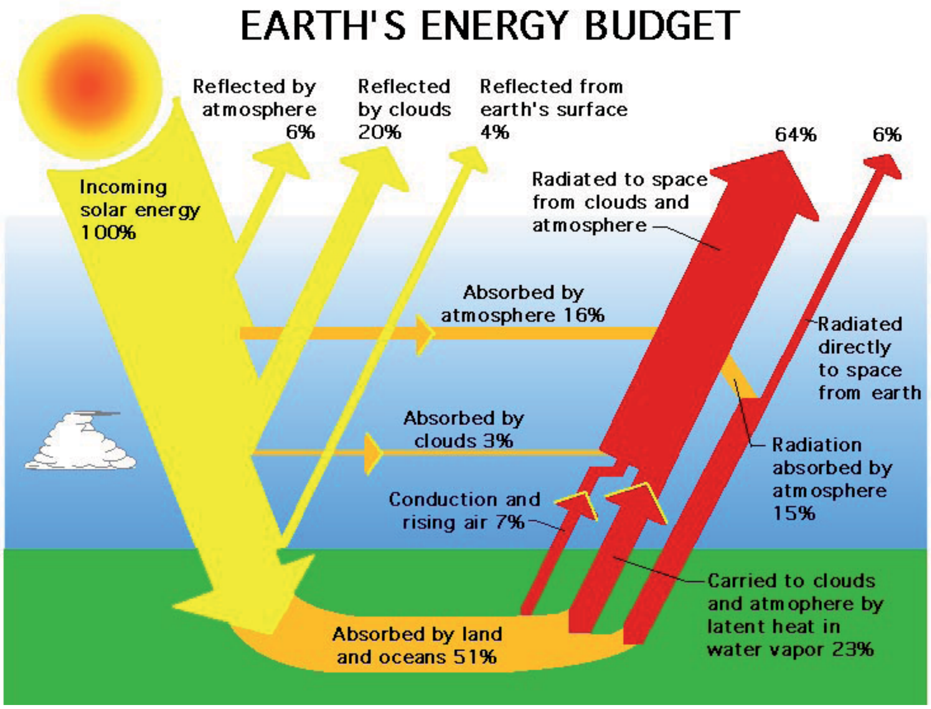

Figure 1. Earth's Energy Budget [2]

The first geothermal system in Palestine is part of the Etihad Subdivision, the largest residential subdivision undergoing construction in Palestine. Built in the city of Ramallah, located just north of Jerusalem and Bethlehem, the subdivision includes 62 semi-detached villas and a commercial centre built on an area of 24,000 square meters. The purpose of the first geothermal system is to test the feasibility and functionality of geothermal heating and cooling in Palestine. The model semi-detached villa in the Etihad Subdivision was selected as the location for installing the pilot project.

The climate in Palestine presents potential for geothermal heating and cooling. In the city of Ramllah, where the first geothermal system is located, the summer experience outside dry bulb temperatures as high as 31 degrees Celsius and the winter experience temperatures as low as 0 degrees Celsius. For a residential building, these temperatures would result in balanced heating and cooling loads, which for a geothermal system would mean a balanced amount of energy rejected to and extracted from the earth, leaving the undisturbed ground temperature largely unaffected. The remainder of the report below will discuss the actual ground temperatures tested in Ramallah and its effects on the size and efficiency of the geothermal system.

The Energy Concept

Considering that construction is the primary industry in Palestine and that roughly 60% of the energy consumed by a typical building is for heating and cooling, MENA Geothermal focused on setting an example of how heating and cooling demands and operating costs in a building can be significantly reduced. Therefore, the basic concept of the project was to reduce the energy demand (building heating and cooling loads) of the model home and reduce its energy consumption by increasing building insulation and utilizing an environmentally friendly geothermal heating and cooling system in an affordable way. The aim was to demonstrate to the Palestinian community that renewable energy is not just a commodity of developed nations, but an economically feasible approach that can be fully implemented in developing nations as well.

Geothermal technology was selected for its ability to significantly reduce operating costs and its environmental friendliness. Geothermal technology works by utilizing a ground-source heat pump to access the energy stored in the earth's surface or earth's crust. Since earth absorbs 50% of the suns energy and stores it as clean renewable energy, the temperature below the frost line (2 metres deep) remains relatively constant throughout the year [1]. Figure 1 below displays the energy budget of the earth.

