

Investigation of Production Capacity of Thermo-Electric for Heating-Used Geothermal Energy in Turkey

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ABSTRACT:In this study, we investigated the use of thermoelectric generators in geothermal transmission pipelines. Turkey is one of the leading countries in the world in terms of geothermal resources. Geothermal energy is especially used in many houses, facilities and greenhouse in western Turkey. Because of renewable, clean and cheap, the energy usage increases. The hot waters coming from the underground are first transferred to the source of supply from the source to meet the warming requirement. The transfer is done with the help of pipelines. In this study, a pipeline design with thermoelectric generator was proposed and electrical energy was generated from the heat losses that would occur during transmission. Thermoelectric generators are an element that can generate electricity from temperature difference between two different sides. Various temperature differences are taken into account with the reason that the thermoelectric generator produces different electricity at different temperatures in this study. When the amount of electrical energy generated is taken into account, the transmission is sufficient to meet the needs of a residence, depending on the length of the line.

KEYWORDS:Thermoelectric Generator, Peltier, Geothermal Energy, Electricity Generation.

I. INTRODUCTION

Recently, because of cost and pollution of fossil fuels, generation of electricity has turned towards renewable resources. Renewable resources are continuous, green and cheap sources. One of the renewable sources is geothermal sources. Geothermal energy is briefly ground temperature and is defined as thermal energy contained in hot water, steam, gas or hot dry rocks under pressure accumulated at various depths of the Earth crust [1]. Although geothermal energy resources have a great advantage, they are mainly renewable as previously mentioned, that is, it is a kind of energy that cannot be depleted with proper use, easy to detect and produce, low cost, return of investment in a very short time, and the damage is minimal [2].

%95 known geothermal area in Turkey is used for heating and spa while the other is suitable for electricity production. Because of generally low and medium enthalpy in geothermal resources in Turkey, the main assessment areas can be listed as follows [3]:

- Heating (house, city, thermal facility, greenhouse, etc.)
- Thermal Tourism
- Electricity Generation
- Chemical Production

In order to meet the rapid growth in energy demand, the use of renewable energy sources would be helpful. From renewable energy sources in terms of geothermal energy resources in our country, is located on the Alpine-Himalayan belt is a country with relatively high geothermal potential. 55% of the geothermal areas in Turkey are suitable for

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heating applications. In our country, greenhouse heating using geothermal energy made 1200 acres and 100,000 residential units in 15 settlements are heated with geothermal energy[4].

Thermoelectric technology is used both the electricity generation and the air-conditioning. Thermoelectric power generators convert the thermal energy into the electrical energy directly. Moreover, the thermoelectric technology is environmentally friendly. It has no moving parts and is long-lived. Although their efficiency is about 5–10%, considering reuse of waste energy gain, their efficiency cannot be ignored [5].

TEGs are environmentally friendly in the electricity production for using waste heat as the input source, and they allow the efficient use of energy [17-18]. Despite the low productivity of the TEGs being renewable of energy input source increases the economic viability of the systems. Many studies related to increased efficiency and economic feasibility have been conducted [6-19].

In this study, the use of two clean energy sources has also been combined. The energy remaining in the transmission lines of the geothermal energy used for housing and greenhouse heating has been converted to electricity by the thermoelectric generator. In addition to the heat needs of the houses, they also meet the electricity needs.

1.1. TURKEY'S GEOTHERMAL RESOURCE POTENTIAL

Geothermal energy can be defined as hot water and steam, which contains more dissolved minerals, salts and gases than the normal underground and surface waters, whose temperatures are above the regional atmospheric temperatures, generated by the accumulated heat at various depths of the Earth crust (See Fig. 1). Turkey has rich geothermal resources, potentially is the world's 7th country. Depending on the geothermal energy temperature, many areas such as electricity generation, residential heating, greenhouse heating, thermal tourism-treatment and industry are used. Established capacity of 20.4 MWe for electricity production in Turkey is met borne solely by the Kızıldere Geothermal power plant. Total non-electric geothermal utilization capacity is 820 MWt including 493 MW residential heating and 327 MW spa [20].

