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Economic Challenges for Direct Utilization of Geothermal Energy in Iran

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ABSTRACT

Low-temperature geothermal resources exist throughout entire Iran, and there is tremendous potential for new direct-use applications. Recent surveys identified many thermal springs and low- to moderate-temperature geothermal resource areas, and hundreds of potential direct-use sites. Direct utilizing geothermal energy in homes and commercial operations is much more costly than utilizing fossil fuels in Iran because of highly subsidized fossil fuels in an oil-reach country such as Iran. But geothermal energy is also very clean, producing only a small percentage (and in many cases none) of the air pollutants emitted by burning fossil fuels. Thus, governmental support for the development of these clean energy sources is required. Geothermal energy becomes immense potential to contribute to our clean energy future. In this paper, we described how the new Iranian legislation on green energy development can be changed to have effective support for the development of direct utilization of geothermal energy in the future. Government can help bring this cleaner energy future to reality by increasing funding for geothermal research, development, and demonstration; streamlining permitting; offering financial incentives to ease geothermal adoption into the marketplace.

1. INTRODUCTION

Geothermal energy is one of the favorable renewable energy resources from which the heat is driven from the earth's core (Barbier 2002). This energy source is clean, reliable, and abundant. If properly developed, it can offer a sustainable energy resource for any heat application. In 2017, geothermal power generation grew by 3.1%. Universally, the geothermal share of global power generation is 0.3%, but in some countries, it plays a significant role, e.g., Kenya (40%), Iceland (25%), and New Zealand (18%) (Gholamhassan Najafi and Ghobadian 2011). They used geothermal energy in three primary applications, including power generation, direct heat application, and geo-heat pumps. Direct use includes applications such as heating buildings or greenhouses and drying foods. Since they use ground source heat pumps for heating and cooling the buildings employing shallow soils as a heat source.

The use of geothermal energy in Iran has made less progress in recent years compared to alternative sources of renewable energy (Younes Noorollahi, Eslami, and Noorollahi 2021). But, in recent years, due to the progress in heat exchange and drilling technology, the development, and use of this energy has increased (IREA 2020). Today, energy production from fossil fuel sources is accompanied by considerable pollution of the environment (Romanov and Leiss 2022). On the other hand, the expansion of renewable energy meets the energy demand with less pollution. Fortunately, besides to being renewable, geothermal energy has less pollution compared to alternative sources of energy production and is considered one of the cleaner sources of energy. This does not mean that geothermal energy is completely free of pollution, but its level of pollution is very low compared to the fossil fuel or nuclear power plants that it can be minimized at a relatively low cost (Asmaryan et al. 2022). It is worth noting that some power plants and direct heat plants to use this energy are completely free of pollution, which are mentioned (Nouri, Noorollahi, and Yousefi 2019). The amount of pollution from the aforementioned facilities has a direct relationship with the geothermal source temperature. Thus, high-heat sources produce more pollution than low temperature heat sources, and direct application plants also harm the environment less than geothermal power plants. Geothermal energy has a high potential to provide electricity and heat at a low cost (Mani and Pillai 2010) for buildings and industrial processes.

In recent years, there has been much research on geothermal energy use and the opportunities and challenges it faces in different countries. Zhu et al. conducted a review of the geothermal energy resource and application in China (Zhu et al. 2015). Their research aim was to recognize geothermal resources, exploit them, and attract a roadmap to develop geothermal energy. They determined that to attain sustainable development of geothermal energy in China, they should focus on issues such as geothermal energy technology development, small and small low-cost power plants, hybrid geothermal systems, and the sustainable use of geothermal resources. Shortall et al. studied geothermal energy for sustainable development. The objective was to examine the relationship between geothermal energy and sustainable development. They analyzed all negative and positive results and create a foundation for future research (Shortall and Kharrazi 2017).

This paper provides a brief overview of geothermal activities in Iran and Its major obstacles and barriers to direct heat application including economic, policy, and technological barriers. This is divided into the following three main sections: Iran's geothermal resources, and heat energy demand and supply, direct application major obstacles. In the following, we will discuss the future and obstacles to geothermal heat development in Iran.