Ten metres below the earth's surface the ground temperature remains even more constant and undisturbed [3]. Instead of consuming significant amounts of energy to raise or lower the temperature of a building, geothermal technology simply transfers energy between the building and ground by utilizing the difference between the constant ground temperature and the temperature of the building above the ground. As a result, geothermal systems can lower energy consumption significantly.

BENEFITS OF GEOTHERMAL HEATING AND COOLING

The following points outline the benefits of a geothermal heating and cooling system:

- Lower operating costs: a geothermal system operates more efficiently than ordinary heating and air conditioning systems – up to 70% in many cases.
- Comfortable: because geothermal uses the relatively stable temperature of the earth as an energy source, you are assured of constant, even winter heating and better humidity control in summer.

- Safe and clean: ground-source heat pumps do not use a flame and do not emit odors; just safe reliable operation year after year.
- Flexibility: geothermal heat pumps can provide heating, central air conditioning and hot water all from the same compact unit.
- Attractive: a ground-source heat pump is a completely self contained indoor unit that does not require a noisy, unsightly outside condensing unit.
- Environment: geothermal systems emit no direct carbon dioxide.
- Long life: geothermal heat pumps have a long service of 20 years and geothermal ground loops are guaranteed to last over 50 years.

System Features

BUILDING DETAILS

The model villa is a semi-detached villa that is part of a building that contains 5 semi-detached villas. The unique hill elevations in Palestine provide separate entrances to each semi-detached villa. Before getting to the geothermal system, it was necessary to first focus on improving the model villa's energy efficiency. It was necessary to improve the villa's insulation thereby reducing the total heating and cooling energy requirement (loads) and the total required geothermal ground heat exchanger (ground loop). In Palestine, there are no minimum insulation standards; as a result the conventional building used in this analysis will include no insulation.

The villa's walls and windows were insulated to reach U-values of 0.87 W/K·m^2 and 2.98 W/K·m^2 respectively. Local 3cm compressed polystyrene insulation was used in the walls and double-glazed glass for the windows. Even the floor was insulated to a U-value of 0.8 W/K·m^2 to reduce heat loss and heat gain from the walk-out basement and garage below. This improvement in insulation reduced the heating and cooling load requirements by 20 percent. The 392 square-metre model villa includes three floors, a walk-out basement and a garage. Table 1 below displays the reduction in heating and cooling loads for the geothermal model villa compared to a conventional villa (same villa with no insulation).

The energy loads in Table 1 were calculated using weather data for Jerusalem and inside temperatures of 21°C for heating and 24°C for cooling.

GROUND-SOURCE (GEOTHERMAL) HEAT PUMPS

To meet the 23.8 kW cooling load and 21.4 kW heating load, two water-to-air ground-source heat pumps were selected to provide both heating and cooling to the model villa. Water-to-air ground-source heat pumps are the most efficient ground-source or geothermal heat pumps since they operate with only two loops of exchange between the building and the earth: a ground heat-exchanger loop and a refrigerant loop in direct contact with the air. Water-to-water ground-source heat pumps, on the other hand, require three loops of exchange: a ground heat-exchanger loop, a refrigerant loop, and another water loop that runs to fan coils or radiant floor heating. The refrigerant used in the ground-source heat pumps chosen is the environmentally friendly 410-a refrigerant.

Table 1. Energy Load Comparison

Villa	Heating Load (kW)	Cooling Load (kW)
Conventional	26.4	29.8
Geothermal	21.4	23.8

DOMESTIC HOT WATER

Although water-to-air heat pumps are more efficient, they usually do not come with a “desuperheater” or hot-water assist option offered with some ground-source heat pumps. A desuperheater is a water to refrigerant exchanger connected to the beginning of the discharge line of the compressor that collects excess heat generated by the compressor to preheat domestic hot water. In addition, the only space allocated for the domestic hot-water (DHW) tanks is on the roof of the building containing the semi-detached model villa, which is 3 floors above the location of the heat pumps. The cost of extending piping all the way up to the roof versus the efficiency of a hot-water assists system (ground-source heat pumps can achieve between 10% to 66% DHW saving for free) compared to the very efficient and inexpensive locally manufactured DHW solar panels, a choice was made to incorporate solar panels with an electric coil tank.

