

REVIEW

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Study of geothermal energy potential as a green source of energy with a look at energy consumption in Iran

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Abstract

Regarding disadvantages of fossil fuels, renewables like geothermals can be an eco-friendly source of energy. In Iran, the availability of fossil fuels and poor policies surrounding subsidies (ranked as the first in giving subsidies) caused high energy consumption (1.75 times higher than the global average). Energy is mainly provided by fossil fuels that leads to high CO₂ emission. This study evaluates the energy consumption trend and potentials of more sustainable resources like geothermals in Iran. The formation of geothermals is tightly linked with geological prerequisites that are partly present within Iran. Adjacency of the metamorphic with volcanic zones, existence of numerous faults and seismic activity of Iran are notable geological characteristics confirming the geothermal potential. In Iran, 18 regions are being explored as the most promising geothermal prospects. To test the potentials of one of these regions, a geothermal power plant with a capacity of 5 MWe is installed in the Sabalan Field. Northwest (where Sabalan Field is located), central (like Mahalat Region) and southeast of Iran (Makran Zone) can be regarded as promising zones for hosting geothermal prospects.

Keywords: Energy consumption, Iran, CO₂ emission, Renewable energy, Geothermal energy, Geology

Introduction

Energy plays a fundamental role in macroeconomic growth, welfare and development. Energy is an important component of the sustainable development (Gunnarsdottir et al. 2021), but how to supply and consume energy has recently become a matter of debate (Güney 2019; Karasmanaki and Tsantopoulos 2019). Electricity, as the most demanding type of energy, provides a wide range of necessities. International Energy Agency (IEA) predicted a 1.6% annual growth of the electricity demand in 2030 (Arslan 2010). Energy demand already rose by 2.9% in 2018 (the highest increase of the last decade) confirming that energy shortage is inevitable. Consequently, carbon emissions have been increased by 2.0%, which is also the largest growth during the recent 7 years (BP 2019). Shares of different types of energy suppliers in global consumption are presented in Fig. 1. As this figure shows, fossil fuels are the major contributor, whereas numerous

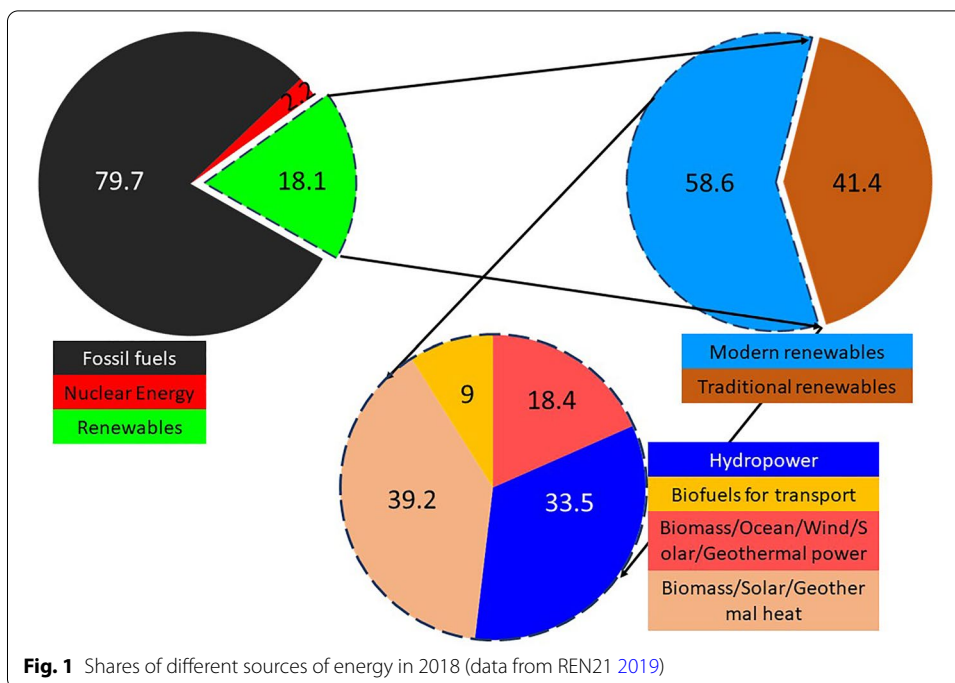


Fig. 1 Shares of different sources of energy in 2018 (data from REN21 2019)

