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Analysis of geothermal energy as an alternative source for fossil fuel from the economic and environmental point of view: A case study in Iraq

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ABSTRACT

In the field of electricity production, factors such as the restricted availability of investment resources and the state of the surrounding environment are among the most significant factors that influence this process. Minimizing the cost and the harmful effects of the environment has always been and will be the concern of experts. The method of generating electricity using geothermal power plants is being highlighted due to the gravity of the issue of environmental protection as well as the security of electricity. Obviously, the resources necessary for investment in our country are overshadowed by environmental issues. Now, the main question is whether it is possible to replace fossil power plants with geothermal ones, or at least in the future? Given the high cost of electricity production by geothermal power plants and the state of electricity production costs in the country, this study tried to do an economic study of the aforementioned issue, taking into account the social costs. In this study, the total cost of electricity generation per kilowatt hour (kWh) in each of the power plants has been calculated. Then, a necessary evaluation has been made taking into account the pollution and greenhouse gas emissions from fossil fuel power plants along with the imposed external costs. At the end, it was found that the production of electricity by geothermal power plants is not economically justified, compared to fossil power plants in scenarios 1 and 2. However, this can be taken into consideration in scenario 3, and it is economic in scenarios 4 and 5. Finally, it seems using energy from fossil power plants based on scenarios 1 and 2 will not be economically justified in the not-too-distant future given the rise in electricity demand, the scarcity of fossil resources, and the high level of pollution from these sources.

Keywords: external costs, geothermal power plant, social costs, total costs.
Article type: Review Article.

INTRODUCTION

One of the most important concerns for sustainable development is energy. While industrial civilizations and large cities are concerned about environmental pollution, it is also evident that the amount of fuel and raw materials needed is declining, since fossil fuels are non-renewable resources (Masoudi *et al.* 2020; Molajou *et al.* 2021a; Moosavian *et al.* 2022; Hasheminasab *et al.* 2022). Clearly, how high energy consumption exhibits an adverse

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effect on the environment, and some people believe that the only way to address this, is to minimize energy use (Martins *et al.* 2019; Molajou *et al.* 2021b; Afshar *et al.* 2022). However, sustainable development dictates that this is not only false, but also impractical. Since electricity is arguably the most versatile energy source in the contemporary global economy, it is largely associated with both anthropogenic and economic progress (Swain & Karimu 2020; Mobaseri *et al.* 2021). Maintaining social resource consumption at a level that won't deprive future generations of their requirements is the definition of sustainable development (Kaygusuz 2012). Sustainable development is a dynamic process that circuits investment while orienting technology and institutions to be in line with both current and future demands (Sharvini *et al.* 2018; Noorollahi *et al.* 2019; Hao *et al.* 2021). Therefore, focusing on renewable energies, especially geothermal energy, is one of the crucial elements to achieve sustainable development (Shen *et al.* 2021; Bąk *et al.* 2022). The objectives of this study are: (i) Evaluating the issue of whether the development of geothermal power plants will be economic in terms of social costs; (ii) Analyzing the impact of social costs on decisions regarding the construction of geothermal power plants, or, to put it another way, evaluating the efficiency of social costs (increasing and reducing them); and (iii) Examining which fossil thermal power plants are competitive with geothermal power plants in terms of social costs. It is absolutely necessary for the continued economic growth of highly developed industrialized nations to have access to an adequate and reliable supply of power (Eisenmenger *et al.* 2020). This holds true for every aspect of a contemporary economy, from private families all the way down to the production sector, transportation, and the service sector. Given that majority of the country's power plants use fossil fuels, the fundamental question is whether geothermal power plants are superior to thermal power plants in terms of environmental concerns and the cost of social services (Timilsina 2021). To put it another way, the study aims to look into and compare the cost-benefit of various fossil thermal power plant types with geothermal ones.