2. HEAT ENERGY DEMAND AND SUPPLY IN IRAN

Iran's energy policy is mostly focused on the sector of industries rather than the residential sector. The existing studies on energy consumption are extensive and focus particularly on the economic development and the industrial sector in Iran. In a study investigating energy intensity in Iran. The results of the studies are show the major contribution to research in terms of natural gas consumption by the heating sector. The complexity of issues arising from energy consumption, and sustainable development, has resulted in the need for a comprehensive investigation into energy consumption by the heating sector in Iran.

The share of heating in the total natural gas demand in Iran in 2021 has been about 59%, which makes it the highest compared to other sectors as shown in Figure 1.

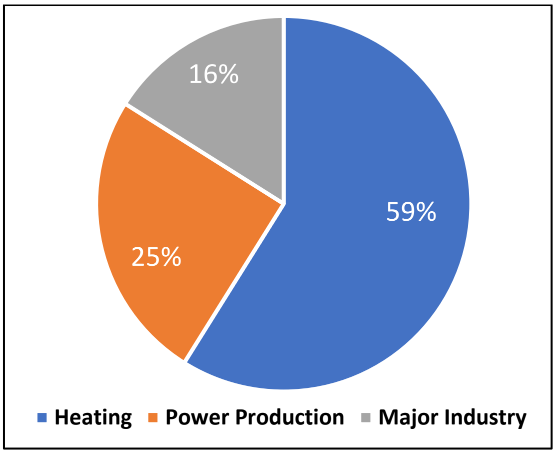

Figure 1 Natural gas consumption by sectors in Iran (2021)

The heating sector is the largest gas consumer with 59% in 2021, closely followed by the power sector (25%) and major industry (16%). The share of heating is increasing, while the share of industry is stable. Iran's gas production is on the decline due to both natural causes and a lack of investments and technology.

Iran's natural gas consumption grew by 2.7%/year between 2017 and 2021, reaching 233 bcm in 2021. Previously, it had jumped by 6%/year between 2013 and 2017. They projected natural gas consumption to reach 337,113 million cubic meters by 2030 within the framework of the baseline scenario, which is based on the continuation of the current trend

Iran has the second largest reserves of natural gas in the world but is barely able to satisfy domestic demand as production steadily declines because of a lack of investments in the oil and gas sector and Western technology. The government claims it has no plans to cut off gas from households and instead has reduced gas deliveries to the industrial sector due to its inability to extract enough gas. This means many factories and steel as well as petrochemical plants stopping production, which will deal a severe blow to an economy

Geothermal energy as a sustainable-based load heat source can be employed to supply parts of the heat demand of the country for the residential, commercial, and industrial heat demand sectors.

3. GEOTHERMAL DEVELOPMENT IN IRAN

Iran is located on the global geothermal belt, which makes it a significant geothermal potential. The temperature of some of the hot water springs in the northern areas reaches to 86°C at the ground surface. They did geothermal energy potential measurement for the first time in 1975 in Iran (H Yousefi, Noorollahi, and Sohrab 2003). Through a contract that was signed with the Ministry of Energy (MOE) of Iran, the state-run electric company of Italy (ENEL) and Tehran Berkeley of Iran began the systematic study of Iran's geothermal fields in 1975 (Younes Noorollahi, Eslami, and Noorollahi 2021). The studies came to an end at the beginning of the 1980s and introduced four major possibilities. The first of the geothermal potential regions, Sabalan, was chosen for in-depth exploration. Five promising areas have been identified through surface exploration and feasibility studies since 1995 (Younes Noorollahi et al. 2019, 2007). Among those imminent regions, NW Sabalan geothermal field was characterized for the definite investigation to legitimize the investigation penetrating and assessing the repository qualities and limits.

Being located in the volcanic belt has made the area of Iran to be very active in terms of geological structure and benefits from the high potential of geothermal energy, and the existence of many volcanic activities and hot water springs is proof of this claim (Seyedrahimi-Niaraq et al. 2019, 2017). The potential of geothermal energy in Iran is based on the studies conducted in more than 18 high-potential regions, these regions have been identified based on the number of tectonic activities, the number of hot water springs, the emergence of the earth's surface, and other geological evidence (Younes Noorollahi and Yousefi 2010).

