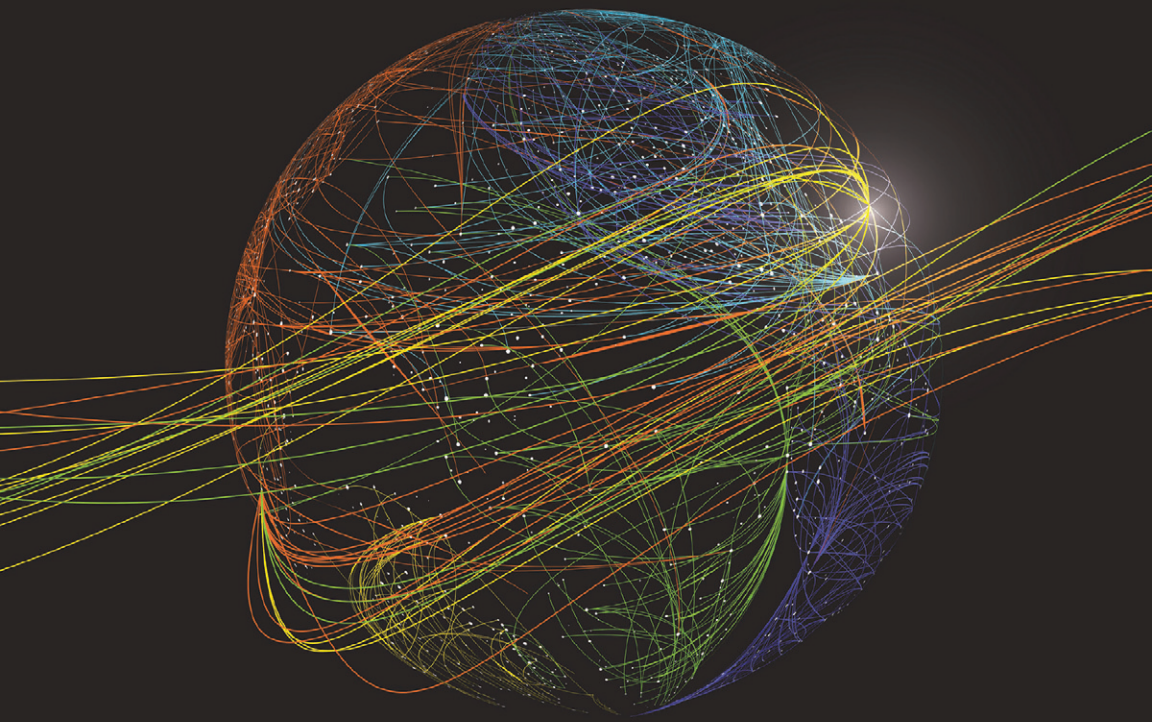
Multidimensional Strategic Outlook on Global Competitive Energy Economics and Finance



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Chapter 1

Identifying New Perspectives on Geothermal Energy Investments

Zafer Adalı, Hasan Dinçer, Serkan Eti, Alexey Mikhaylov and Serhat Yüksel

Abstract

This chapter aims to identify new perspectives of geothermal energy investments. For this purpose, all studies in the Web of Science regarding the geothermal energy are taken into consideration. These studies are evaluated with the help of text-mining approach. In this framework, most frequently stated words, two words, and three words are identified. It is concluded that technological development with respect to the geothermal energy is an important issue in this framework. After that, it is also determined that risk is another important factor in this regard. Finally, new implications regarding the geothermal energy are also considered by the researchers. Geothermal energy has a positive contribution to solve many different problems, such as energy dependency, current account deficit problem, and carbon emission. Hence, this study generated the significant issues to improve these investments. While considering the results, it is understood that technological developments related to the geothermal energy projects should be followed effectively. In addition, an effective risk evaluation should be conducted before implementing these projects.

Keywords: Geothermal; energy investment; risk evaluation; technological development; text mining; web mining; renewable energy; carbon emission; energy dependence; current account deficit

1.1 Introduction

Energy has a very important role in both human life and economic development. In other words, energy is a necessity that must be supplied (Dinçer et al., 2019). Therefore, there is an obligation to supply energy, regardless of its price. As can

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be understood from this, the situation is much easier for countries that have energy reserves (Zhao, Xu, Yüksel, Dinçer, & Ubay, 2021). These countries can meet their energy needs without being dependent on others. On the other hand, there are some risks for countries that do not have energy reserves. As mentioned earlier, the supply of energy is mandatory. Therefore, countries with energy reserves can meet these needs themselves (Yüksel, Mikhaylov, & Khomyakova, 2021).