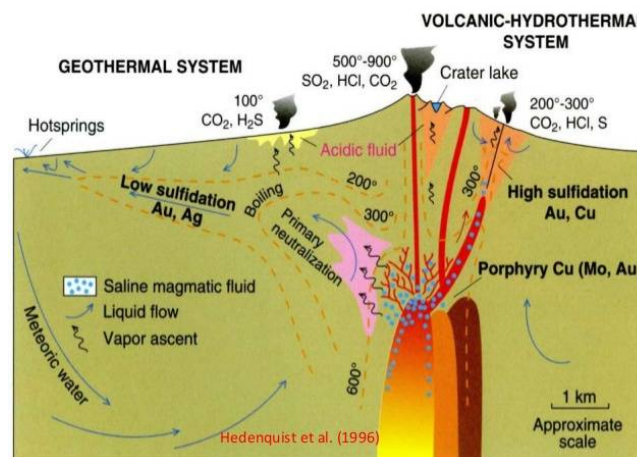


Fig. 1. Formation model of geothermal system [21]

The water temperature geothermal resources in Turkey are high. Especially in Western Anatolia, geothermal resources with water temperatures of 223 °C exist [22].

1.2. THERMOELECTRIC GENERATORS

There are several ongoing studies focusing on the thermoelectric recovery of waste heat, some rather recent and audacious, such as Shape Memory Alloys (SMAs) to generate electricity [23] but this project is still an early stage of development.

One way of regenerating exhaust heat is the use of thermoelectric generators (TEGs) based on the Seebeck effect (see Fig. 2).

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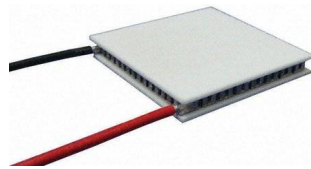


Fig. 2. Thermoelectric module

The thermoelectric effect was first discovered by Joann Seeback and is expressed by reading a potential from the open ends of the post-heating metals by combining two different metals from one point [24]. A typical multiple thermoelectric power generator principle diagram is given in Fig. 3. The thermoelectric generator consisting of P-type and N-type semiconductors consists of serial and parallel combinations of thermal elements.

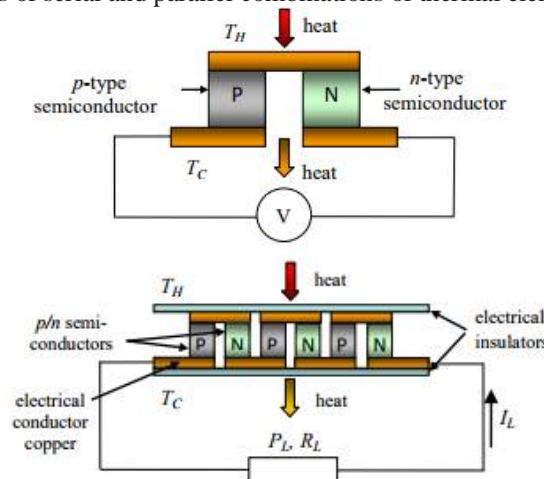


Fig. 3. a) The structure of a thermoelement, b) A TEM in the generator mode [5]

In a study conducted by Küçükkömürler and Taşdelen in 2012, thermoelectric element convert waste heat to electricity to power up. Radio frequency (RF) receiver and transmitter to measure wireless and sensorless high temperature. For that reason, the TMG-450-0.8-1.0 thermoelectric generator, the ATX-34RF transmitter, the ARX-34RF receiver and the 8051 Microcontroller have been utilized. System has been tested in the laboratory environment and promising results for wireless and

sensorless high temperature sensing and telemetry. In this study, the electricity production according to the temperature change differences is given in Table 1. [25]

Table 1. The electrical characteristics of TMG-450-0.8-1.0 thermoelectric generator used by Küçükkömürler and Taşdelen in their study [25]

Temperature Difference (°C)	V (Volt)	Current (milliampere)	Power (Watt)
22	2.68	0.059535	0.000159554
33	3.86	0.094884	0.000366252
42.1	5.23	0.117674	0.000615435
50.3	6.36	0.14	0.0008904
60.4	8.13	0.165581	0.001346174
72.1	9.14	0.197209	0.00180249
79.2	9.82	0.214419	0.002105595

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91.4	10.87	0.246047	0.002674531
99.1	11.61	0.267907	0.0031104
111	12.93	0.289767	0.003746687
120.2	13.35	0.305581	0.004079506
127.4	14.39	0.316279	0.004551255
134.1	15.2	0.328372	0.004991254
144.8	15.95	0.350698	0.005593633
154	16.76	0.36186	0.006064774
168.6	17.03	0.378605	0.006447643
179.2	17.64	0.391163	0.006900115
187	18.3	0.400465	0.00732851
193.2	18.76	0.405116	0.007599976
200	19.03	0.417209	0.007939487

1.3. USAGE AREAS OF THERMOELECTRIC GENERATORS

Many tools we use heat energy released into the environment. Using this heat energy instead of throwing it out can provide significant savings. Thermoelectric generators are also one of the devices used to save heat energy. Thermoelectric generators are used for energy saving in many areas.