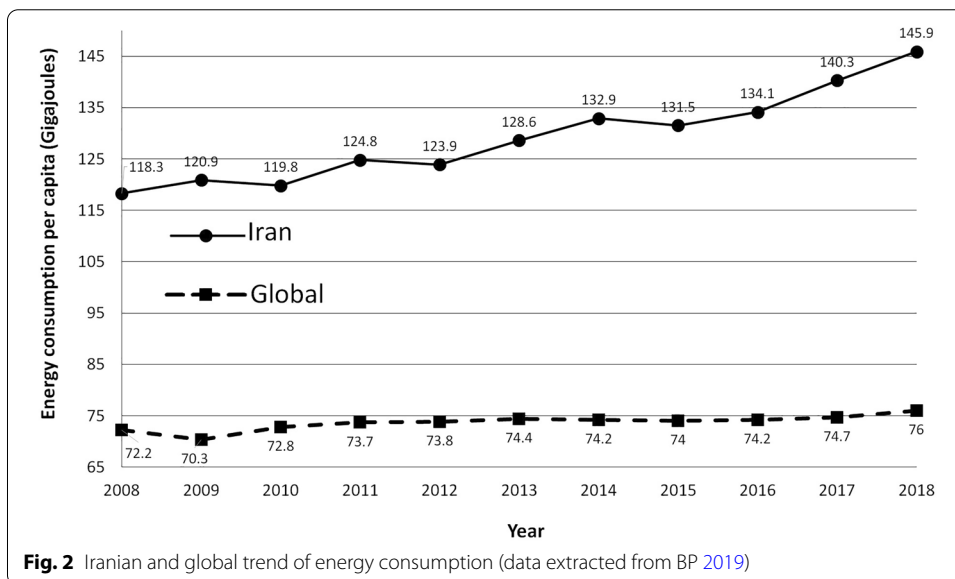


Fig. 2 Iranian and global trend of energy consumption (data extracted from BP 2019)

studies documented details of their environmental footprints (Crutzen et al. 2016; Dölle et al. 2020; Kuik et al. 2019; Martins et al. 2018; Musa et al. 2018; Oncel 2017; Vassilev et al. 2015; Yaqoob et al. 2021). Therefore, the global energy provide should be revised to prevent from environmental footprints of fossil fuels.

Based on the BP (2019), rate of energy consumption in Iran is relatively high (1.75 times greater than the global average). Figure 2 shows the increasing trend of the energy consumption in Iran in which the increment between 2016 to 2018 is clearly observable. During this period (2016–2018), energy consumption in Iran increased by 8.7% while the global trend increased by 2.4%. Iran has the world's second and fourth-largest reserves of

gas and oil, respectively (Abbaszadeh et al. 2013; Esen and Oral 2016). Therefore, such a high energy consumption in Iran is due to the availability of cheap resources. Iran faced problems to export its hydrocarbons after 2012 and its share in the Organization of the Petroleum Exporting Countries (OPEC) has been decreased due to sanctions (Moeeni and Sharifi 2020). Meanwhile, the oil and gas production continued and have been consumed internally rather than being exported. The first figure in Shah et al. (2021) clearly shows that the energy consumption trend during the sanction period increased, but oil production also decreased. Reduced part of the production mainly includes exported hydrocarbons. As expected, CO₂ emissions have been observed to be considerably high in Iran (Hosseini et al. 2019).

Greenhouse gas (GHG) production is the biggest drawback of fossil fuels. McGlade and Ekins (2015) documented that 30, 50 and 80 percent of current proved resources of oil, gas and coal reserves, respectively, must remain untouched until 2050 to keep on track for 2 °C of global warming. However, the Paris Agreement in 2015 urges the policymakers to consider strategies to limit the global mean temperature rise to 1.5 °C. Meanwhile, the existing competition for fossil fuel exploration resulted in high CO₂ emissions (Beckage et al. 2018). The drawbacks of fossil fuels are well documented, but there are many obstacles for shifting completely to renewables. Fossil fuels have high energy density and are relatively cheap comparing their benefits with invested energy for exploration and extraction (Yu et al. 2020). However, the extraction cost of fossil fuels is increasing, and renewables are becoming cheaper due to decrease of fabrication costs (Dhar et al. 2020; Kalair et al. 2021). The supply–demand balance is also another constraint for renewable energy sources like wind and solar (Leonard et al. 2020). In the case of geothermals, their high availability factor results in regarding them as the base-load (Dhar et al. 2020). Compared to fossil fuels, the potential of geothermal is considerable, but it takes time to make geothermal economically more profitable. Designing an efficient hybrid renewable energy system (HRES) is crucial to make a feasible (economically) shift from fossil fuels to renewables (Ciupageanu et al. 2020; Wang et al. 2020). For example, solar energy can be exerted to heat the geothermal fluids coming from low temperature reservoirs (Cardemil et al. 2016; Li et al. 2020).

As expected, natural gas and oil have been the main sources of energy in Iran from 2014 until 2018 (BP 2015, 2016, 2017, 2018, 2019). Hydro-electricity, nuclear and coal are the next main energy supplier during this time. Unfortunately, the share of renewables is reported to be less than 1% in these years (Solaymani 2021). In the case of energy consumption, transportation is generally the major progressing sector in Iran (Solaymani 2021). Meanwhile, among all sectors, transportation is emitting 21.2% of the total CO₂ (Dubois et al. 2019; Rahmani et al. 2020). Transport-related pollutions are considered as the main source of air pollution in the capital of Iran (Tehran) (Mohammadiha et al. 2018). Given the presented information about the energy consumption in Iran, there are three major concerns: high rate of energy consumption (Fig. 2), unfavorable energy sources (fossil fuels) (BP 2015, 2016, 2017, 2018, 2019) and the misuse of energy sources (transport). To overcome the environmental impacts of the above-mentioned concerns, using renewable energy resources can be an appropriate solution (Rana et al. 2020; Vakulchuk et al. 2020). Renewable sources has advantages like renewability, eco-friendly, economic benefits for locals, etc. (Ahmadpour et al. 2021; Berrill et al. 2016;

Corrêa Da Silva et al. 2016; Koengkan et al. 2021; Noorollahi et al. 2021; Stigka et al. 2014; Stricker et al. 2020). Hybrid renewable systems like geothermal and solar energy are promising alternatives to substitute fossil fuel as the base-load, but they still need to be more developed. Capacity of renewables is confirmed to be high but their efficiency must be evaluated by exerting them (Solé et al. 2020).

