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RESEARCH ARTICLE OPEN ACCESS

The Effective of Geothermal Energy in Buildings: A case study in Madaba city in Jordan

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ABSTRACT
A substantial portion of energy use is expended on heating and cooling of buildings. geothermal technology has considerable ability to generate and produce both thermal and electrical power to supply residential and industrial buildings. Some of the most exciting renewable technologies of thermal control for buildings are low geothermal energy, which uses nearly steady and mild ground temperatures as either a heat source or a tank during the year. This research aims to study the potential of producing energy for buildings from near geothermal sources to the building. The analysis of the case studies presented show examples of residential and office buildings in Jordanian that applied a geothermal system and obtained a reliable sourse of power. The results showe that geothermal power systems in buildings at a depth of 20 meters is sufficient to gain the energy needed for a mediam size residential building with an area up to 300 square meters. applying geothermal energy system for existing buildings by drilling the well is alsopossible in the building setbacks.
Keywords: renewable energy, geothermal system, Jordan

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I. INTRODUCTION

Power generation has negative impacts on the environment as a result of the combustion of fuel needed to run it, as burning fossil fuels is one of the oldest ways to generate electricity. The fluctuating changes in oil prices that occur in each period and period negatively affect the consuming countries if the change is an increase in its price. With the global escalation of the amount of global energy consumption, countries tend to use renewable energy sources to meet their needs, mainly if the state does not produce oil. The homes are the most used for energy, whether electricity, gas, diesel, or kerosene. As the use of high-energy electrical appliances in the world is a big problem as they are generated by burning gas or diesel and other methods, as a result of this. After adding the infrastructure and generator expenses and others, it becomes more expensive at the total rate, and it has become the most used to meet the needs of heating and cooling. Also, thermal insulation is often not enough to reduce the energy lost in the building. Also, the power loses a large amount of it in the electrical network through transportation from the station to another station or the generator in the neighborhood. Many countries do not face significant energy problems using sustainable sources. Thermal energy, a sustainable source that can be found anywhere in the world, is not used in Jordanian cities and other Middle Eastern countries. Also, it works on economic development well when using this energy to generate electricity by the organization, and it can also be used to reduce energy lost in one building and on a personal level by combining it with heating and cooling works. Buildings in different countries of the world and different regions work to reach the comfort zone using both heating and cooling systems. The HVAC process is the single most abundant indoor use, currently accounting for 36% of the building's total energy consumption. The cooling capacity used in buildings has doubled since 2000, from 3.6 to 7 EJ, making it the fastestgrowing end-use in buildings[1]. Residential buildings in Jordan use about 45% of total electricity consumption[2]. Electric energy is lost 1.98% during transportation - and 20% of petroleum products[3].

II. TYPE OF RENEWABLE ENERGY

It is the energy collected from renewable energy derived from untapped natural resources. It does not generate carbon dioxide, greenhouse gases, and other harmful gases. Thirty countries use renewable energy, and these countries contribute more than 20% of the energy supply. As for Iceland and Norway, they generate all their electrical energy using renewable energy[4].

Based on REN21's 2019 report, renewables contributed 26% to their generation of electricity by the end of 2018. It had become more economical than power from fossil fuelfired plants in many

places. This energy consumption is 1% coming from Biofuels for transport, 3.6% from Hydropower, 7.5% from Traditional biomass, 2.2% from Nuclear energy, and 4.2% is electricity from Biomass, solar and geothermal heat[5]. Energy is often critical to human development. Since most renewable technologies provide electricity, renewable energy is usually used with other energy sources, which have many benefits. Energy can be converted to heat and to mechanical energy very efficiently, so it going to be cleaner at this point of consumption than other. Also, electricity, in particular, is more flexible. As a result of the possibility of converting it into useful heat without losing energy, in addition to its efficiency in generating temperatures higher than the combustion of any fossil fuel[6]. Renewable energy sources[7]are : sun, wind, water, tides, crops and trees produced oils, Geothermal, Bioenergy, Radiative cooling. Renewable energy often provides power in four critical areas: Electricity generation, Air and water, Transportation, Rural (off-grid) energy services. Solar water heating mainly contributes to renewable heat generation in many countries, meeting part of the population's hot water needs, and serving an estimated 50-60 million families in China[8].

