

Review

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Review

Geothermal Resilience to Energy Production Issues

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Abstract: The modern era has numerous issues associated with power generation, especially with old fashioned combustion power plants. Since fossil fuels are primarily responsible for the emission of greenhouse gasses, there is a desperate need for adaptation and sustainability. Looking at those challenges, geothermal energy which civilization had a long time ago becomes the desirable solution. This paper aims at establishing the feasibility of geothermal power plants in meeting the challenges of energy intensity and environmental conservation. This study also illustrates that the categories of geothermal energy systems which include the dry steam, flash steam and the binary cycle power plants are capable of achieving high capacity factors, initiating feasibility studies, and have relatively low impacts on the environment. While it is likely to cost more in the initial stages of construction, geothermal power plants provide more long-term cost benefits and significantly fewer toxic emissions relative to the fossil fuel plants. Switching to geothermal energy not only means that the world will have new sources of energy in the near future but also that it will be clean and environmentally friendly. Through incremental steps, geothermal power plants may well open the door to a full energy source infrastructure for subsequent generations.

Keywords: geothermal energy; energy efficiency; greenhouse gas emissions; sustainable energy production

Modern Energy Production Issues

After the introduction of fossil fuels during the Second Industrial Revolution and ever-escalating into the current years, the persistent issues involved with the production and distribution of affordable and efficient energy continue to afflict the world and have also had many disastrous consequences upon the environment through the emission of greenhouse gasses into the atmosphere. As stated by Laurie Alexander and her colleagues at the United States Environmental Protection Agency in their report describing the various origins of greenhouse gasses within the current United States' economic sector, "electricity production [accounted for] 25% of 2020 greenhouse gas emissions" which is estimated at around 1495 million metric tons of carbon dioxide (Alexander, et al. para. 1). In addition to the significant release of greenhouse gasses, the predominant modern forms of energy production, such as combustion power plants, are exceedingly energy inefficient. According to the data collected upon transforming power systems, conducted by researchers of the United States Department of Energy, "the average coal-fired power plant in the United States operates near 33% efficiency" (Crabtree et al. para. 2). Both modern complications of large greenhouse gas emissions and minimal energy efficiency continue to become increasingly menacing upon society as energy production struggles to adapt and the world's population continues to exponentially expand and grow.

In spite of these issues created in prominent deficiencies in the energy production system, this has sparked innovation within many indigenous communities in order to develop and adapt to things such as climate change by becoming more in touch with nature. Upon her visitation to many of these indigenous communities, Julia Watson states that "we have thousands of years of ancient knowledge that we just need to listen to and allow it to expand our thinking about designing symbiotically with nature" (Watson 0:08:02-0:08:13) This leads to the indefinite, innovative possibilities which lie in the history of human civilization building with nature, leaving one major possibility, geothermal energy. Through the harnessing of geothermal energy and through the implementation of geothermal power plants, society will be able to minimize and possibly eliminate

these energy production issues by allowing it to stay resilient through the provision of a clean, sustainable source of energy in comparison to combustion systems through high energy efficiencies, low greenhouse gas emissions, and beneficial side products.

Types of Geothermal Energy and Energy Efficiency

Geothermal energy has been an energy production method that has been around since ancient times and mainly utilized for heating and cooling; however, it has recently evolved to be suited for urban energy production usage through the incorporation of new technologies. Currently, geothermal power plants are power plants that utilize the Earth's natural heat which "draw fluids from underground reservoirs to the surface to produce steam [which] then drives turbines that generate electricity" as defined by the Geothermal Technologies Office in their article on electricity generation (Geothermal Technologies Office para. 4). Extended from this basic definition of a geothermal power plant stems three major types of systems used to generate electricity from geothermal energy which includes dry steam power plants, flash steam power plants, and binary-cycle power plants, of which dry steam is currently the most widely used in the world today and will be the basis for the majority of the research uncovered within the rest of this paper.