In this study, a general evaluation of geothermal prospects considering their efficiency and occurrence, which is tightly linked with geology, is provided. Based on the Iran's energy consumption, potential of the geothermal resource are also appraised. Regarding the energy consumption trend in Iran, it is tried here to present a review to assess the potential of substituting a part of fossil fuels with a green source of energy.

Geothermal energy

"Year zero of geothermics" is the title proposed by Cataldi et al. (1999) for early stage of relationship between human and geothermal. The early history of using geothermals dates over 2000 years ago. This usage changed dramatically through the time and various applications of geothermals are invented and employed. Areas hosting hot springs have a twofold character: the negative face of horrible events, such as volcanic eruptions and earthquakes, and beneficiary profits, such as medical and relaxation applications (Bertani 2017).

Raw/direct-use of geothermals implicates applications such as heating, agricultural drying, bathing, snow melting, greenhouse heating, geothermal heat pumps and so on (Dickson and Fanelli 2013). In the case of indirect use, heat is employed to generate electricity by driving turbines using the extracted steam. Based on Lund and Boyd (2016) and Lund and Toth (2021), the number of countries directly using geothermal resource increased from 28 in 1995 to 88 in 2015. Installed thermal power for direct utilization at the end of 2019 is 107727 MWt, which almost more than two times higher than 2010. From 2010 to 2015, used thermal energy is increased by 39.8% (Lund and Boyd 2016) and from 2015 to 2019, this increase has been much more (72.3%) (Lund and Toth 2021) which confirms the huge potential of geothermals. Energy consumption will continually increase; therefore, geothermal energy must also contribute in both the electricity generation and heating. Based on the World Energy Assessment report of the United Nations (2000), geothermal is placed at the top of all renewable energy resources, because of its potential (predicted to be 5000 EJ/year). In the case of other resources such as solar, wind, biomass and hydro, the potential is 1575, 640, 276 and 50 EJ/year, respectively (Goldemberg 2000; Johansson et al. 2012). Regarding the capacity factor (ratio of actual electrical energy output to the maximum possible electrical energy output), geothermals provide the best outcome compared to other renewables. This high capacity factor is directly cause by the independency of geothermals from weather (Bošnjaković et al. 2019). It is forecasted to have a 33% increase from 2020 to 2025 in the installed capacity of geothermal power plants (Huttrer 2020). This growth can help to mitigate the unfavorable environmental effects of fossil fuels. Cost of generated renewable power depends on factors like potential of the location, cost of capital, project size and state remuneration policy. In the case of costs of geothermal projects, it is predicted to have a decreasing trend because of the new developments (Gupta and Roy 2007; Weides et al. 2013; van der Zwaan and Dalla Longa 2019).

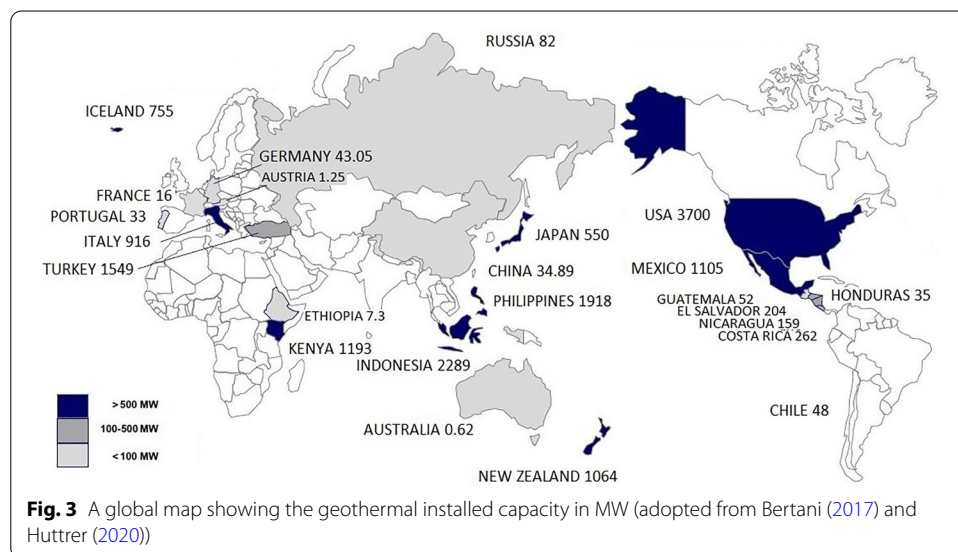
Figure 3 shows the global energy generation from geothermals and reveals two important facts. Firstly, there is an observable pattern in the distribution of the countries exploiting considerable amounts of the geothermal energy. These countries (e.g., the US, Mexico, Japan, Philippines, and New Zealand) are located around the Pacific Ocean and have a special geologic nature (more discussed in the next section). The second fact is the high level of development or welfare of countries that are paying more attention to renewables like geothermals. For instance, developed European countries are using this green resource to replace fossil fuels.