MATERIALS AND METHODS

The information for this study was gathered through the use of the internet, as well as libraries and documents. Statistics reports and statistical tables that were readily available were used to gather pertinent data, and in some cases, interviews with specialists were also conducted. Economic plan evaluation methodology, information analysis methodology, cost-benefit analysis, and analyses based on determining the benefit and true cost of power plants are the types of research methods employed in this study. After calculating the overall costs associated with producing a unit of energy in fossil power plants, various production scenarios were examined by taking external and social costs into account. Additionally, the overall cost of producing one unit of energy in geothermal power plants was determined. The social cost and the total cost of producing an energy unit in the geothermal system were regarded as being equal, disregarding the negligible external expenses associated with various types of geothermal technology. The social costs analyzed in this study only comprised the external costs of air pollution due to the limited information that is currently available; the external costs of water, sewage, soil, and noise pollution have not been taken into account. Finally, the social cost of producing a unit of energy in various scenarios of fossil and geothermal energy is compared.

Geothermal power plants

The energy that has been trapped as heat under the Earth's surface is called geothermal energy. There are regions where this energy can be used to generate power as well as heat homes and businesses. This heat is primarily generated by processes occurring deep within the planet. The Earth's core is approximately 5,000 ºC, and heat is continually being transferred from the core to the surface. The natural radioactive decay of elements is what generates a large portion of the heat deep inside the Earth (Bayer *et al.* 2019). When geothermal energy is used indirectly, it typically refers to the process of generating electricity by utilizing heat from a geothermal source. Direct use of geothermal resources is the employment of underground hot water to heat buildings, pasteurize milk, heat water for fish farming, dehydrate onions and garlic, grow plants in greenhouses, and for many other applications (Dwita Silambi 2019; Hasan *et al.* 2022). Geothermal power plants are divided into two important categories: (i) Geothermal power plants with two-phase fluid (steam and liquid); (ii) Geothermal power plants with single-phase fluid (liquid).

Geothermal power plants with two-phase fluid (binary cycle power plant)

The geothermal wells release the fluid, which typically takes the form of two phases: liquid and steam. The more wells, where the more liquid and steam are released, and the more energy is produced as a result. These fluids are collected in the vapor-liquid separation tank and the vapor phase fluid is separated from the liquid. Separated

steam enters the turbine and rotates the turbine blades, which in turn move the turbine axis and subsequently the generator axis, resulting in the appearance of positive and negative poles in the generator and the generation of electricity (Fig. 1) (Meng *et al.* 2022).

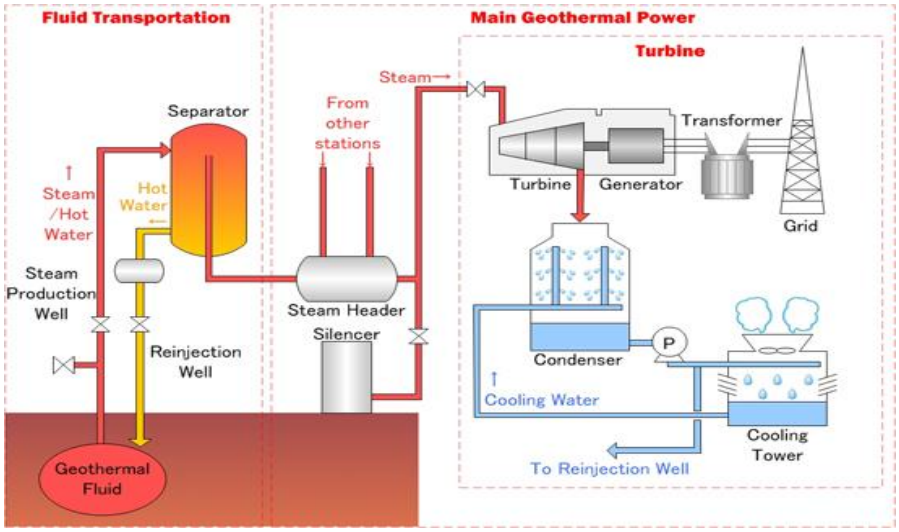

Fig. 1. Binary cycle power plant.

