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Graphene: The Key to Revolutionize Geothermal Energy

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ABSTRACT

Geothermal energy has been under research and development for several decades, with its full potential yet to be explored. The greatest advantage being, its worldwide availability regardless of the location. A few thousands of meters below us lies the unlimited potential for heat energy. The challenge is to extract this energy in a way that is economically feasible. A major step forward would be to bring a change in the current method, which depends on heat transfer through moving fluid. Graphene is one of the world's thinnest materials, a two-dimensional crystalline structure of carbon with an extremely high thermal conductivity in the range of 3000-5000 W/mK at room temperature. Also being one of the strongest materials, graphene introduces the possibility of using wires for transferring geothermal heat to the surface of Earth. This paper considers and explores all the factors related to the use of graphene for production of geothermal energy. While examining the current scenario in the development of this method, discussing future scopes and challenges would also be the objective of this paper. Obtaining a balance between an expensive set-up and a sustainable operation might be the key to effectively utilizing this incredible renewable resource.

1. INTRODUCTION

Energy demand is widely increasing in the current century due to rapid population growth and automation. Electricity is a necessary form of energy in the current scenario. Worldwide electricity consumption is around 22,315 TWh in 2018-19 [https://www.iea.org/reports/electricity-information-overview]. Nowadays electricity production mostly generated with steam turbines using fossil fuels, nuclear, biomass, geothermal, and solar thermal energy. China and USA produce the most electricity per country, and India is in third place (Figure 1). China is producing 27,644,800 GWh per year, and India producing 2,561,100 GWh of electricity per year [https://www.iea.org/reports/electricity-information-overview]. Fossil fuel is a non-renewable energy source, so the entire world is shifting dependency from fossil fuel to renewable energy resources like tidal energy, water turbines, wind energy, solar energy and geothermal energy.

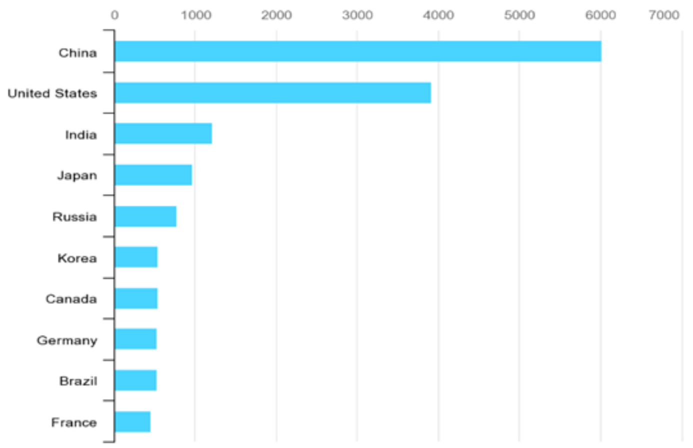

Fig. 1 Worldwide energy production by different countries [https://www.iea.org/reports/electricity-information-overview]

Geothermal energy resource is stored thermal energy content of the rock and fluids underlying land masses to a depth of around 10 km from the earth's crust (Tester, 2007). Normally, the heat is transported from depth in geothermal energy regions initially by conduction and then by convection, and geothermal fluids like water are carriers of heat. Geothermal energy resources have high temperatures around 300°C. Penetration of water into a geothermal reservoir leads to conversion into vapour by using geothermal heat, and turbines at the surface convert water vapour into electricity (Barbier, 2002). A schematic of a geothermal energy field is shown in Figure 2. Based on a geothermal energy survey in 2010, around 48,500 MWt of electricity are produced per year from geothermal fields. Geothermal energy fields are widely used in electricity production; other applications are snow melting, industrial process heat, agricultural crop drying, desalination, greenhouse heating etc. (Lund et al., 2011).

Water is widely used as the carrier of heat (or heat transfer medium) in geothermal wells. Water can cause pollution, so the option of using water should be reconsidered. Graphene is a super-conductive carbon-based material. Graphene is used for energy storage (Shah et al., 2018; Shah et al., 2019).

In this paper, a discussion of geothermal energy recovery is presented. Graphene material may potentially be used as a super conductor for extraction of geothermal energy. Challenges and features of graphene as geothermal energy recovery also considered herein.

2. APPLICATION: GRAPHENE IN GEOTHERMAL ENERGY.

Graphene is a two-dimensional sp^2 bonded carbon atom laid out in a honeycomb type crystal (Figure 3). It has special features, such as: large specific surface area, flexibility, chemical stability, and extraordinary electric and thermal conductivity (Mulopo and Abdulsalam, 2019). Graphene was originally named by Hans-Peter Boehm in 1962 as a combination of the word “graphite” and the suffix “-ene” (Ferrari et al., 2015). The distance of C-C in graphene is 0.142 nm, and three million graphene sheets would amount to a thickness of around 1 mm (Saati, 2015). The thermal conductivity of graphene at room temperature is around 3000 to 5000 W/m*K, which is the highest value of any known material. Based on this very high thermal conductivity, graphene is potentially very suitable as a transmitter of geothermal heat from the reservoir to the surface.