Geothermal resources

General geological viewpoint

Similar to other subsurface resources, geology plays the main role in the formation of geothermal reservoirs. Plate tectonics is a term proposed to describe the large-scale movements of the plates existing on the Earth. Dickinson (1974) explained all the aspects and rules of the plate tectonics in detail which are briefly summarized as definition of the plates (convergent, divergent and transform). Convergent and transform movements lead to the huge amount of friction and divergent also paves the way for upflow of hot material kept inside the earth (Gill 1981). Many detailed studies has been carried out to track the influence of geological elements on the formation of the geothermals (Bellani et al. 2004; Ito and Zoback 2000; Meixner et al. 2016).

Geology controls lots of geothermal reservoirs properties like hydrogeological regime, fluid chemistry, thermal regime and heat flow, etc. (Moeck 2014). As concluded from Fig. 3, countries in an especial pattern have huge and profitable geothermal prospects. This especial geologic zone is called the ring of fire and countries close to this zone have exploitable geothermal prospects. Iceland is one the most successful countries in applying geothermal energy due to its unique geologic setting (divergent boundary in the middle of the Atlantic Ocean) (Sæmundsson et al. 2020). The East African countries (like Kenya) are also hosting terrestrial form of divergent boundaries and these days are



interested in exploiting their high-enthalpy subsurface resources (Kanda et al. 2019). In the case divergent zones, Meixner et al. (2016) documented that structural features facilitate fluid circulation within a reservoir.

Geothermal systems classification

Geology, hydrogeology and heat transfer are usually major categories to classify geothermal systems. However, geothermal systems lack the clear definition of petroleum systems (having source, reservoir and cap rocks). Not only volcanic rocks, but also sedimentary and metamorphic rocks can act as a host for geothermal fluids, i.e., geothermals are independent of lithology. Several publications attempted to provide a standard classification for geothermal reservoirs, but they considered the temperature as the main input for clustering geothermal reservoirs. Such methods propose three different temperature ranges: low, moderate and high-temperature (Moeck 2014; Nicholson 2012; Sanyal 2005). Table 1 summarizes some of the classification results. Moeck (2014) presented a detailed review on the classification of geothermal reservoirs as two distinct groups: the convection and conduction-dominated systems. Majority of installed geothermal power plants are classified under the first group (convection dominated) of geothermal systems.

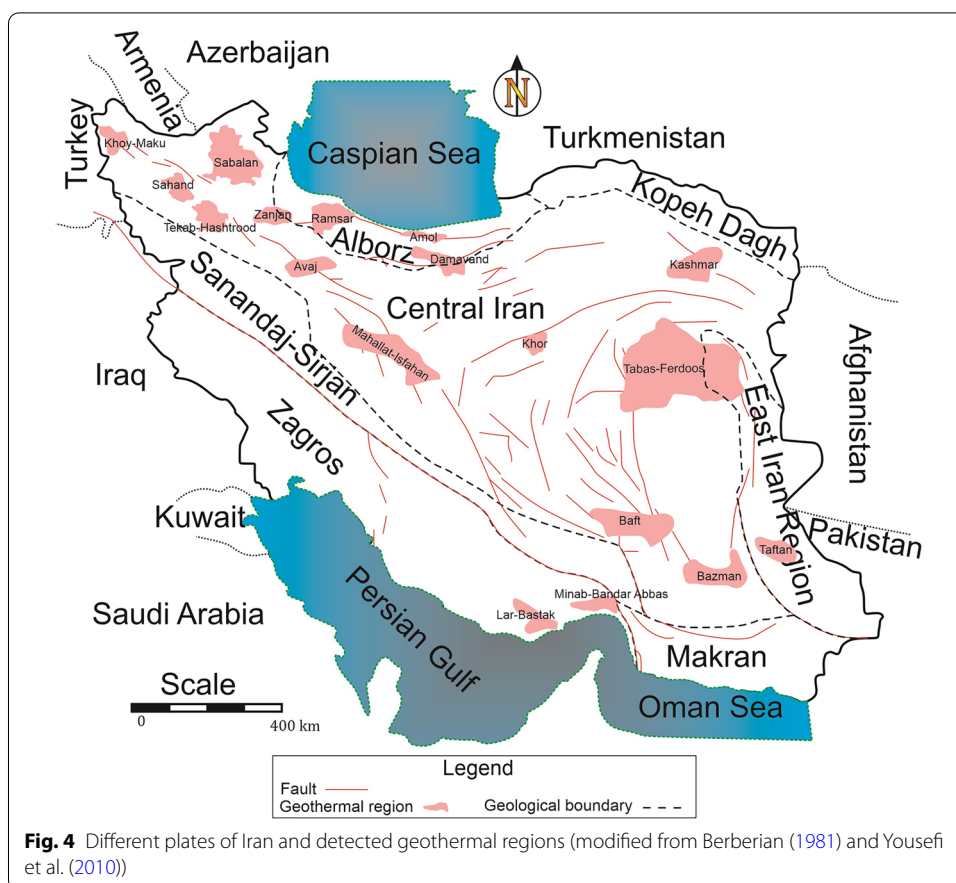
Geological features of Iran for hosting geothermal source