First of all, working on generating electricity from idle heat has been done. One of the most important of these is the electrical energy obtained from the hot exhaust gas taken from the vehicle exhausts. The high temperature gas generated by internal combustion engines is released into the environment. A difference of 10% between the outside temperature and the exhaust pipe can be achieved by generating electricity from the difference in temperature (Fig. 4). [26]



Fig. 4. Conceptual design of thermoelectric generator producing electricity from waste heat in the engine exhaust. [26]

A clock was produced by a large clock company using a thermoelectric generator. The energy required for operation of clock comes from the thermoelectric generator, which operates with the difference between the heat in the human arm and the temperature of the clock. It keeps running on the watch without battery replacement (See Fig. 5).

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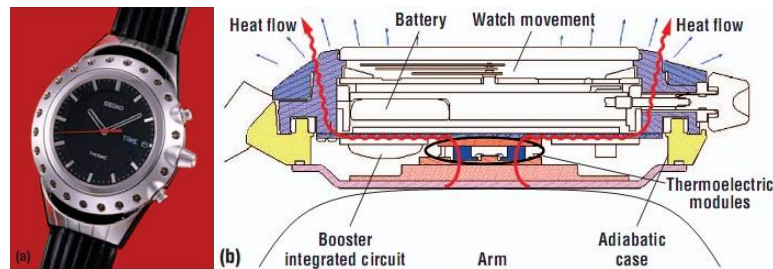


Fig. 5. Time and internal structure of the thermoelectric generator

Thermoelectric generators have been the subject of academic research as well as many developed devices. For example, a test set was created by using thermoelectric generators. The surface of the generator, which should be kept hot, was heated by the waste gas produced in the stove pipe and cooled by passing water over the cold surface. Here, the voltage values were changed between 5.11 V and 8.69 V[27].

In another work, a thermoelectric generator was placed on the intermediate plate, cooled without a prototype pipe passing high temperature through it. In the work, researchers have stated that electricity can be produced with this system and it will be useful for generating electricity in the future[28].

II. MATERIAL METHOD

As seen in Fig. 6, the hot waters coming from the geothermal wells are given to houses and greenhouses. The water coming from geothermal sources at around 200 °C enters the houses at 90 °C and reaches 70 °C. The water is used to warm the greenhouses. Finally, it is injected back into the geothermal source.

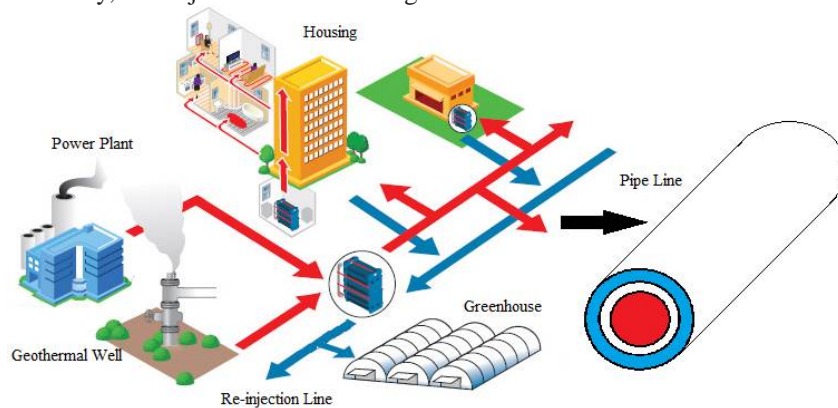


Fig. 6. Geothermal wells, distribution networks and recommended pipe design

This study investigated the electricity generation from the high-temperature water-borne thermoelectric generators carried out for geothermal heating plants. The temperature difference required for the thermoelectric generator to generate electricity is provided by the pipe type shown in Fig.7. The high-temperature water from the source passes through the center of the pipe designed as 3 layers. Cold water passes through the outermost layer. A thermoelectric generator layer is placed between the two layers. The thermoelectric generator between the hot and cold layers produces electricity.