THERMAL CONDUCTIVITY TESTING

The first geothermal heating and cooling system in Palestine was designed to meet 100% of the heating and cooling demands of the model villa. In order to accurately design the geothermal ground heat exchanger component of the system, a thermal conductivity/diffusivity test was completed at the actual building site, on a 70 meter deep hole, resulting in an undisturbed earth temperature of 18.3°C. Thermal conductivity/diffusivity of the ground is essentially the ability of the ground to absorb and/or release energy. A thermal conductivity test requires the installation of a single vertical borehole, associated pipe, and grouting to facilitate the acquisition of data from the soil and rock formations beneath the earth; information which is necessary to accurately design a geothermal heat exchanger capable of transferring energy to and from the earth.

GEOTHERMAL SYSTEM FEATURES

The distribution system selected was a duct distribution system, as it can economically provide both heating and cooling. In addition, in order to create a comfortable and healthy indoor environment in the villa, a fresh-air intake was incorporated in the duct design. Due to the population density of Palestine, there is a lack of land area available for installing ground heat exchangers. To save space and provide an efficient heat exchange with the earth, the ground heat exchanger was designed as vertical closed loop, with borehole radial spacing of 3 meters between each borehole. Figure 2 below displays an example of how the vertical ground heat exchangers look with the semi-detached model villa.

Based on the results of the thermal conductivity/diffusivity test, 10 holes were drilled at a depth of 70 meters, giving a total ground heat exchanger area of 700 metres. Using the best available methods and software for modelling, this design is able to