From the plate tectonics point of view, Iranian Plateau can be divided into several segments (Fig. 4). Iranian Plateau is transected by adjacent active, recent and mostly reverse faulting (Berberian 1981). This plateau is confined by the convergent movement of the African (in the west) and Arabian (in the south which makes Makran Zone) plates (Stern et al. 2021). In such locations, subduction happens: the oceanic belt dives beneath the continental landmass because of its higher density (Tatsumi and Eggins 1995). A brief history of Iranian Plateau can decipher its geologic condition and potential for hosting geothermal prospects.

Geology of Iran is well documented in the literature (Agard et al. 2005; Aghanabati 2004; Berberian 1995; Berberian and King 1981). Movement of African Plate (southwest of Iran) toward northeast resulted in the subduction of the Neo-Tethys I beneath Iran (Glennie 2000) (Fig. 5A). Then, collision between plates occurred and the resulted in formation of Zagros (Fig. 5B). Movement of African Plate continued and led to subduction of Neo-Tethys II beneath central Iran. Accordingly, another magmatism formed and made the Urumieh-Dokhtar Zone (Fig. 5C). Magmatic activity of this zone started about

Table 1 Different classes of geothermal reservoirs (temperatures are in °C). Adopted from Moeck (2014)

References	Non-electrical	Very low	Low enthalpy	Moderate enthalpy	High enthalpy	Ultra-high
Muffler (1979)	–	–	< 90	90–155	> 150	–
Hochstein (1988)	–	–	< 125	125–225	> 225	–
Haenel et al. (1988)	–	–	< 150	–	> 150	–
Sanyal (2005)	< 50–100	100–150	150–180	180–230	230–300	> 300



50 million years ago and continued until 3 million years ago (Berberian and King 1981). Finally, the second ocean was also derived totally beneath the continental parts (Fig. 5D). Numerous important events that occurred within Iranian Plate but the only the major ones are presented here for a general understanding. From the geothermal point of view, such an active platform can host many susceptible prospects. Regarding a bigger scale (all the Middle East), volcanic activities are mostly found around Red Sea rift and Gulf of Aden (Al-Douri et al. 2019; Elzain et al. 2020).

Makran is the second and ongoing subduction zone [initiated in the Paleocene (Abedi and Bahroudi 2016)] in southeast of Iran. Bazman and Taftan volcanos in Iran are considered to be the active volcanic arc of Makran subduction zone. Ages of Bazman and Taftan are confirmed to be 0.84, and 7.5 Ma, respectively (early Miocene to late Pleistocene). Therefore, they can named as the younger phenomena occurred during Cenozoic of Makran (Pang et al. 2014). Kopp et al. (2000) discussed structure of this important zone (from a geothermal point of view) in details. This zone is less investigated than other parts of Iran (Motaghi et al. 2020), but more studies can show more details and decipher its geothermal potential.

Frequency of earthquakes in Iran proposes that it is located on an active seismic belt. This activity has been caused by the faults that can facilitate the formation of geothermal prospects. Karim (2012) claimed that distribution of seismic activity of Iran is heterogeneous because large magnitude events mostly happen in Central Iran, Alborz (especially