A. comparing

Using water to generate energy is more effective than air because the denser is 800 times than air, and it has a slower flowing stream than air. but Tidal power has the potential to generate electricity, in addition to having better predictability than wind and sun, but its limited availability causes an increase in operating costs as using in both Europe and the Atlantic coast of North America. The incoming water was contained in large storage ponds, and as the tide went out, it turned into water bottles that used the mechanical energy it produced to grind grains.

Energy extraction from plants is through obtaining alcohol by fermenting carbohydrates in sugar crops, the starch in corn and sugar cane, cellulosic biomass in trees, and herbs. Currently, global biofuel production is relatively low, but it is constantly increasing9. Biomass and biological materials can be used in living organisms as a source of energy after they are converted into biofuels. Where heat is converted through biochemicals. Biomass can also be artificially cultivated from many types of plants. Heat or electricity can also be produced by burning straw[9].However, these incineration processes harm the environment by producing sulfur and nitrous oxides, the global production of biofuels is comparatively low, but continuously increasing[10].

Radiative cooling Just as crucial as geothermal, it is a renewable technology that reduces the total annual energy loads associated with cooling and normalizes the electrical demand curve as well. The studies have proven that the average net cooling using night sky radiation was 26 W / m2[11].

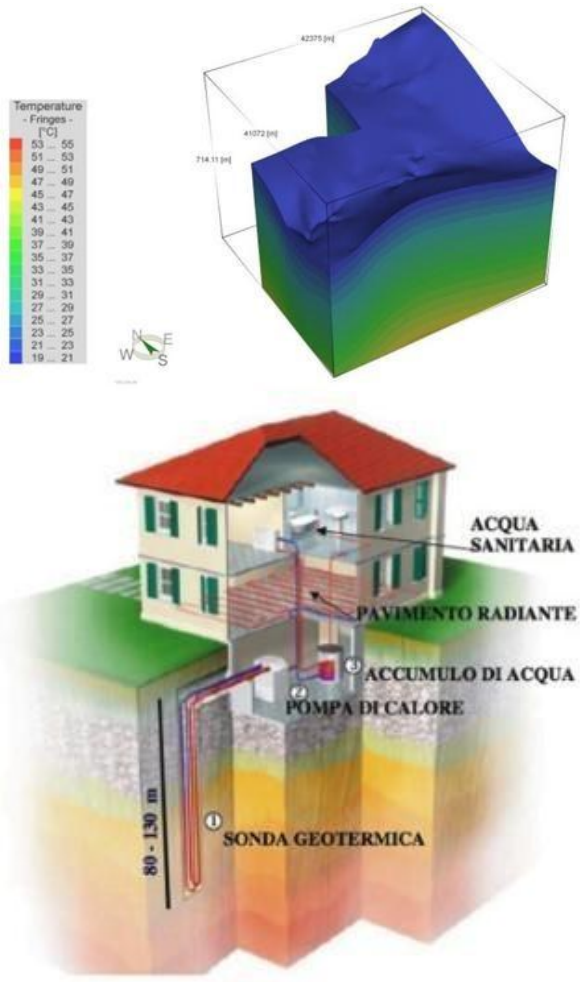


FIG. 1. 3D view of the internal temperature distribution[14].

III. GEOTHERMAL SYSTEM

The ground energy is an ascending heat from the center of the Earth to the surface where the temperature can reach more than 5426.85 degrees Celsius[12].

This heat is emitted to the surface of the Earth from hot minerals in the Earth's core, where it heats the oxygen and the surrounding water to 371 C, as the oxygen is lighter than the iron that rises in the liquid. This energy is extracted using a geothermal heat pump with a heat exchanger. As the heat energy is transferred from the ground for cooling and transferred to the ground for heating, where the opposite may be true depending on the nature of the Earth 13. Thus, geothermal energy is renewable as it

reduces the total energy loads associated with thermal adaptation work and reduces the supply on the main electrical network.

The study showed that geothermal utilization is feasible. Geothermal has hydraulic and thermal properties that allow us to use it to achieve the goals of heating and cooling[13].

Also, Also, Jordan's geothermal energy is like other countries because it is a renewable source that can be obtained for free. that may be available a few meters underground, unlike other nonrenewable, high-cost energy sources. Fig. 1, 2 show temperature distribution inside the Earth. The minimum temperature is 12-14 degrees Celsius at a depth of 100 meters in Countries of the Mediterranean Basin[14], and 17 Celsius degree at a depth of 714 meters[15].

A. Geothermal system

elements amount of use, the nature of the land and its set of considerations, determined by the party responsible for the system.