Figure 2. Vertical Ground Heat Exchanger at Model Villa

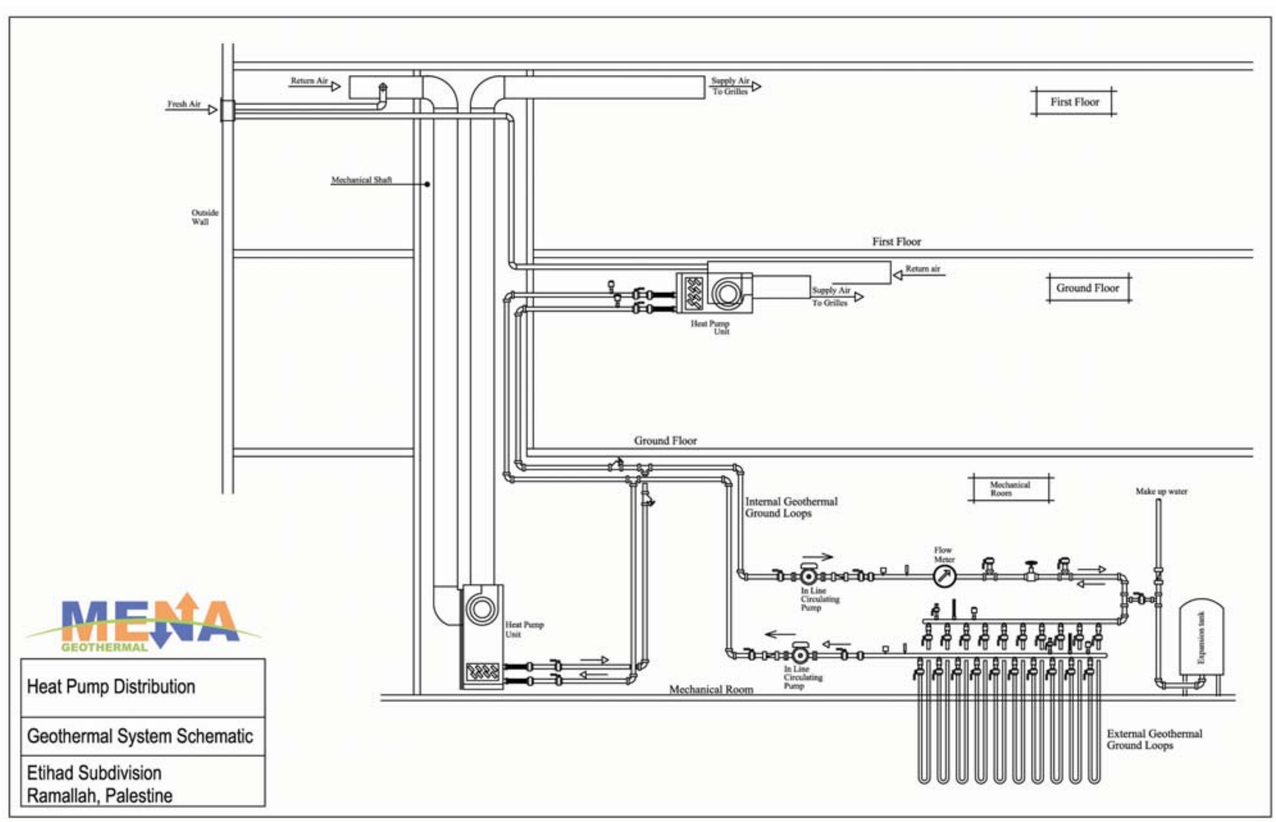

Figure 3. Geothermal Heating and Cooling System Schematic Design

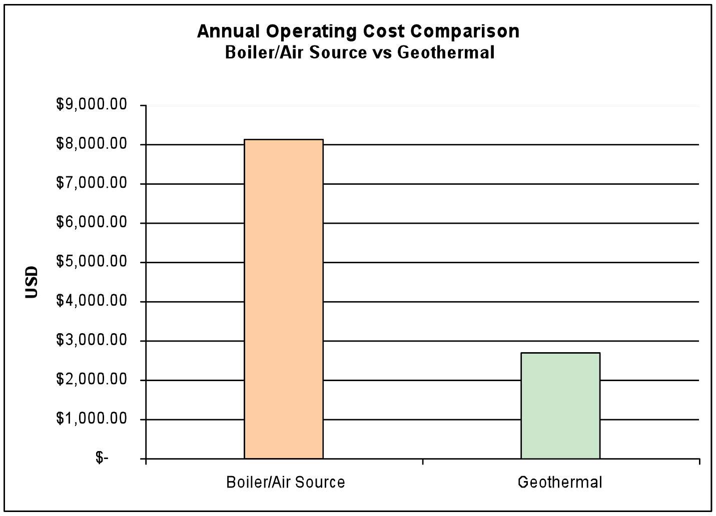

Figure 4. Annual Operating Cost Comparison

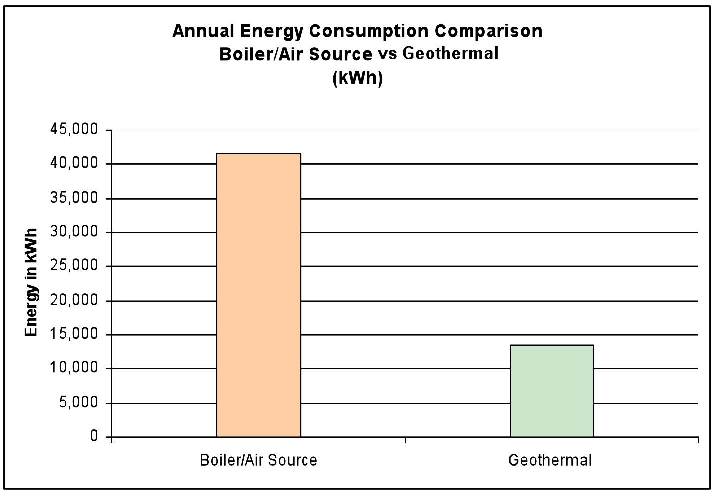

Figure 5. Annual Energy Consumption Comparison

achieve a worst case scenario COP (coefficient of performance) of 4.2 year round in heating and 14.5 EER (energy efficiency rating) in cooling. That is, for every 1 unit of electricity required to power the geothermal heat pumps and the small water circulating pumps, the system will provide 4.2 units of heating energy, giving the geothermal system a worst case efficiency rating of 420%. High density polyethylene plastic (HDPE) piping of size-dimension-ratio (SDR) 11 and 25 mm outside diameter was used in the ground heat exchanger. Figure 3 below displays a schematic drawing of the entire geothermal heating and cooling system.