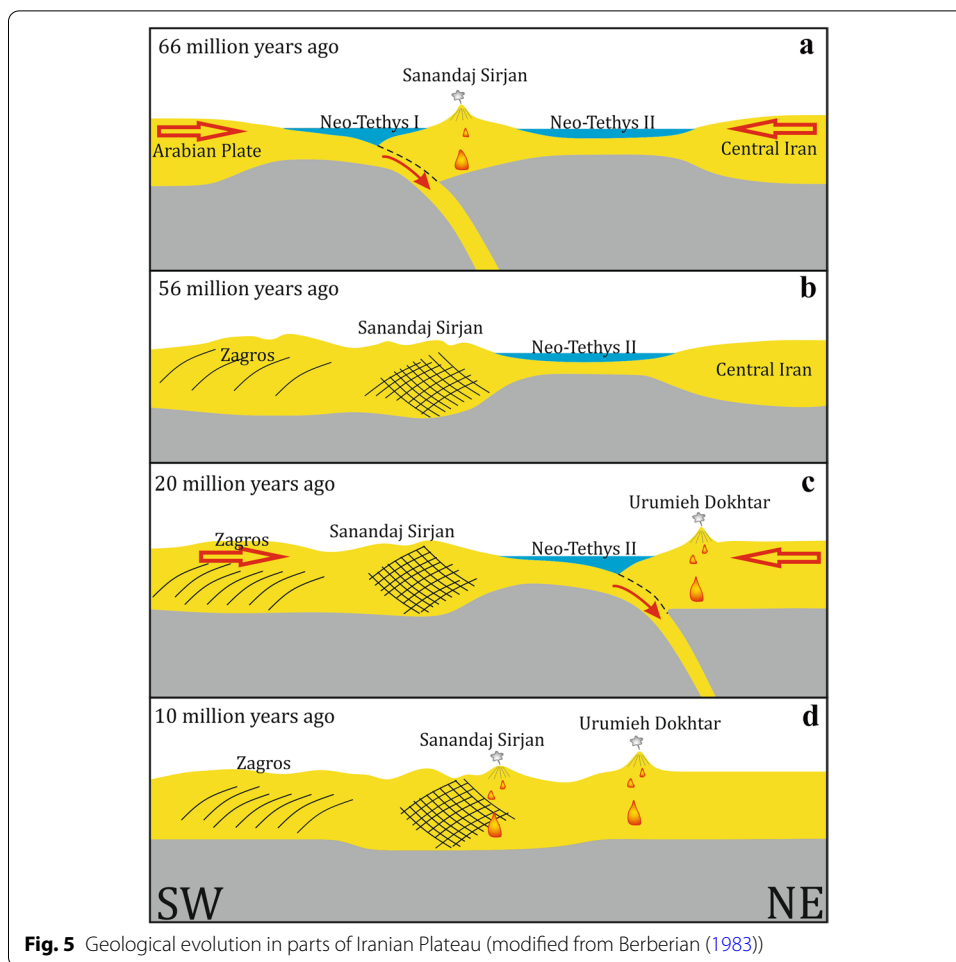


Fig. 5 Geological evolution in parts of Iranian Plateau (modified from Berberian (1983))

northwestern zone) and Kopeh Dagħ. Details of the earthquakes with $M_w > 7$ in Iran during 1900 to 2015 revealed that the majority of them (6 ones) occurred in Central Iran. Four large earthquakes have also occurred in middle and the northwestern Alborz (for more information refer to Table 1 in Salamat et al. (2017)).

Exploration of geothermals in Iran

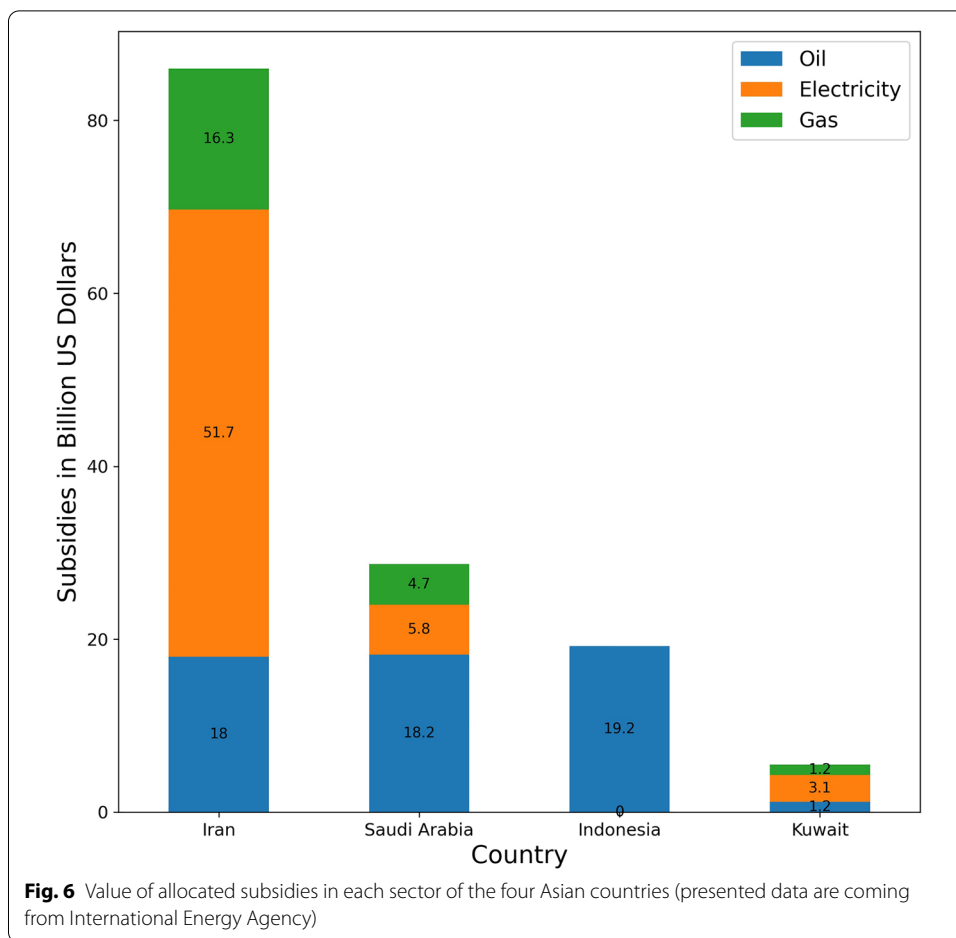
Geothermal resource explorations in Iran, as one of the most prolific hydrocarbon-bearing countries, can be regarded as a tough task due to availability of the fossil fuels. Fortunately, a strong scientific interest is devoted to renewables in Iran, but the real situation is still far from the Paris Agreement 2015 agenda. Historically, Iranians used hot springs for bathing and swimming, but more modern plans are founded by the Iranian Ministry of Energy in 1975. Accordingly, a comprehensive exploration project in the northwestern regions of Iran was planned since numerous hot springs were observed in this area. This program resulted in detecting four geothermal regions: Sabalan, Damavand, Khoy-Maku and Sahand. Two decades later, Renewable Energy Organization of Iran paid more attention to geothermal prospects exploration and proposed other sites susceptible for being a geothermal prospect (Fig. 4). Since Sabalan was the most promising geothermal site, it was selected for drilling and possible power generation. After drilling three deep