3. Ground absorbers: Horizontal ring of pipes, similar to the underfloor heating system where the heat transfer surface has already been determined. The use of groundwater in this system is direct without any other treatments: The pumps transfer the groundwater from the well through a heat exchanger, and the "thermally exploited" water returns to the well.

This system implemented in an existing building that runs on the central heating system because it is most commonly FIG. 2. 3D view of the domestic temperature distribution[15].

used. The existence of the necessary infrastructure, Which consists of heat radiators or underground heating pipes, or in new buildings that are going to use renewable energy in the heating and cooling system, both of these types have the same primary elements. These are:

Two wells of water, Pipe, Pump, Radiators, or underground heating system and Water Tank.

The Geothermal system used in the Heating and cooling systems need three tanks of water; underground tank (wells), top roof tank (main water tank), and internal tank (the pipes in the building).

In winter, the water temperatures are measured in these sections. When the heating system is operated, the hightemperature water is pumped into the radiators at home. The lower temperature is pumped to the well to keep the hot water in the house in a closed system. In summer, in the same processes, the system is operated. The lowtemperature water is pumped into the radiators at home. The highest temperature is injected into the well to keep the cold water in the house in a closed system. The most commonly used geothermal systems in the world can be mentioned in3methods:

1. Borehole heat exchangers: This system works individually, or as a group of heat exchangers, its location can be near or below the building, where the depth ranges from 50 to 150 m.
2. Energy piles: It is a set of heat exchanger tubes embedded in the foundation piles of the building, the depth of which in this method can be from 10 to 30m.

B. Using Geothermal energy in the buildings

1. The offices building – A case study in Germany

The Building and Energy Design Services Institute (IGS) at the Technical University of Braunschweig, with support from the German Federal Ministry of Economics and Technology, conducted a research project studying energy efficiency and economic efficiency in eleven buildings using heat exchangers and energy piles or land absorption. Its result is showing that geothermal energy can be brought up to heating temperature in the offices building using heat pumps in the winter, and excess heat can be removed from the building to the ground using free circulation in the summer months. These systems are subject to various conditions imposed by the authorities, depending on the German federal state and the authority involved. Shallow geothermal energy is primarily suitable for providing temperature control in office and office buildings. With the suitable design and right operating policy, significant energy savings and reduction of CO2 can be achieved compared to conventional heating and cooling systems. It depends on the size, efficiency, and degree of system use[16].

The office building located in Germany has a net area of 20,693 m. The geothermal system used in this building consists of 196 energy piles of 9 meters long. In winter, the geothermal heat of the water heating pump 106 kW extracts heat from the ground to supply the TABS tablets. The rest of the heat consumption is provided by central heating through radiators, floor heating, and ventilation systems. In summer, the full cooling load is supplied by geothermal energy through TABS (Free Cooling Mode 150 kW.

The results show a reduction of 12,000/year in comparison with a traditional heating and cooling system and a reduction of 27 tons of CO2 per year for the office building analyzed due to the high gap of cost between the traditional system that amounts of 16,653.6 compared with the geothermal energy of 16,653.6 . So the geothermal energy used in cooling is free as it has been proven that the geothermal system can reduce the running cost by a large rate that may reach 71% when compared to the systems currently used, in addition to that it reduces the emission rate of carbon dioxide by 54%[17].

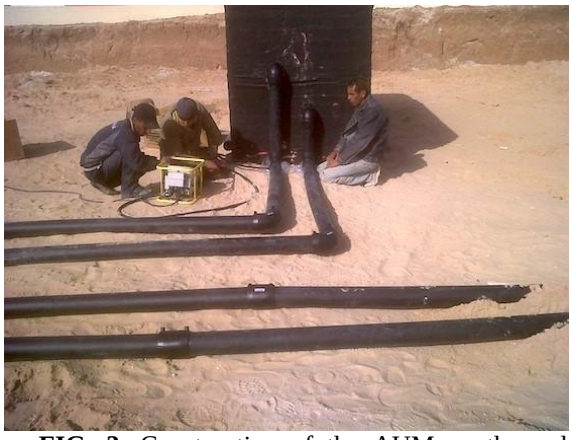


FIG. 3. Construction of the AUM geothermal system.