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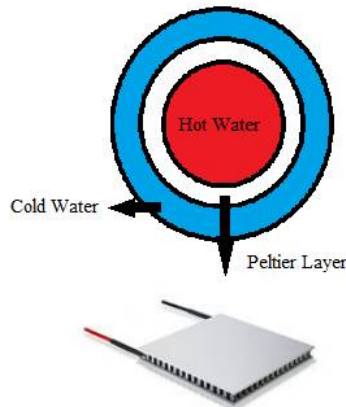


Fig. 7. Recommended pipe section

In this study, TMG-450-0.8-1.0 was chosen as the thermoelectric generator type. Thermoelectric generator specifications are given in Table 2.

Table 2: TMG-450-0.8-1.0 fabricated characteristic values

Product No	TMG-450-0.8-1.0
Measurements: Cold Surface	54.4x57.0x3.4 mm
Measurements: Hot Surface	54.4x54.4x3.4 mm
Open-Circuit Output Potential	21 V @ 125 °C temperature difference
Internal Resistance	21.5 Ω
Output Potential at Optimum Load	12 V @ 28 Ω load resistance
Output Current at Optimum Load	416 mA
Output Power at Optimum Load	5 W
Module Thermal Conductivity	1.45 W/°C
Module Thermal Flow	159.5 W
Module Thermal Flow Density	5.46 W/cm ²

The electricity produced by the thermoelectric generator was taken without the work of Küçükkömürler and Taşdelen. The operating temperature difference (°C) and generated energy (Watt) are plotted as in Fig. 8. The curve and equation of graph are determined to find the amount of energy produced per degree centigrade.

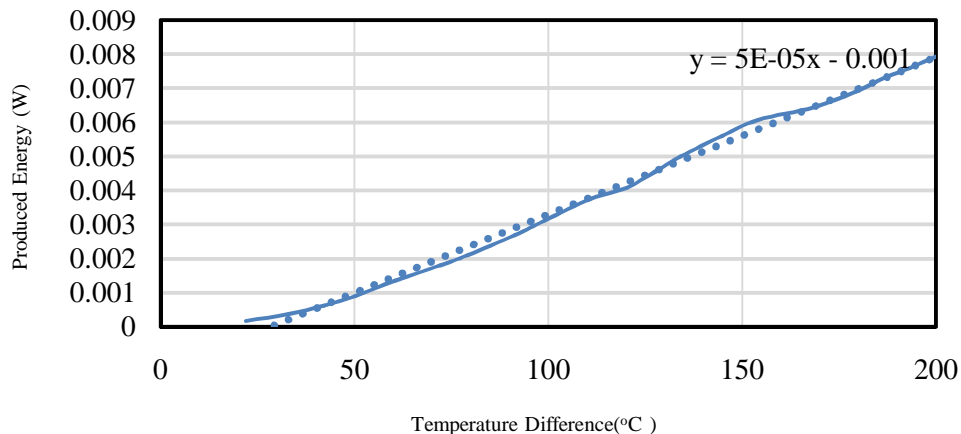


Fig. 8. Energy production of small coal and stone by temperature differences

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III.RESULTS

The results will vary depending on pipe type, pipe diameter, water temperature, water flow and thermoelectric generator type. In this study, water flow and thermoelectric generator type were not changed. Four diameters are used as pipe diameter. 50, 100, 250, 500 millimeters were selected. The diameter of the inner tube was evaluated because it would be placed on the outer diameter of the thermoelectric generator as a diameter value. Firstly, produced energy is calculated for 1meter pipe and it is presented in Fig. 9.