wells, a huge amount of field data were obtained and the government was persuaded to establish the first geothermal power plant there. Other researches on geothermal susceptible sites are also presented by several authors to evaluate the different susceptible geothermal zones (Ebrahimi et al. 2019a, b; Noorollahi et al. 2019; Nouraliee et al. 2015, 2021; Yousefi et al. 2010, 2019). The first geothermal power plants of Iran are installed in Sabalan and the potential energy production from planned power plants is also modeled (Najafi and Ghobadian 2011). Nevertheless, Fig. 4 shows that more regions with a wide variety of geothermal susceptibility exist throughout Iranian Plateau, which should be explored. In spite of having such great potential, lack of a comprehensive exploration plan is the major issue for further studies. Numerous hot springs are flowing out from these regions implicating the existence of a thermal source. It can be clearly seen that major geothermal prospects are found close to active seismic regions. Again, it confirms the adjacency of hazards like earthquake and gifts like huge amounts of energy.

Discussion

Nowadays, Iran, as a developing country, faces an increasing rate of electricity consumption. A growth rate of 3000 MW renewable energy per year is planned to guarantee the supply a part of electrical energy demands (Najafi and Ghobadian 2011). Geologic data and published researches on the geothermal susceptibility of Iran confirmed the existence of economic geothermals throughout this country (Amoatey et al. 2021; Ebrahimi et al. 2019b; Yousefi et al. 2010; Yousefi et al. 2007). Therefore, the geologic background of Iran is promising that this land has enough potential to yield considerable amounts of geothermal energy. For example, just West Azarbaijan Province is hosting 11 regions with different potentials and the reservoir temperatures ranging from 50 to 150 °C (Ebrahimi et al. 2019b; Najafi and Ghobadian 2011).

Based on all details provided in this paper, the existing trend of energy supply in Iran is far from a green plan. As discussed in the introduction, the share of all renewables in Iran is negligible which can be easily ignored (1%). Hence, it seems in Iran the renewables and consequently, geothermals are far less developed than conventional fossil fuels. Availability of fossil fuels and poor policies surrounding subsidies resulted in neglecting potentials of geothermals. Chaharsooghi et al. (2015) proposed and modeled various scenarios for Iran's energy consumption in a 20-year frame in which Iran is following the worst possible path (non-targeted subsidy). Predictably, Iran is ranked as the first country in giving subsidies to energy resources such as oil and gas. Saudi Arabia, China and Russia are also following Iran and ranked from the second to fourth. Figure 6 shows the devoted subsidies in four Asian countries in 2019. Three countries are located in the Middle East (Iran, Saudi Arabia and Kuwait) and one from ring of fire (Indonesia). It can be barely seen Iran is giving considerable amount of subsidies to fossil fuels. Compared to Iran, Turkey is giving far less subsidies to fossil fuels (less than 1 billion US dollars). Based on provided data by International Energy Agency, Turkey does not fall within the first 25 five countries that are paying subsidies to fossil fuels. Therefore, subsidy data of Turkey are not shown in Fig. 6 just because it is far less than other countries. In Turkey, strategies like tax advantages have been made to support renewable energies. A sudden end of the subsidies of fossil fuels makes the situation worse because it can result it dramatic increases of



energy. A gradual shift can be the best solution to avoid any possible problem. Saudi Arabia has also made meaningful strategies to promote more sustainable resources like solar energy (Almushaikh and Almasri 2020).

Since 1988 in Iran, an annual increase of 23.2% in the price of the energy has been the only method followed to decrease the energy consumption. Surprisingly, the amount of consumed energy is increasing regardless of the price. Abbasian and Souri (2019) addressed the predictability of these increases as the main reason resulting in the inefficiency of this approach. New policies and regulations must be made in Iran to lead the country towards identifying and exploiting green resources and reducing carbon footprints in the daily life of people. Tenders (competitive bids) compared to feed-in tariff (FIT) mechanism for large-scale renewable energy projects can make the renewables output as cheap as fossil fuels (Grau 2014). In Iran, moving toward the right direction can also make geothermals more feasible and economically competitive. Iran, Turkey and Yemen are the only countries in the Middle East having some high-enthalpy (> 150 °C) geothermal fields (Amoatey et al. 2021). Comparing Iran and Turkey can clearly show two completely different policies surrounding subsidies. Generating 30% of Turkey’s electricity demand from renewable resources is one of the main aims of Turkey’s Vision 2023. In Turkey, the subsidies from the government and

supports of the private sector facilitated the application of geothermals (Melikoglu 2017; Telli et al. 2020). Using the experiences of a neighbor country like Turkey, can solve many possible technical problems in bigger geothermal projects of Iran.