3.1. Power production

According to the global classifications, Iran is in the group of countries that have potential reserves for generating electricity from geothermal energy and the ability to produce geothermal electricity with a capacity of more than 200 MW. The 5 MW power plant has been under construction since 2001. It became operational in 2010 and making it Iran's first geothermal power plant. It makes use of steam that is created when water is injected into specially drilled wells that can be over 3,000 meters (9,800 feet) deep (Hossein

Yousefi et al. 2018; Younes Noorollahi and Yousefi 2010; Younes Noorollahi, Eslami, and Noorollahi 2021). Deep in the ground, at temperatures above 250 °C, the water is heated. Upon depressurization at the surface, the heated water becomes steam, which powers steam turbines for electricity generation. This power plant is going to be developed in the next phases and can provide part of the electric and thermal energy of the Ardabil Province. The power plant's non-polluting nature is also hoped to help preserve the natural environment and increase tourism in the touristy Sabalan area (Y. Noorollahi et al. 2019; Younes Noorollahi et al. 2019, 2007). In the long run, Iran intends to install up to 12 additional geothermal stations in the country using the knowledge gained from this power plant.

3.2. Direct use

Iran has various locations with a wide range of thermal manifestations with surface temperatures ranging from 25°C to 85°C (Saffarzadeh and Noorollahi 2005; Younes Noorollahi, Eslami, and Noorollahi 2021). Nonetheless, the most springs are geologically situated in the northwestern with the cold winters. The concepts of directly utilizing thermal water have not yet been fully comprehended due to the energy sources (oil, gas, and electricity). Sporting and balneological purposes through swimming and washing pools are a major variant of direct-heat usage of geothermal energy in the area (Hossein Yousefi et al. 2018; Seyedrahimi-Niaraq et al. 2019). However, efforts have been made to make the idea of direct use for agricultural, fish-farming, and greenhouse purposes known to governmental authorities since 2001. While trying to assess the momentum status of high temp water use, the Ardebil region was chosen as the most well-known site for the sporting utilization of warm waters in Iran. In the northwest of Iran, the province of Ardebil is home to one of the most active geothermal prospects near the Sabalan stratovolcano (Saffarzadeh and Noorollahi 2005).

3.3. Geothermal Heat Pump

Geothermal Heat Pumps (GHPs) are regarded as new space and water heating options. Low electricity consumption and low maintenance repair costs have made the use of heat pumps popular in heating systems (Golshanfard and Noorollahi 2022; Eslami et al. 2022). Among the types of systems that include heat pumps, the combination of geothermal and heat pumps is more popular due to the more stable ground temperature, lower maintenance costs, and there is no need to add heat in extremely cold environments. The first geothermal heat pump project was established in 2003 in Iran and then 5 GHP each 75 kW units were installed in different parts of the country (Kavian, Hakkaki-Fard, and Jafari Mosleh 2020; Younes Noorollahi et al. 2016) and finally, in 2021, the total capacity of installed geothermal heat pump reached to 300 kW (Younes Noorollahi, Eslami, and Noorollahi 2021).

4. GEOTHERMAL HEATING ECONOMIC BENEFITS

Geothermal energy can play a significant role in dropping carbon dioxide and other greenhouse gas emissions. This energy is available for power generation in 26 countries (Lund and Boyd 2016) and 82 countries around the world in the form of direct utilization. Also, this energy source can play an important role in world energy policies. In addition to identifying the benefits of geothermal energy, this brief also identifies some of the major challenges such as transmission constraints and regulatory barriers. The ability of geothermal energy is to (Y. Noorollahi et al. 2019):

- Deliver reliable heat at a constant price;
- Help government to diversify the fuels mix for heat supply;
- Supply heat with minimum environmental affects and air emissions;
- Generate economic development opportunities, especially in rural areas; and
- Provide reliable heat for agricultural, industrial, and other heating applications.

4.1. Trustworthy energy source

A principal benefit of geothermal heat pants is that they supply base-load energy. Base load means to provide heat all or most of the time compared to the "peaking" plants, which turn on or off as demand rises, or peaks throughout the day. Unlike other renewable sources which generate intermittent energy, geothermal plants can produce a constant rate of heat during the year. On average, geothermal plants are available to operate approximately 98% of the time. Such prime ages make them favorable compared with fossil fuel and nuclear power plants that work between 75 and 90% of the time depending on the technology and age of the equipment.

4.2. Heat at a steady price

Using geothermal resources for power can help to protect against volatile electricity prices. For any power plant, the price of the fuel used to generate power influences the price of the electricity produced; if the price of fuel is unpredictable, the price of electricity is unpredictable.