Energy Consumption Analysis

The most common conventional HVAC systems in Palestine are diesel-powered boilers with radiators for heating and forced-air split units for air conditioning. With the current energy prices in Palestine, operating costs for conventional systems, especially diesel-powered boilers, have become simply unbearable for most Palestinians. If the geothermal system in this project is operated to maintain a comfortable room temperature all year long it is expected to reduce operating costs from 8,100 USD (5,818 Euro) per year to merely 2,700 USD (1,939 Euro) per year, which is a 67 percent saving. The total investment cost of the geothermal system was around 48,000 USD (34,477 Euro) compared to a 23,000 USD (16,520 Euro) conventional system. Including the fact that the geothermal system requires virtually no maintenance; the resulting simple payback period for the project is around 4.2 years. This amounts to a reduction in energy consumption of roughly 28,000 kWh per year and roughly 7,000 kg of CO_2 emissions. Figures 4 and 5 display the annual operating cost comparisons between the geothermal system and a conventional system.

Conclusion

Knowing that developing countries will face the toughest energy challenges, MENA Geothermal and its parent company, UCI, took the challenging of setting an example of how energy-efficiency measures and renewable energy technology can be implemented in even the poorest of nations. The first geothermal system in Palestine was successful in meeting its aims of reducing building heating and cooling loads and reducing overall building energy consumption. Heating and cooling loads of the villa were reduced by 20% by simply adding 3cm of locally manufactured compressed polystyrene in the walls and using double-glazed windows. A thermal conductivity and diffusivity test provided the necessary data, including an undisturbed ground temperature of 18.3°C at a depth of 70 meters, to allow the accurate designing of a geothermal heating and cooling system for the villa. A ground heat-exchanger was designed and installed with 10 holes each at 70 metres deep, a design that is expected to achieve a worst case scenario COP of 4.2 in heating and 14.5 EER in cooling. The geothermal system is expected to reduce operating costs from 8,100 USD (5,818 Euro) per year to merely 2,700 USD (1,939 Euro) per year, which is a 67 percent savings. The system is currently undergoing monitoring to verify the expected results.

The model established with this first geothermal system has proved to be completely replicable. The success of this first geothermal project has created enormous momentum for MENA Geothermal. In addition to being able to offer geothermal to the remainder of the 61 villa residents in the Etihad Subdivision, MENA Geothermal has completed the first commercial geothermal system in their very own 260 kilowatt (74 ton) office building in Ramallah. This commercial geothermal system recently won the National Energy Globe Award 2008. MENA Geothermal is demonstrating that developing countries are in fact in a unique position to incorporate renewable energy in new constructions as their economies rapidly develop.

References

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[2] National Aeronautics and Space Administration (NASA), "Earth's Energy Budget", http://asd-www.larc.nasa.gov/SCOOL/energy_budget.html (current January, 2009)

[3] Oklahoma State University, "Closed-Loop/Ground-Source Heat Pump Systems", Oklahoma State University 1988, p. 82.

Acknowledgements

The first geothermal system in Palestine could not have been accomplished without the dedicated hard work and effort of the entire MENA Geothermal engineering team. The semi-detached villa was provided by MENA Geothermal's parent company, Union Construction and Investment Corp, which provided a flexible location to test the geothermal system. In addition, the support and assistance of Mr. Klaus Wenzel and the MED-ENEC team was crucial in the development of the system. MED-ENEC funding was essential in alleviating the risk of investing in the largely unfamiliar territory of renewable energy in Palestine.

Glossary

COP – Coefficient of Performance
DHW – Domestic Hot Water
EU-EI – European Union Energy Initiative
HDPE – High-density polyethylene plastic
kW – kilo-watt
kWh – kilo-watt hour
MENA – Middle East North Africa
UCI – Union Construction and Investment Corp.
USD – United States Dollar
$W/K{\cdot}m^2$ – Watts per Kelvin meter squared
EER –Energy Efficiency Rating
Ton – 1 ton of refrigeration = 3.5 kW of thermal energy