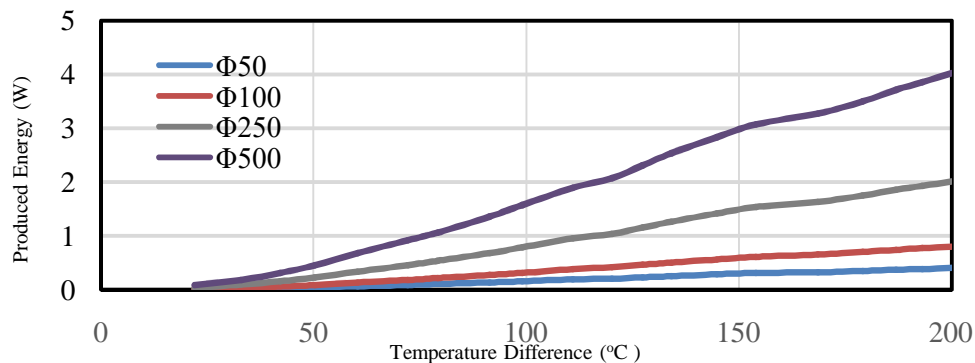


Fig. 9. Energy quantities produced by 1meter length pipeline according to different pipe diameters and temperatures

The amount of energy produced at 1 meter at different pipe diameters was evaluated as suitable values for high suitability. Energy is provided to burn a 4 Watt bulb by 200 °C and Φ500 pipeline. However, Φ500 cannot be used, lower pipe diameters will be used. In addition, the tube diameter will prolong with prolonged surge, as the thermoelectric generator will be in contact with the cause. This is thought to be 0.2°C less than the combined temperature of the water from the geothermal well. In Turkey, for the water temperature, water temperature from Aydin wells for the water temperature at 223°C and 23°C to the outer layer is selected. Thus, the calculated temperature difference for well is 200°C. Pipe distance was taken to 100, 200, 500 850 meters. It is placed at Fig. 10 according to pipe diameters and lengths.

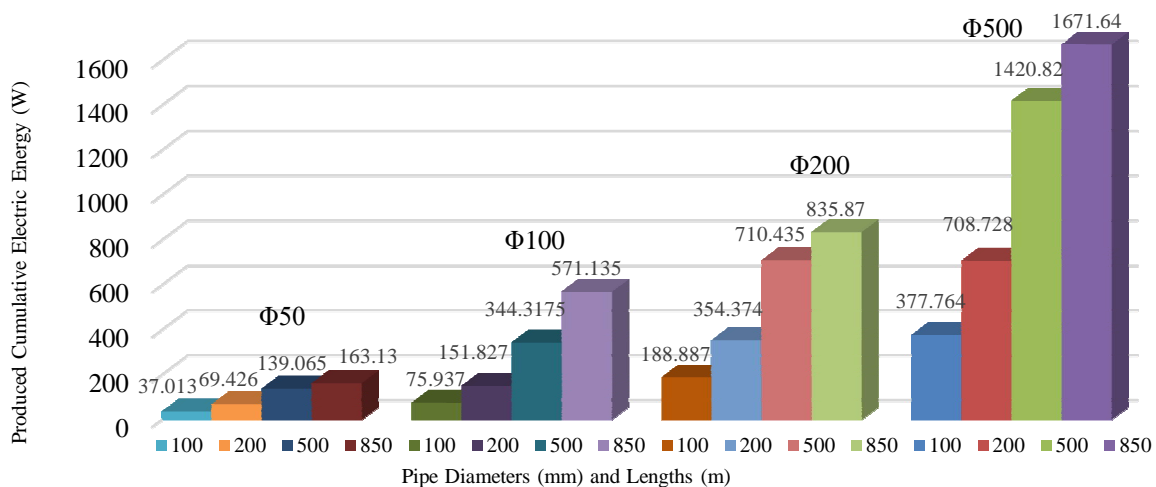


Fig. 10. Total electricity values according to pipe diameters and lengths

As can be seen, at least electricity produced a pipeline with a diameter of 50 m and a length of 100 m. The electricity produced is 37 Watt. Although 37 is less energy, it is the amount of energy that will run 3-4 energy-saving lamps

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working with 10 Watts. As a matter of course, the amount of energy produced increases as the diameter of pipes increases and diameters increase. However, as can be seen from Fig. 11, the increase does not proceed linearly. The reason is that the temperature of the water falls in every meter. The theoretical end result is the production of a thermoelectric generator with a diameter of $\Phi 500$ and a length of 850 meters.