Unlike the current systems of producing energy, mainly combustion power plants, geothermal power plants are capable of producing energy efficiently while maintaining a practical cost. One of the primary and fundamental ways utilized in the determination of the energy efficiency of electricity production in power plants is the term capacity factor which is defined as "how often a plant is running at maximum power" (Office of Nuclear Energy, para. 10). This statistic is a common method in which researchers employ in order to compare the various capabilities in energy efficiency within various types of power plants. Based upon the research of the Office of Nuclear Energy for the United States government on the generation capacity of various types of methods for energy production, coal combustion power plants, one of the most common energy production sources, only had a 49.3% capacity factor in 2021, meaning that it only produced energy at its maximum capacity less than 50% of the time (Office of Nuclear Energy, para. 11). Upon examination of this issue upon a global, or even national, scale, it is evident that the capacity factor for coal combustion power plants is highly inefficient since the energy generation is only optimized around half of the time during times of production. In spite of this, geothermal power plants provide a possible evolutionary change within the energy production systems since "modern geothermal power plants deliver a capacity factor upwards of 90-95%", according to research conducted by the Office of Energy Efficiency and Renewable Energy (Office of Energy Efficiency and Renewable Energy para. 4). The capacity factor of geothermal power plants can be seen to be nearly double that of coal combustion power plants, which will provide a significant advantage to a booming population. Through the enhanced capabilities to produce energy at the maximum capacity twice the amount of times that the current energy production methods do, geothermal power plants will be able to provide significantly more amounts of energy to supply new technologies and maintain the power supply for increased consumption. Due to this significant increase in production capacity, the implementation of geothermal power plants will allow for increased resilience in the face of the escalating demand for affordable, efficient energy driven by the current, booming population growth.

Costs Associated with Geothermal Power Plants

Geothermal power plants not only provide significant advantages in the realm of energy efficiency and energy production capabilities but also to the affordability of energy despite initial construction costs due to low production and maintenance costs. The economic cost can be broken down into two major categories, the initial cost for implementation and construction of the power plant and the operating and maintenance costs associated with the power plant. Based on data collected by the United States Energy Information Administration, natural gas power plants, a form of combustion power plants, has an average construction cost of \$965 per kilowatt while geothermal power plants have an average construction cost of \$2851 per kilowatt (Ray and Lee para. 1). Despite this significant difference in initial costs, the majority of it consists of scouting for proper locations

for the harnessing of geothermal energy. This is primarily due to the requirement of specialized equipment and technology used for measuring subsurface conditions and transportation over challenging terrain. However, the high initial costs are completely outweighed by the significantly lower operating costs of geothermal power plants in comparison to the current combustion power plants. In research conducted by Sanyal, published under Stanford University on the cost of geothermal power, the operating cost and maintenance cost of geothermal power plants was discovered to be only 1.4 cents per kilowatt per hour or 14 mills per kilowatt per hour (Sanyal pg. 2). This operating cost, or the cost required to maintain and produce energy at the average level produced by the power plant, is significantly lower than that of combustion power plants. According to the United States Energy Information Administration in their data collected on the average operating expenses for major power plants, fossil steam power plants, a form of combustion power plants, had an operating cost of 35.66 mills per kilowatt per hour in the year 2021 (DeCarolis et al., pg. 1). The difference between the operating costs for geothermal power plants is more than half of the operating cost for combustion fuel power plants. This disparity enables geothermal power plants to be considered more economically sustainable than combustion power plants in spite of the significantly higher initial costs since its effects are ongoing. Although the early years of energy production by the combustion power plants would be cheaper overall, after a few years the overall costs associated with the combustion power plants would surpass that of the geothermal power plants and the difference between them would continuously increase. Therefore, the implementation of geothermal power plants would be substantially more economically beneficial in comparison to combustion power plants over time due to their lower operating and maintenance costs.