Unlike conventional power plants that require fuel purchase, geothermal power plants secure their fuel supply before the plants begin operating. Since the price of geothermal resources will not change, it is possible to know what the price of electricity generated at a geothermal power plant will be over time.

4.3. Diversification of the energy mix

Diversifying the energy resources is the obligation of the government of Iran to meet the 6th National Development Plan. In the 6^{th} development plan, under Article 13 of the environmental and clean energy section, in order to diversify the country's energy resources, the government is obligated to serve the base for the generation of electricity from renewable resources. Renewable energy resources like geothermal can benefit the country to diversify the mix of fuels. Diminishing the domestic consumption of fossil fuels can benefit the state by exporting them at a universal price. Geothermal energy among other renewable energies can be utilized to meet this objective.

4.4. Clean heat

Geothermal power plants produce only a limited amount of air emissions. Compared to conventional fossil fuel plants, they emit very small amounts of carbon monoxide, particulate matter, sulfur dioxide, carbon dioxide, and typically no nitrogen oxides.

The low levels of gasses emitted from geothermal power plants are not created during power production due to absence of any no combustion; rather, they are natural minor constituents of all geothermal reservoirs. These gasses eventually would emit to the atmosphere without geothermal power development, though at much slower rates. Dry-steam and flashed-steam plants emit mostly water vapor. Binary-cycle power plants emit virtually no gasses because they operate using a closed-loop system.

Geothermal power plants mostly emit carbon dioxide, which is not a pollutant but a greenhouse gas. However, geothermal power plants emit much less carbon dioxide than fossil fuel power plants. Fig. 2 compares the life cycle of CO2 eq emission from different energy sources(World Nuclear Associations 2011).

4.5. Economy development potential

States with valuable fossil fuel resources often suffer from an economic disease caused by dependence on selling raw fossil fuels. Oil exporters have often failed in their planning to reduce dependence on oil. Overdependence of their economies on oil exporting has disrupted the process of economic development and thus they are trying to cut down this dependency by applying various solutions. Iran as a developing country and one of the richest countries with fossil fuel resources such as natural gas and crude oil(Bahrami and Abbaszadeh 2016) also suffer from this issue. Therefore, some policies have been anticipated to overcome these economic problems in this country like developing geothermal power plants. Utilizing geothermal energy resources can provide economic and social development opportunities for provinces in the form of jobs, road construction, cultural effects, land use, and trading.

One of the very important economic aspects of geothermal energy is the generation of electricity by indigenous and nontransferable resources; therefore, the results of the installation and utilization of 55MW of electricity from the geothermal power plant in NW Sabalan will decrease the country’s dependence on fossil fuels, increase oil export, lead to an energy saving equivalent to 220,000 tons of coal or 0.825 million barrels of oil, and reduce some environmental impacts each year.

4.6. Jobs creation

Geothermal power plants are often placed in rural areas, which generally have chronically high unemployment rates. Building a 100 MW geothermal power plant may create several hundreds of temporary (from two to three years) construction and related development jobs and between 80 and 150 permanent highly skilled full-time jobs at the facility that pay well above the minimum wage. Considering the economic multiplier effect, this plant should provide approximately 100 to 250 new full-time jobs in the community. Because geothermal plants have long working lifetimes, they can become a stable and reliable part of a community’s economic base.

For example, geothermal power plants at the Geysers geothermal field in California can generate almost 1500 MW of electricity and have been a significant source of revenue and jobs for many years. These power plants employ approximately 425 people full time plus an additional full-time equivalent contract workforce of 225 (Manijean and Saffache 2017).

5. ECONOMIC AND NON-ECONOMIC CHALLENGES FOR GEOTHERMAL HEAT UTILIZATION

Now a day, almost 15% of the world’s natural gas reserves and 9% of oil resources belong to Iran, as a result of which geothermal energy development has stiff competition (G Najafi and Ghobadian 2011). There are a variety of economic and non-economic (managerial, technical, and regular) challenges that prevent the regular progress of geothermal heat utilization projects in the world, in general, and some concerns in the first development of the geothermal heating project in countries such as Iran, in particular.