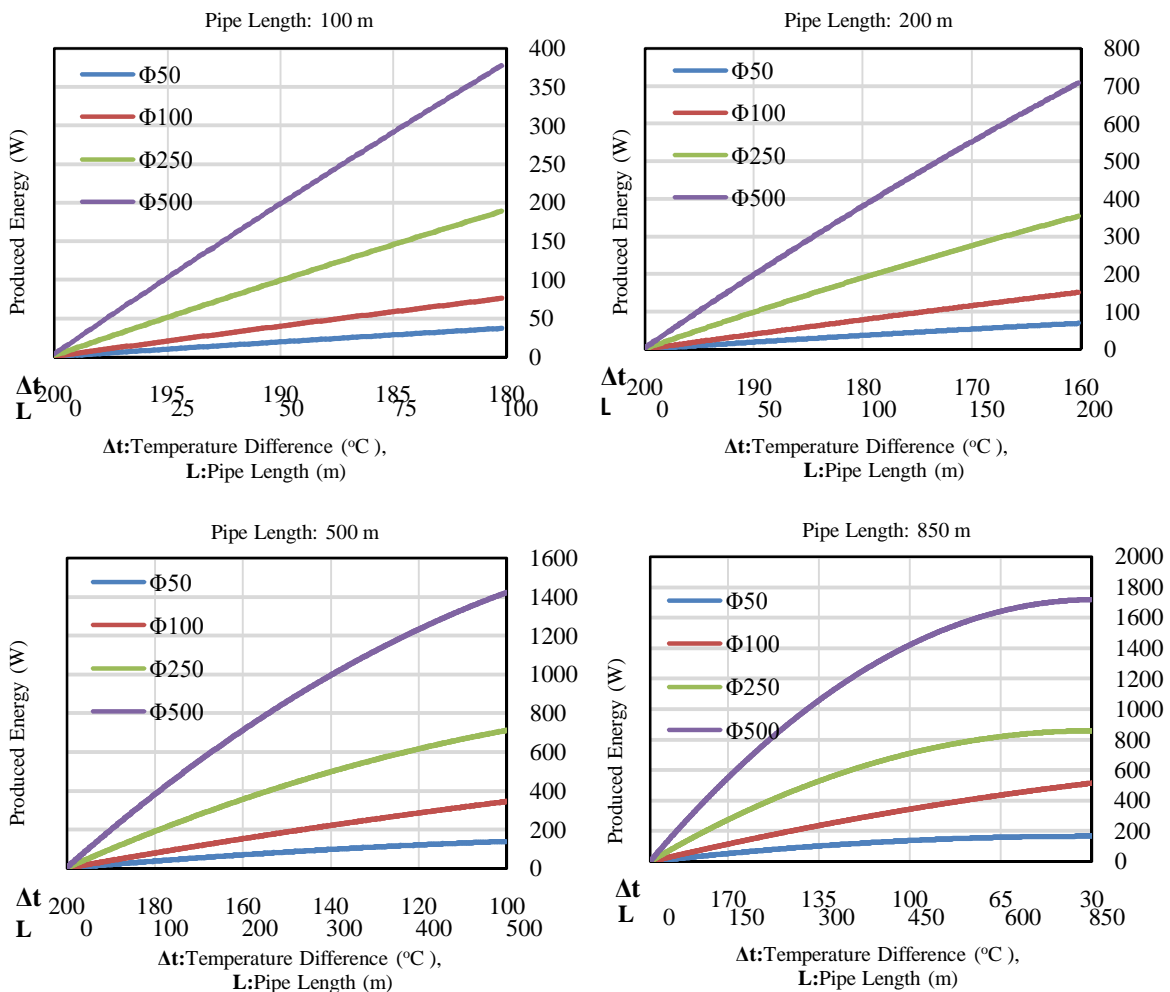


Fig. 11. Cumulative electricity values according to pipe diameters and lengths

IV. CONCLUSION

The use of the geothermal resources of the world for the duration of his art. Reservoir, to generate electricity, to heat geothermal in other areas. For this work, it is suggested to use a thermoelectric generator to convert the residual heat energy into electric energy in the transmission of geothermal waters. Thermoelectric generators are devices that produce electrical energy by means of heat differences between the surfaces. Geothermal waters always create the heat difference required by the thermoelectric generator with the specialized pipe type. With the energy obtained from the idle heat with the proposed method, it is sufficient to meet the lighting needs of many dwellings. Experimental studies will be carried out in the future, and the exact amount of energy produced will be determined. With the increase in thermoelectric generator efficiency, it is predicted that more areas will be used in the future.

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