There are three different paths in front of countries that do not have energy reserves. First, these countries can meet their energy needs by purchasing from other countries (Fang, Zhou, Dinçer, & Yüksel, 2021). However, in this way, they become dependent on the other country both politically and economically. The second way is to increase energy exploration activities in their own countries. A country may have as yet undiscovered reserves (Haiyun, Zhixiong, Yüksel, & Dinçer, 2021). Therefore, it is possible to detect these reserves with extensive exploration activities. In this way, countries can meet their energy needs without being dependent on others. On the other hand, despite extensive exploration efforts, energy reserves may not be found in a country (Dinçer & Yüksel, 2019).

The third way that countries that do not have energy reserves can apply is the development of renewable energy projects (Yüksel, Dinçer, & Meral, 2019). Renewable energy projects aim to generate energy using natural resources such as the sun and wind. The biggest advantage of these types of energy is that they reduce environmental pollution (Du, Dinçer, Ersin, & Yüksel, 2020). These types of energy contribute significantly to the solution of the carbon emission problem. In addition, renewable energies also help countries to produce their own energy. In this way, the dependence of countries on foreign energy will decrease (Meng, Dinçer, & Yüksel, 2021).

Geothermal energy is one of the renewable energy types that has increased in popularity especially in recent years. It is aimed to obtain electricity by using the steam of hot water underground. As can be seen, it is possible to minimize environmental pollution thanks to geothermal energy. On the other hand, geothermal energy is not affected much by climate and weather conditions. This situation brings geothermal energy to the forefront compared to other renewable energy types. In this study, it is aimed to identify new perspectives on geothermal energy investments. For this purpose, studies regarding geothermal energy investments are evaluated with the help of text mining methodology.

1.2 General Aspects of Geothermal Energy Investments

Adequate energy sources have been accepted as the cornerstone of economic development, and ordinary people's lives worldwide have become more dependent on energy in especially last three decades. Communication, transportation, cooking, heating, and even education have been integrated with energy. Without energy, the modern civilization is not envisioned. The primary energy resources involving oil, natural gas, and coal play a critical role in fulfilling social and economic demands. The primary energy resource is nonrenewable energy sources.

They are limited in supply and are eventually subject to run out of fatefulness. Along with the unsustainable appearance of nonrenewable energy resources, environmental degradation has been experienced because of the devastating effects of these energy sources used. CO_2 emission, marine pollution, water degradation, and habitat destruction are regarded as the detrimental effects of nonrenewable energy resources. The nonrenewable energy sources based on limited supply lead the world to the prepper. These unintended scenario has been documented many international nongovernmental and governmental institutions. For example, Intergovernmental Panel on Climate. Change's (2018) report indicates that economic activities push the global temperature to approximately 1°C compared to the preindustrial level. Unless the current energy usage and economic habit do not change, the global warning seems to pass 1.5°C between 2030 and 2052. This incremental rise will cause various animal species extinction, drought, and rising sea levels. In addition to scientific reports, many international agreements and engagements (the Kyoto Protocol and Paris agreement) have been prepared to show evidence of the detrimental effects of human activities. They offer a set of solutions to prevent these harmful experiences (Çelik, Korkmaz, & Adalı, 2021). At this point, regarding investigating all documents, agreements, national legal documents, it can be indicated that renewable energy sources seem to be prevailing solutions to overcome environmental degradation and substitute nonrenewable energy sources to meet daily and economic demands (Yu et al., 2019). Renewable energy resources are equipped with many advantages. For example, renewable energy technologies use the power generated by the environment, such as sun, wind, and thermal, so the renewable energy resources will not run out in contrast to nonrenewable energy resources (Li, Wu, Dinçer, Kalkavan, & Yüksel, 2021). Furthermore, renewable energy generates few greenhouse or pollutants into the air compared to nonrenewable energy resources, renewable diminish reliance on foreign energy sources, and its maintenance requirements are lower. The environmental degradation caused by the nonrenewable energy sources and the fostering of sustainable economic development have generated massive pressure on policymakers worldwide to accelerate the utilization level of renewable energy sources. Biomass, solar, wind, and hydropower have been widely recognized as the most important renewable energy sources to substitute nonrenewable energy sources because of several environmental and economic advantages (Liu, Dinçer, Eti, & Yüksel, 2021).

Among the renewable energy resources, geothermal energy resources are a particular case, and the usage of geothermal energy resources relies on the countries' specific geographic position. Geothermal energy is a unique energy source located in one area based on the near tectonic plate boundaries worldwide. In other words, geothermal resources can be reached in the area linked to active fault systems, volcanic and magmatic units (Malafeh & Sharp, 2015). Literally, geothermal is made up of two Greek words; Geo signifies earth, and thermal denotes heat. The word combination means that energy is generated from the ground (Alhamid et al., 2016). Regarding scientific explanation, geothermal energy is a kind of thermal energy achieved by some artificial process applied to hot water, steam, hot, dry rocks, and dry steam. The heat of fluids or stones is

generated from the original composition of the planet and radioactive decay materials (Carella, 2001) This thermal form is collected in rocks and fluids in the core of the earth. The difference between the earth's heart and the outside induces continuous conduction of thermal energy from the center to the planet's surface. For example, to produce electricity via geothermal energy, wells are dug a mile deep into underground reservoirs to access the steam and hot water, which is transferred to drive turbines connected to electricity (Devrim Elvan & Turker, 2013).