2. Institutional buildings – A case study in Jordan

Also, in Jordan, geothermal energy was used at the American University of Madaba designed by MENA Geothermal, a leading
Palestinian company specializing in the design and installation of geothermal heating and cooling systems.it was completed in August 2012. The system used in the university is the largest geothermal heating and cooling system in the MENA region, with a total cooling load of 1680 kW and a heating load of 1350 kW, enough energy to power both faculties on campus. The system has the capacity to reduce carbon emissions by roughly 220,000 kg per year or 47% compared with conventional chiller/LPG boiler cooling and heating systems.

Construction of the AUM geothermal system began in July 2010 and involved drilling 420 boreholes in a vertical configuration 100 meters into the ground. But unlike drilling for shale oil, geothermal energy is considered to be one of the cleanest, most efficient and safest forms of renewable energy. Also, Geothermal heat pumps are able todeliverlowcost heating and cooling because they tap into a free, renewable energy source. It is due to the effectiveness lies in the efficiency and low cost of heat pumps by release more heat than the energy they use: For every dollar, you spend on heating, you get $ 4 in thermal energy. This process makes heat pumps much more efficient than traditional sources. “Considering the CO2 emission reductions, the higher efficiency, lower required maintenance, added to comfort to occupants, and most importantly affordability, geothermal is an excellent alternative to fossil fuels.” Nonetheless, the firm had to gain permission from a formidable collection of agencies and ministries before he could proceed with this project, which received blessings from Pope Benedict XVI in 2009. (The University belongs to the Latin Patriarch in Jerusalem). “In addition to an environmental impact assessment, we were required to receive approval from the Ministry of Industry and Trade, Ministry of Interior, Jordanian Intelligence Agency, Ministry of Energy, Ministry of Environment, Ministry of Water, the
Prime Minister’s Office, the Engineering

FIG. 4. Construction of the AUM geothermal system (Vertical heat exchanger).

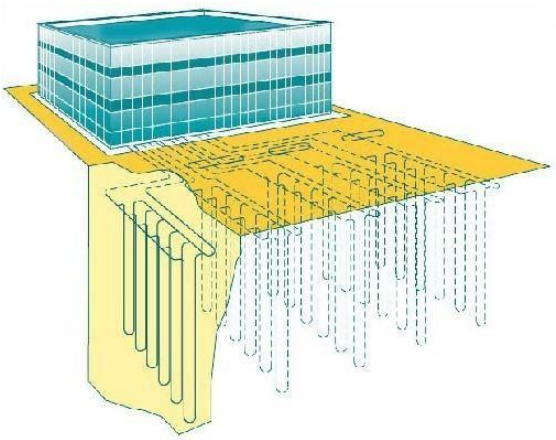


FIG. 5. Close loop system of AUM[18].

Association, and the Contractors Union. No joke,” said Al Sabawi.

Two geothermal systems were installed in AUM to meet the full heating and cooling requirements of the College of Science -A Building and the College of Business-B Building. The geothermal system at the College of Science-A is designed to meet a cooling load of 1020 kilowatts (291 tons) and a heating load of 880 kilowatts (251 tons). While the Business-B geothermal system is designed to meet a cooling capacity of 660 kilowatts (189 tons), the heating load is 470 kilowatts (134 tons).

Due to the size of the geothermal system at AUM, the ground loop (ground heat exchanger) was designed in a vertical configuration with boreholes drilled at roughly 100 meters deep. The geothermal system at AUM was awarded the National Energy Globe Award, today's most prestigious environment award, in 2011.

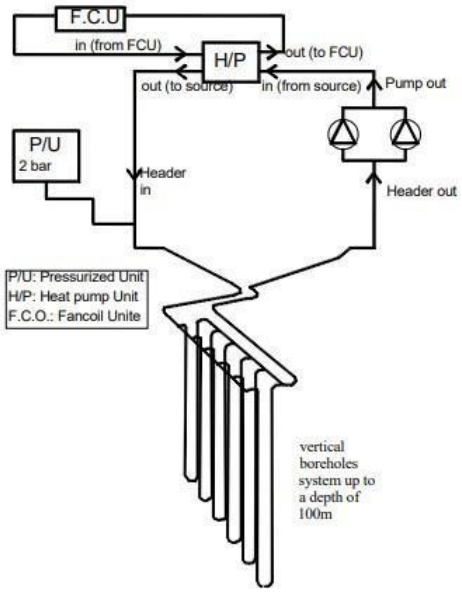
On average, the system is in operation 330 days per year, from 07:30 until 17:00. During the design phase, The observed significant difference between heating and cooling loads is mainly due to the high solar loads and is typical for office buildings in Jordan. During intermediate seasons (autumn and spring), due to the shape and orientation of the building, a requirement for the simultaneous heating and cooling of different parts of it is observed. Design conditions for heating are 21 degrees dry winter with 50% relative humidity and design conditions for cooling is 23 degrees dry Summer with 50% relative humidity. The system is using Central Air Handling Units (AHUs) with water coils to provide supply air to the building B and FCU units for heating and cooling (Building A). In terms of their connection to the hot, chilled water loops, the fan-coils are organized in groups, based on the operation and the thermal characteristics of the room they serve. As a result, fan-coil loops are formed, serving building areas with similar thermal behavior and operation profile. Two-stage water to water heat pumps is used. The heat-pump systems are capable of totally independent operation, meaning that, depending on the requirements of the zones they serve, some of them may provide heating while the other loops offer to cool. 22 Central Air Handling Units (AHUs) with water coils +15 indoor Fan