Geothermal power plants with single phase fluid (flash steam power plant)

This type of power plants does not need a separator tank, since hot water enters the heat exchanger and transfers its heat to another operating fluid, which is usually isopentane and has a lower melting point than water. In this process, isopentane is converted into steam and transferred to the turbine, where the turbine and generator can produce electricity according to the abovementioned explanation (Fig. 2; Alhamid *et al.* 2016).

A discussion of private, external, and social costs

Private and external costs

Any expense that an individual or business incurs to purchase or manufacture products and services is referred to as a private cost. This covers the price of labor, supplies, equipment, and any other costs that the client or business bears. Uncompensated social or environmental repercussions are referred to as external costs (also known as externalities) in the context of economics. For instance, when consumers purchase fuel for a car, customers cover the cost of producing that fuel (an internal cost), but not for the costs associated with burning that fuel, including air pollution (Greenstone & Looney 2012).

Destruction costs

This type of cost compensates for the damages caused by the release of pollutants. This means that as a result of activities contrary to the principles of environmental protection, human health, ecosystems, agricultural products, buildings and the global climate are exposed to adverse changes. Costs that can compensate for such changes are called destruction costs (Smith *et al.* 2014).

Social costs

The sum of private costs and external costs are called social costs. The calculation of external costs leads to the fact that, firstly, we can calculate the actual cost of the power plant that the society bears and hence have a correct guide in choosing the right power plant; secondly, the imposition of taxes that can be used to reduce pollution and improve renewable and clean energy technology (Hohmeyer 2012). When the rise in energy demand is foreseeable and we need to have a plan to expand the capacity of power plants, so that the market finds equilibrium as well as the price and the final social cost are equal, calculating social costs is a valuable decision-making tool to manage electricity demand (Samadi 2017).

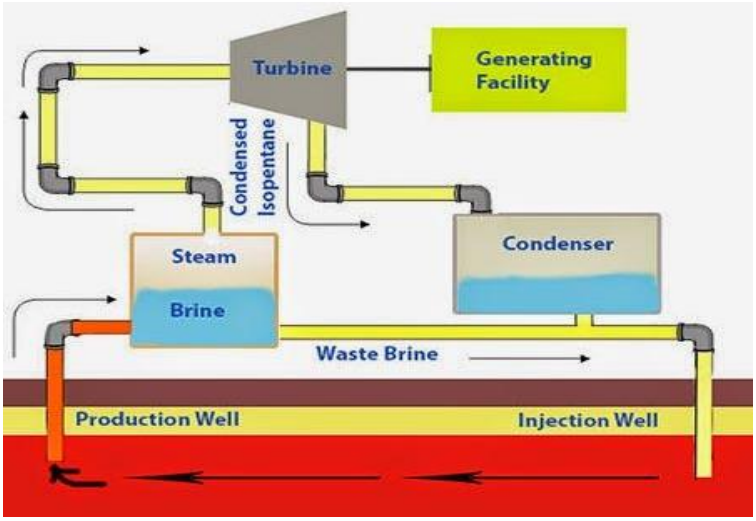

Fig. 2. Flash steam power plant.

Estimating the cost of power generation

Estimating the cost of electricity generation in geothermal power plants

In geothermal power plants, the running and maintenance costs of the system are examined in terms of percent per year, with the investment and construction costs expressed in terms of Iraqi dinar per kilowatt-hour (kWh) of electricity produced. Table 1 displays the results of calculations for the final cost of geothermal technology-based power production.

Table 1. The cost of producing electricity based on geothermal technology.

Net costs of electricity production (Iraqi dinar/kWh)			
Net cost components			Sum of net production costs
Fuel cost	Capital depreciation cost	Maintenance and personnel costs	
0	395.86	75.92	471.78

According to Table 1, the total cost of producing one kWh of electricity in the geothermal power plant is 471.78 Iraqi dinar. The predictions showed that in the coming years, the investment costs and also operational and maintenance ones will decrease (Al-Kayiem & Mohammad 2019). The advancement of technology and the enhancement of production techniques will result in cost reduction.

