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P1_6 Geothermal Power

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Abstract
Geothermal power is a green power source that could provide substantial renewable power. This paper looks at the approximate energy that the planet could provide using the stored thermal energy beneath the surface of the Earth. It was calculated that the energy that could be used was $3.9\text{x}10^{30}$J. However, actually extracting this energy is unrealistic with today's technology, as well as hazardous to the planet.

Introduction

Sufficient energy supply is a growing problem for the globe. Geothermal power is a green renewable energy supply that for the moment is limited to a small number of regions such as Iceland. This paper takes geothermal energy to the extreme by estimating the planets internal thermal energy and the power that could be generated from that energy.

Discussion

To estimate the thermal energy, the planet's internal structure must be considered as each layer has its specific properties such as temperature, density and volume. These properties will all affect the energy stored in each layer. A simplified version the Earths structure was used with a: lithosphere, mantle, upper and lower core [1]. Averages for temperature, mass and specific heat were then calculated or reached in the case of the specific heats.

Geothermal energy works by extracting the thermal heat from the rock by super heating high pressure water. Using this system the internal structure of the planet could eventually be cooled to room temperature. This excludes gravitational and radioactive heating inside the planet as is just an estimation of the current thermal energy stored in the planet. There will be additional energy from the latent heat as the rock in the mantle and core change state from liquid to a solid.

Theory

The mass of each section or layer of the planet had to be calculated. To do this we, used the volume of the layer and the average density of the material. Using the equation,

$$M = \rho V, \tag{1}$$

where M is the mass of the layer, ρ is the average density and V is the volume of that layer. The volume being calculated by,

$$V = \frac{4}{3}\pi\left(R_{Outer}^3 - R_{inner}^3\right), \tag{2}$$

where R_{outer} is the larger radius of each layer and R_{inner} is smaller radius of each layer. Using the mass of each layer and the specific heat's, the thermal energy can then be calculated using,

$$\Delta Q = c_p m \Delta T, \tag{3}$$

where ΔQ is the change in energy, c_p is the specific heat of the material, m is the mass of the layer and ΔT is the change in temperature. The change in temperature was from the layer's average temperature to room temperature, 20°C. The total energy for the planet is just the sum of each layer. However the transformation from thermal to electrical energy is not 100% efficient, therefore the actually usable energy output is,

$$\Delta Q \eta = E_e, \tag{4}$$

where η is the efficiency of the generator and E_e is the energy out.

The mantle and both the upper and lower core would undergo a phase change due to the energy released as latent heat, which can be calculated using the equation,

$$Q = mL, \quad (5)$$

where Q is the energy released, m is the mass of each layer and L is the specific latent heat for the material.

Results

Using the equations above as well as table 1 and table 2 in the appendix we calculated a total energy of all layers including latent heat to be 7.0×10^{30}J. Using a geothermal power plant turbine with an efficiency of 55% a usable energy of 3.9×10^{30}J can be generated [2]. This energy has been increased due latent heat of fusion as the rock solidifies. The total energy from the latent heat of fusion can be calculated using equation 5 and the masses from table 2. This value was calculated to be 4.9×10^{29} J.

Analysis

The current global energy consumption is approximately 19,500 TWh [8] which is 7.02×10^{19}J per year. With the energy from the planet the globe could be powered for over 10^{10} years. This figure ignores the increased energy from radioactive and gravitational sources that help to power planets geological structure. This is an unrealistic result as the all thermal energy from the planet could not be completely extracted. To meet growing global energy demands only an insignificant percentage of the energy would be required.

Conclusion

The result shows that geothermal energy is a real possibility to replace current power generation methods. However access to geothermal power is currently limited to geological hot spots that provide easy access to high temperatures. Furthermore energy would be extracted from the upper layers first, as it is much easier to access from the surface of the Earth. The heat extraction results in outer layers cooling and solidifying making it harder to extract the heat from the deeper layers. There are many dangers of solidifying the core, one of which may be the loss of the magnetic field that protects the planet.

References

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Appendix

Table 1 [9][10]

Material	Latent Heat of Fusion (kJ/kg)
Oxygen	13.9 [9]
Magnesium	368 [8]
Silicon	1.926 [8]
Iron	272 [8]
Nickel	297 [8]

Table 2 [3][4][5][6][7]

Layer	Mass (kg)	Change in temperature, ΔT (K)	Average specific heat (J/kg K)
Lithosphere	8.5×10^{22}[3]	1180 [7]	1.2×10^{3}[3]
Mantle	1.5×10^{24}[6]	2230 [7]	0.98×10^{3}[4]
Upper core	1.24×10^{24}[3]	5230 [7]	445 [5]
Lower core	5.32×10^{22}[3]	5680[7]	450 [5]