Coil units – Two pipe type- provide supply air to the building B and 85 FCU units–Two pipe type plus one AHU provide the supply air to the Building A. A total of 26 heat pumps units are installed, 10 serving the fan-coils as well as the AHUs in Building B and 16 heat pumps units are installed serving the FCU and the AHU in Building A., The cooling capacity of each heat pump group, is 68 kW, (matching heat pump units). The heat pumps of each group are connected in parallel and operating under common control The following GSHPs charts represent the two-unit systems for building A and building B, respectively.

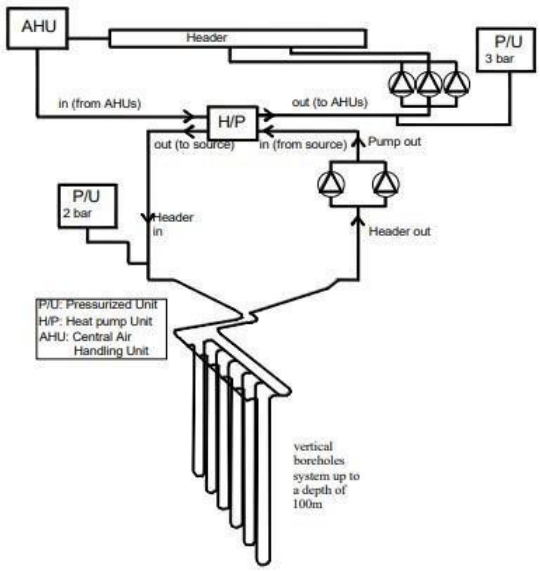
As shown, the indirect geothermal energy was used for heating and cooling through ground source heat pumps (closed loops). This system is used when the land area available is limited, as a vertical closed-loop system, and where the land is too rocky for trenching, for existing buildings, and extensive commercial or educational facilities. The system was constructed by installing a vertical loop; the contractor bored the holes into the ground. Long, hairpin-shaped loops of pipe are then inserted. The hole is backfilled, plugged or grouted, and the tubes are connected to headers in a trench leading back to the building. The drilling depth was determined based on the energy needed. In general, the typical borehole depth is 45 to 70 meters in the large buildings.

The drilling depth was determined based on the energy needed. In general, the typical borehole depth is 45 to 70 meters in the large buildings. The objectives of the vertical well are to install a specified amount of pipes, not to reach a specific depth. So, the well with 100 meters deep can be divided into five wells 20 meters depth which has is steady temperature and it is in which geothermal energy is used for heating and cooling despite the changes in air temperature. It may be more costeffective when the depth is that the central well expands enough water to transfer geothermal heat because geothermal drilling is more easily accessible than drilling to find well water. After all, it is smaller and reduces drilling time[19].

The system's categories used in the American University



Building (A)



Building (B) FIG. 6. GSHPs charts at College of Science[18]. in Madaba is based on the low enthalpy resources (<150 C) which generally employed for direct heat uses and electricity generation using a binary fluids cycle.

3. Using geothermal in residential buildings

Using the geothermal system is possible in residential buildings, there is a villa project located in Palestine supported with this system using a vertical closed-loop installed at 100 meters deep. Five heat pumps distribute hot and chilled water to a fan coil distribution system in the summer, an underground heating distribution system in winter, as well as a 4pipe AHU year around. This villa is in a large area. There is an indoor and outdoor swimming pool.As well as, there are Jacuzzi and DHW. The geothermal using is effective. The measure showed that the cooling load is up to 190 kW in summer, heating load is up to 210 kW in winter, as well as, this project is saving 121.031 kg of Co2. The result showed reducing in operating costs from 77,900 $ using the traditional system to 31,266$ using geothermal energy, and a decrease in maintenance costs from $ 3,000 to $ 1,440 annually. Thus, it saves 60 % of running cost per year and 52 % in maintenance cost per year. also, it saves 27,093 liters of diesel and 65,163kwh of electricity.