For geothermal projects in general, exploration, land leasing, and site selection processes take a long period and are fraught with many uncertainties. Although the cost of generating heat from geothermal resources has decreased during the last three decades, still exploration and deep wells drilling are expensive with high risk. Fundamentally, detecting potentially productive geothermal reservoirs is difficult but the rate of success wells increased significantly after they have found a resource. Furthermore, there are various specific preventing challenges risen during the last decade regarding geothermal developments in Iran including:

- Low cost of natural gas for heating
- Lack of national and local legislation on renewable heat
- The inability of technology transfer
- Lack of Environmental emission costs
- Lack of appropriate financial incentives for renewable heat

Some of these preventing challenges are briefly described and analyzed in the following sections.

5.1. Low cost of natural gas for heating

The price of natural gas in Iran is very low, and it stops all renewable heat source development in Iran. The natural gas price is 0.001 U.S. Dollars per kWh for households and 0.0001 U.S. Dollars per kWh for businesses in Iran. For comparison, the price of natural gas in the world in that month is 0.101 U.S. Dollars per kWh for households and 0.086 U.S. Dollars per kWh for businesses. These rates include all taxes, fees, and other components of the gas bill. With this low Natural gas price for heating plication and lack of any intensives for renewable energy heat, its future development is almost impossible.

5.2. Lack of national and local legislation on renewable heat

The Renewable Energy and Energy Saving Organization of Iran (SATBA) previously called SUNA was established in 1995 as a governmental organization for the development of renewable energy resources in Iran. Before that, it was very little action done in various organizations and there was not any summarized a policy for renewable energy development. By establishing SATBA, all renewable energy developments among geothermal have to accumulate there and it was the initial regulation about renewable energies in Iran. Finally, in 2004, the law was acted and all renewable energy planning, budget, and a specialist from alternative organizations were gathered in SATB. Nowadays, SATBA is responsible for all power generation planning and development from renewable energy resources.

Heat generation from geothermal sources is not subject to power generation, and the SATBA is not responsible for its planning development. There is no other national or local organization in Iran to be responsible for heat generation from renewable energies such as geothermal and solar heat. It is one of the important barriers to renewable heat development.

5.3. The inability of technology transfer

There are two generally accepted approaches for international technology transfer, which can apply to geothermal energy technology in Iran.

The international research and development agreements facilitate collaborative research and development between SATBA and international universities or research centers in leading geothermal industry countries. The Foreign Buys Program (international project managing agreement) enables to buy the research or engineering services from governmental and private entities.

National universities and research institutions have key roles in advancing renewable energy (heat) research and education. Focus students and researchers on new challenges:

- Curricula in all areas of study need to be reviewed concerning energy for sustainable development issues.
- Master's and Ph.D. programs are required to raise experienced people needed for the design, construction, and operation of renewable energy systems.
- These programs must cover technology, economy, business, and policy issues.

Enhancing the research on renewable heat and supporting students' research projects and theses in order to localization of renewable energy technologies. Research to support renewable energy development is needed in natural sciences, engineering, economics, health, law, social sciences, and other areas.

5.4. Lack of Environmental emission costs

Iran was the world's eighth-greatest emitter of greenhouse gases in 2015. It is a resource-rich state with huge reserves of oil and gas, as well as considerable renewable energy potential. Currently, there is no cost for air pollution in Iran for the industry and power plant for their emissions. It means that the major pollution producers such as fossil fuel power plants are not obliged to pay for pollution emissions. Due to the lack of a special law for emission, there is no economic incentive to utilize renewable heat.

5.5. Lack of appropriate financial incentives for renewable heat

Currently, there is a Feed Tariff system for renewable power purchase in Iran which is the obligated government to buy the power produced by renewable energy sources with a high price (almost 5-10 times) of fossil fuel base power. It encourages renewable power plant developers to continue investing in this field but there is no support for renewable heat at the time. This is one of the major obstacles to renewable/geothermal heating projects.

6. CONCLUSION

We can follow the development of geothermal heat in Iran in three areas: knowledge and technology, human resources, and financial support. In the field of science and knowledge development, goals such as the localization of design and transfer of heat plant technologies, as well as the development of non-technical knowledge, and the improvement of knowledge transfer between the main players in this field can be determined and pursued. Also, establishing policies for targeted financial support for commercial and non-commercial research, financing technology companies with venture capital, and granting loans and bank facilities to carry out pilot projects can be effective. In addition to the mentioned cases, measures such as providing tax incentives to private companies in the field of geothermal exploitation development, developing the necessary mechanism to support risky investments by the private sector in the field of geothermal exploration, and creating a reliable market through the government's purchase of quality products can accelerate the development of geothermal energy.

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