Estimating the cost of electricity generation in fossil power plants

The cost of producing one unit of electric energy in each of the fossil power plants includes the initial investment costs for the construction of the power plant, repair and maintenance costs, operating costs and also the fuel cost of the power plant. In this study, the total cost of producing one kWh of electricity, in all types of fossil power plants in the country, under various scenarios and taking into account the current conditions, the internal price of fuel and the global price of fuel, external costs caused by pollution and greenhouse gas are reviewed based on the World Bank and Environmental Organization studies along with the US Environmental Protection Agency (USEPA) coefficients. The 1st scenario displays the overall cost of producing one kilowatt hour of power under the current circumstances. According to the study conducted by the World Bank and the Environmental Organization, the 2nd scenario outlines the overall social costs of producing one kWh of energy, including the internal cost of fuel and the total external costs of greenhouse emissions and air pollution. Based on the coefficients of the USEPA, the 3rd scenario displays the overall social costs of one kWh of energy, including the internal price of fuel and the total external costs of polluting gases and greenhouse gases. According to studies by the World Bank and the Environmental Organization, the 4th scenario estimates the total social cost of producing one kWh of energy, including the free on board (FOB) price of fuel of the Persian Gulf and the complete external costs of greenhouse gases and pollutants.

The 5th scenario estimates the total social cost of producing one kWh of energy, including the free on board (FOB) price of fuel of the Persian Gulf and the complete external costs of greenhouse gases and pollutants based on the coefficients of the USEPA. The defined scenarios are shown in Table 2.

Table 2. The social cost of finished electricity production (Iraqi dinar/kWh).

Type of power plant	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Thermal	220.38	279.56	443.34	527.83	691.61
Gas	158.18	224.48	435.12	570.49	781.13
Combined cycle	205.60	239.52	373.19	413.30	534.97

The cost of electricity generation: a comparison

As determined by the computations, it is evident that:

- Geothermal power plants cannot compete with any of the fossil power plants when taking into consideration the country's current fuel prices, ignoring the expenses resulting from the production of polluting and greenhouse gases, and doing so as a result of ignoring the societal costs.
- The geothermal power plant cannot compete with any of the fossil power plants given the present cost of fuel within the country and the social costs based on the study conducted by the World Bank and the Environmental Organization.
- Given the current price of fuel in the country and the social costs based on the EPA coefficients, electricity generation from the geothermal power plant can be considered.
- With the exception of the combined cycle power plant in 4th scenario, producing electricity from geothermal power plants in competition with fossil fuel power plants will be preferable and economically viable when taking into account the global fuel price as well as the social costs, according to studies conducted by the World Bank and the Environmental Organization, as well as the USEPA coefficients.

RECOMMENDATION

1) The primary sources of fossil fuel power plants are refined and processed before being sold domestically or abroad. In this case, the added value of the raw materials is regarded as an opportunity cost that is not currently taken into account.
2) The costs of water, sewage, soil, and noise pollution produced by power plant activities have not been accurately quantified due to the difficulties of determining external costs, hence this study was forced to overlook these expenses in the calculation and comparison.
3) Fossil resources that are currently used as raw materials in fossil power plants certainly have inherent or non-use values such as existence and bequest values. Therefore, if these values are quantitatively calculated and monetized, using fossil resources may not be very economic.
4) By raising public awareness, which will enhance people's willingness to pay for not polluting the environment, the price elevation of electricity produced by renewable sources of energy may be more widely accepted by society.
5) Efforts to improve the quantity and quality of scientific and practical studies on the employment of renewable energies and, as the case may be, geothermal energy.
6) Trying to attract financial assistance from international organizations such as Global Environmental Facility (GEF).
7) Attracting funds from the financial mechanisms of the climate change convention and actually entering the publishing business as a seller of the right to pollute and spending this income on investing in the development of geothermal power plants.

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