IV. THE EFFECTIVENESS OF USING GEOTHERMAL ENERGY IN JORDAN

There are 14 gas and massive diesel stations use to generate the electrical power in Jordan[2], these stations increase the proportion of gases emitted into the atmosphere, which are an essential reason for the process of Global Warming[20].

Due to climate change, the maximum summer temperatures in arid regions, as well as in other parts of the world are generally increasing[21].As a result, the demand for cooling of buildings and industrial facilities is growing and requires significant energy-related investments. Conventional energy sources mostly serve these increasing cooling demands. The residents in Jordan are using various systems to achieve cooling and heating needs. This comparison shows the difference between the energy sources we use at the Jordanian home for heating and cooling in terms of budget, annual cost, and risk.

- Gas cylinder
- Electrical devices

The gas cylinder users face many problems in the cost and the internal environment. The heater gas odor due to leakage, non-combustion is a significant danger to the mental and physical health of the population. Also, the condense steam in the cold rooms. This process helps mold to form on the ceiling and the walls. The carbon dioxide concentrations are going up after two hours of continuous operation. The electrical system faces a problem when exposed to high loads on the leading network. The number of interruptions was 12 to 41 times during 2015 and 2016, which was for 31 minutes in 2016[2].Therefore, the use of this system dramatically leads to an increase in loads, then the power outage; after that, this system will stop, which will be with heating or cooling.

Many residents support this system using a solar panel to reduce the cost in the summer, in this case, you have to choose between selling to the national electrical company or add a battery to let it active in winter because there are 55 days without the sun[22].

Noting that the geothermal system is effective in Jordan. Also, studies have shown that the ground heat in the Mediterranean basin at a depth of 20 meters to 100 is constant and its temperature reaches 12-14 degrees Celsius. Where the company has proven that this project is active and works well, also when studying a villa project in Palestine, is exceeding an area of 1500 square meters designed by the same company. The depth of the well is determined according to the required quantity of energy needed. Accordingly, when comparing the spaces between the implemented projects, we find that a well of 100 meters depth with one pump for homes may provide up to 50 kilowatts. In this section, we will study the number and extent of wells to provide the energy needed to heat and cool a 300 square meter house in Jordan. The measure is based on 20-degree celsius inner temperature[23], 8-degree Celsius outside temperature in winter, and 33-degree Celsius temperature in summer[24]. The result shows the loss of energy and energy gained in a 300 square meter residential building built with conventional

materials. As a result, the building needs up to 21 kilowatts of heating load and 14 kilowatts of the cooling load to maintain the temperature of the indoor building. It means that we need one well with a depth of 10 square meters to achieve the required load. But to maintain the system's sustainability, the well needs to be at a depth that provides a stable temperature of 20 meters below the ground. Thus, a well with a depth of 20 meters and four pumps can provide the project with a heating load of 42 kW and a cooling load of 38 kW. Applying geothermal in the existing building The geothermal project can be established in existing buildings, as the building law stipulates that it is forbidden to have any structure under the front setback of the building, the boundary between the plot of land and the exterior wall of the building from the street side. It law gives us the possibility to dig in front of the building in residential neighborhoods that have a setback, and it can also be more useful to link with the necessary infrastructure for the building, since the main parts of the infrastructures, such as water and electricity pipes, pass from the recoil in front of me to the duct from the bottom of the ground floor knot base Of the building

V. RESULT AND CONCLUSION

The study showed that the use of geothermal heat is possible in buildings in Jordan, where:

1. We can use geothermal heat meters deep from the Earth's surface.
2. The depth of the well should not be less than 20 metersto use constant ground heat.
3. One well at a depth of 20 sq.m. is sufficient to providethe necessary heat for a 300 sq.m. house
4. The geothermal system saves energy by up to 60
5. The system provides a ground temperature of 50
6. The geothermal system does not affect the foundations
7. Existing buildings can be supplied with a geothermalsystem by drilling the well in the front setback.
8. The geothermal system can be supported when usedin existing buildings by integrating it with pre-existing systems

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