In Iran, only Meshkinshahr geothermal power plant is being installed in NW Sabalan field, which is located in the northwest of country, but its output has not entered the grid yet (Seyedrahimi-Niaraq et al. 2021). Some publications (Aali et al. 2017; Jalilinasrabad et al. 2012) discussed the potential efficiency of this power plant, although a lack of real data hindered reliable modeling and studies. The reservoir temperature is claimed to be about 240 °C (at 3197 m depth) (Seyedrahimi-Niaraq et al. 2017). Regarding Table 1, this reservoir can be considered as a high enthalpy one. A total number of 11 wells were drilled in the site. If the results of the 5 MWe power plant are satisfactory, a power plant with a capacity of about 50 MWe will be installed on this site in the future. Furthermore, 105 MWt of direct heat utilization for geothermal heat pumps and tourist recreation sites have been also provided for nationwide development plan (Noorollahi et al. 2009; Yousefi et al. 2010). Based on Yousefi et al. (2019), a single-flash power plant is unable to exploit all potentials of the hot (about 200 °C) outflowing fluid. They also proposed a wide variety of other applications for this site to consider a more integrated plan. Aali et al. (2017) modeled different scenarios for Meshkinshahr power plant and claimed exergy efficiencies in single and double flash systems are 32.73 and 43.35%, respectively, but in their proposed system this factor increases to 53.32%. In the case of achieving the proposed output of power plant, the geothermal resource can be regarded as a trustworthy and reliable source of energy for the society.

Comparing the output, geothermal can be even cheaper than other renewables, but their scarcity is the main limit (Clauser and Ewert 2018). After finding a susceptible location, drilling costs are mainly considered as the biggest obstacle in exploiting geothermals. Almost 50% of the cost (2.25 to 2.75 million US dollars) for producing per installed mega Watt (MW) is devoted to wells drilling and completion (DiPippo 2016). Generally, operations in drilling a geothermal well have similarities to petroleum wells (Moya et al. 2018). Therefore, experience of Iran in drilling thousands of petroleum wells (Davaranpanah et al. 2018) can be regarded as a positive point. Modern drilling technologies are also increasing the efficiency, i.e., making this expensive part of geothermal projects cheaper (Jing et al. 2019; Khalilnejad and Lashkari 2020; Rossi et al. 2020). Distribution of hydrocarbon fields (Bordenave 2016) and geothermal prospects (Fig. 4) does not match perfectly, but extensive data of oil and gas wells can help to decrease the drilling risk in locations like Lar_Bastak. It seems transferring knowledge from petroleum industry to geothermal can be a positive step for Iran.

Versatility of geothermals in Iran can be well exploited by designing an efficient district heating system in cold areas like northwest of Iran. This area has the most geothermal potential and is also the coldest part of Iran (Balyani et al. 2017). This match can also be another positive factor for developing geothermal prospects in that susceptible area. Many applications like district heating can be well developed using geothermal potentials in northwest of Iran. High potential of solar energy harvesting (roughly 300 sunny days per year in two-thirds of its land) is the next priority of Iran (Shahsavari et al. 2019). Linking geothermals and solar energy in Iran can increase the efficiency and energy output. Regarding carried out analyses for the 100% renewable energy systems (Mason et al.

2010), it is expected to put more trust on geothermal (besides solar) potentials of Iran. Looking at the status of energy generation in Iran, renewables like geothermals are not yet cost-competitive with fossil fuels. However, for the sake of a cleaner future, it is necessary to run a paradigm shift in which renewables are invested to mitigate the environmental effects of fossil fuels.

Conclusions

Inevitably, future world will face problems in supplying its energy needs. The society is intensively consuming fossil fuels, which will be soon exhausted, and are also a source of CO₂ emissions. Iran is known as one the pioneers in the hydrocarbon industry. Renewable resources like geothermal energy can act as a hope for a cleaner future. In Iran, these type of resources are almost ignored because of fossil fuels' abundance. But special geological setting of Iran persuaded researchers to pay far more attention for exploring this prolific green type of energy. Existence of at least 18 geothermal susceptible zones in Iran is confirmed based on carried out geological exploration programs. In particular, published documents give the hope for the generating of more than 50 MWe of clean energy in Meshkinshahr. But, besides the natural potential, the influential lobbies and associations should be more devoted to green renewable resources. As a matter of fact, geothermals are not as profitable as fossil fuels and these new resources need to be supported by the government policy and also private investors. Meanwhile, confirmed abundance of geothermals besides other ones like solar energy deserves far more serious considerations.

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Authors' contributions

AD as the first author developed the idea of analyzing the energy consumption trend in Iran. MGK has the responsibility of arranging the different sections of the manuscript and rewriting it. Both authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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