Reduction of Toxic Byproducts

Another issue associated with the current energy production methods in the looming circumstances of the ever-growing population is the release of toxic waste into the environment by combustion power plants. As Eric Bender states in his article on urban evolution, "impoverished neighborhoods tend to have higher temperatures, greater exposure to pollutants, and other environmental disadvantages" (Bender pg. 7). This can be observed as a direct result of the heavy release of pollutants such as greenhouse gasses into the atmosphere from combustion power plants since poorer neighborhoods tend to be located closer to factories, refineries, and power plants. In contrast to this, geothermal power plants are widely considered a form of energy production which releases relatively minuscule amounts of greenhouse gasses into the atmosphere. In a research study conducted by Eberle, Heath, Nicholson, and Carpenter on the greenhouse gas emissions from geothermal energy, around 47 grams of carbon dioxide per kilowatt per hour was produced by a flash steam geothermal power plant (Eberle et al. pg. 5). When set in comparison to the carbon dioxide emissions resulting from combustion power plants, the amount produced by a geothermal power plant seems to be a minuscule and almost inconsequential to the issues of climate change. According to research conducted by Mittal and others of the U.S. Environmental Protection Agency on the estimates of emissions of coal-fired power plants, coal combustion power plants produced around 0.91 to 0.95 kilograms of carbon dioxide per kilowatt per hour which is equivalent to 910 to 950 grams of carbon dioxide per kilowatt per hour (Mittal et al. pg. 1). The carbon dioxide emissions produced by coal combustion power plants can be quantified to be nearly 19 times that of geothermal power plants, making it so that a switch to geothermal power would significantly reduce the impact of the energy production sector on the environment. The transition towards the use of geothermal power plants as one of the major energy sources would allow for a significant reduction in the production of greenhouse gasses which would, in turn, decelerate the imminent effects of climate change.

Not only will the use of geothermal power plants reduce the production of toxic byproducts, such as the pollutants of greenhouse gasses, in comparison to the current methods of energy production, but it also is able to generate useful minerals contained within geothermal sites in place of the radioactive waste produced by many fossil fuel combustion plants. In a study conducted on the soil around a coal combustion power plant, Xinwei Lu and others, under the industry classification of fossil fuel electric power generation, uncovered that there are significant amounts of

heavy metal pollution and natural radiation occurring in the areas surrounding a coal power plant (Lu et al. pg. 9). This directly implies that the combustion of coal and other fossil fuels contributes to the release of these heavy metals and radioactive elements into the atmosphere since the environment surrounding the power plant contained large quantities of them. This is in stark contrast to the various byproducts of the production of electrical energy from geothermal power plants. According to Gordon Bloomquist published by the Washington State Energy Program, geothermal energy extraction can allow for “the recovery of such metals as zinc, lithium, manganese, cesium, rubidium, and even precious metals such as gold, silver, and platinum” (Bloomquist pg. 5). The recovery of these metals from geothermal energy production would allow for further expansion in new fields of technology such as lithium-ion batteries which are currently involved in various technologies being the main form of rechargeable batteries. These elemental byproducts combined with their greenhouse effect are completely polar opposites to those produced by coal combustion power, making a clear path for the implementation of geothermal energy in terms of toxic byproducts.

Implementation of Geothermal Power Plants

In conclusion it is only reasonable to support the implementation of geothermal energy in order to allow society to become resilient in the face of modern energy production issues due to the severe benefits which it provides in energy efficiency, long-term economic costs, and the minimal production of toxic byproducts. Due to a minor limitation in the high initial cost, the implementation of the geothermal power plants should occur on a smaller scale at first in order to prevent severe government overspending. In addition to providing the necessary solution for these issues, the creation of several geothermal power plants throughout the world will revolutionize the economy through the creation of new jobs and the increased importance of new specialized fields. In addition to this, it will raise attention towards many more significant indigenous tribes through their implementations of geothermal energy as well as significant historical civilizations which have also utilized this method. Therefore, an incremental, step-by-step approach to the implementation of geothermal power plants would provide society with the necessary advancements to progress into the energy production systems of the future.

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