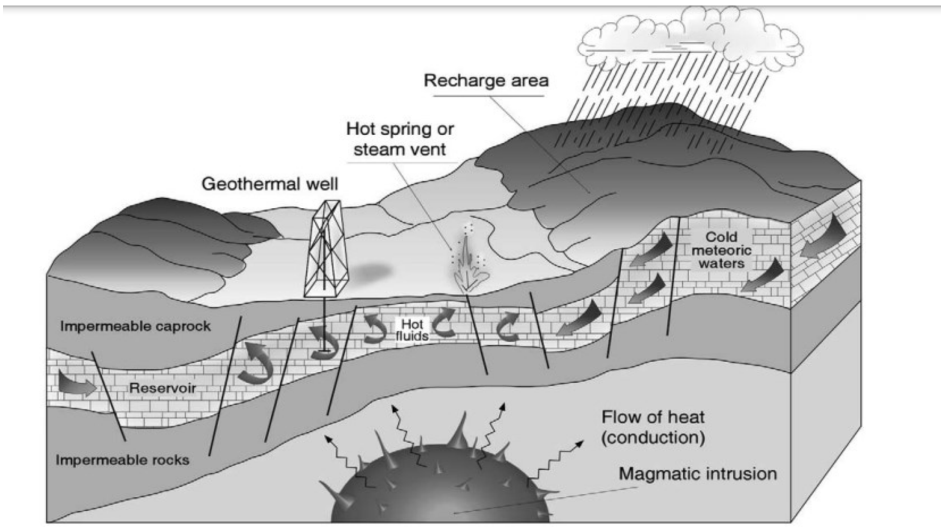

Fig.2: geothermal steam field with different elements (Barbier, 2002)

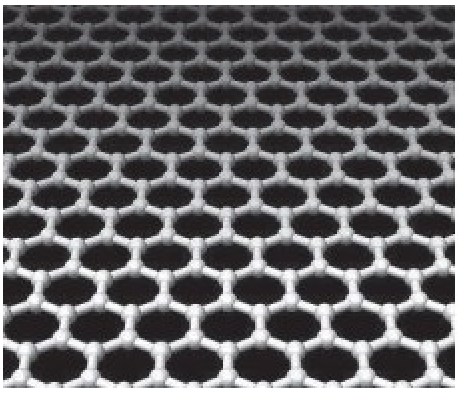

Fig. 3: Graphene structure (Sur, 2014)

The production of geothermal energy has historically used water as a heat-transfer medium. This use of water can potentially have a bad impact on the environment. Graphene is a carbon-based nano material having a high thermal conductivity around 3000 to 5000 W/ m*K. Geothermal energy reservoirs can have temperatures in the range of 200°C to 300°C. So graphene wires could be used as a means of heat transfer for utilization of geothermal energy. Due to the high thermal conductivity of graphene, this material could potentially transfer the energy from the of geothermal reservoir to the surface. Transported geothermal energy from graphene can be converted into mechanical energy and further into electricity. Conduction of heat could be done by graphene wires. This process is environmentally friendly and potentially more economical. Graphene has been used in other applications such as waste energy storage, capacitors, and batteries for storage of energy. Solar energy has also been harvested by graphene-based materials.

3. CHALLENGES AND FUTURE SCOPE

Conventionally, geothermal energy has been developed with water as the heat-transfer medium. This is the cheapest way to utilize geothermal energy. However, there are many challenges in water-based geothermal energy utilization: air pollution, water pollution, the huge amount of water needed, and maintenance. Since the earth's crust contains heavy metals, circulating water may be contaminated by heavy metals and cause water pollution. Gases dissolved in the water (such as SO_2 and H_2S) can cause air pollution. Conventional geothermal development can limit the availability of water for other uses due to water pollution and excessive water usage. Dissolved constituents such as HCl and HF can cause corrosion in steam turbines, so maintenance could be challenge. Graphene could potentially solve all these problems. A graphene wire could directly transport geothermal heat to the surface. It is an environmentally friendly and flexible process. Graphene transmits heat very fast as compared to relying on the circulation and boiling of water for power generation.

Water is widely used as the heat-transfer medium for geothermal energy. Water is easily available and cheap, so it is widely used in conventional geothermal development. Water is economical and generally easy to work with, despite the potential challenges enumerated above. For the production of geothermal energy, water can also be reusable through injection back into the reservoir. Potential challenges for graphene-based recovery of geothermal energy include the fact that graphene is relatively expensive compared to water. Also, graphene would function as the transmitter of energy to the surface, which means that graphene would need to transfer heat to water for steam generation. Further, because graphene would transmit to the surface only the heat from the material it actually contacts, it would need to be immersed in water that is moving through the reservoir in permeable zones; otherwise the available heat would be limited to the near vicinity of the wellbore. Overall, graphene may not initially appear economical as compared to water-based production of geothermal energy.

4. CONCLUSION

Fossil-fuel-based electricity generation will continue to be a challenge in the future, because of fossil fuel is a non-renewable energy source. Renewable energy sources like solar energy, wind energy, tidal energy, and geothermal energy are in the limelight. Geothermal energy has essential features for the future of energy generation. The use of water as the heat-transfer medium for geothermal energy could be replaced by graphene. Graphene has one of the highest thermal conductivity values of any carbon-based material, with a thermal conductivity around 3000 to 5000 W/ m*K. Graphene wire could be used as a replacement of water in geothermal energy recovery. Challenges for graphene-based energy recovery include its expense as compared to water, and the fact that it would still need to transmit its energy to water at the surface for steam generation. Therefore, graphene may not initially appear as economical compare to water for geothermal energy recovery. However, graphene has special features that may still make it attractive in certain circumstances, because it can be considered environmentally friendly and less polluting.

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