The utilization of geothermal energy can be categorized into two views: direct utilization of the geothermal sources and converting geothermal sources into electrical energy. The type of utilization relies on the temperature of geothermal resources. 20° – 70°C is considered low temperature, and low-temperature fields are employed in industry, producing chemicals and other direct utilizations. Intermediate-temperature referring 70° – 150°C and high-temperature presenting above 150°C is used for electricity generation and integrated heating system named indirect utilization. The direct utilization of geothermal energy is one of the oldest energy utilizations in human history, and the historical evidence indicates that geothermal energy has been used as the direct utilization in 25 countries for more than 2000 years. Agriculture applications, aquaculture, heat pumps, industrial processes, swimming, bathing, heating, food dehydration, milk pasteurizing, and cooling are the major geothermal energy direct utilization areas (Bakos, 2007; Mertoglu, Bakir, & Kaya, 2003). Heating and cooling buildings via geothermal energy have been received massive attention in recent decades. Geothermal energy is utilized to heat and cool buildings with the help of district heating systems or directly piped into buildings and industries. This system is named geothermal heat pumps and is based on a principle that transfers heat from the reservoir into a building during the winter and reverses the process in the summer. Generally, the direct utilization of geothermal is associated with small-scale projects, whereas the latest technological development induces the direct utilization to become more efficient and more essential energy resources. For example, district heating in Iceland and France, greenhouse complexes in Hungary and Russia, and significant industrial uses in New Zealand and the USA are examples of larger-scale projects with the help of technological developments (Barkaoui, Boldyryev, Duic, Krajacic, & Guzović, 2016; Devrim Elvan & Turker, 2013; Erdogmus, Toksoy, Ozerdem, & Aksoy, 2006; Melikoglu, 2017).

In contrast to direct utilization, the electricity generation from geothermal energy has become popular since the 1970s and 1980s, which marked the years the energy crisis experienced worldwide while electricity has been generated from geothermal energy through conventional electricity hydrothermal resources for more than 100 years (Ghose, 2004). The first geothermal steam well was dug in Italy in the year 1904 by Prince P. G. Conti. In the exact location, the first geothermal plants began to operate and generate electricity in 1914 (Fridleifsson, 2001; Hepbasli & Ozgener, 2004). However, the electricity generation coming from geothermal energy sources is more complicated and needs some requirements compared to direct utilization. First of all, geothermal power plants should be built to utilize hydrothermal resources involving water (hydro) and heat

(thermal), turning a turbine and creating electricity. Operating fluid temperatures above 150°C is a threshold for conventional electricity generation, whereas improved technologies, especially the binary system, allow for using lower temperatures to generate electricity. Generally, three significant technologies are operating in geothermal plants to produce electricity from geothermal reservoirs. Dry-stream power plants are one of the leading technologies. These plants use high-heat, vapor-dominant, hydrothermal reservoirs, and steam from the well transfers straight by the turbine-generator unit. Flash-steam power plants are preferred when a liquid-dominant compound is produced at the wellhead of the hydrothermal reservoir. Flash-steam power plants are divided into two subpower plants: single flash and double flash power plants. The single flash plants are worked by separating the mixture from the wellhead into different phases in a flash vessel. The vapor obtained from this separation process is transferred to the turbine-generator unit. The double flash power plants receive more energy output from the identical geothermal reservoir than single flash power plants. Finally, binary power plants are based on Kalina or Rankine cycles and are used when the water temperature in the geothermal reservoirs is not adequate compared to other power plants. In these plants, lower-than-150°C geothermal reservoirs are utilized through a closed cycle that covers the heat exchange unit, which produces evaporates. Therefore, achieved evaporates expand in the turbine, condense, and return to the heat exchanger by a pump. In addition to these conventional geothermal techniques, hybrid technologies are also based on combination of fossil fuels and other renewable energies with geothermal energy (Chamorro et al., 2012; Devrim Elvan & Turker, 2013; Melikoglu, 2017; Stelling et al., 2016). In recent years, the new type of geothermal technology changes the vision of geothermal energy and overcomes the drawbacks of the high initial capital required to utilize geothermal energy, such as the temperature of the fluid the land uses. The new geothermal energy system is named shallow geothermal energy system. Shallow geothermal energy is one of the most promising renewable energy sources, which can be used almost everywhere regardless of the location based on a tectonic plate. In addition, the usage of shallow geothermal energy does not rely on hot water, steam, or dry rocks, and dry steam; therefore, the range of the reservoir temperature does not play a vital role in the efficiency of shallow geothermal energy. The shallow geothermal energy is based on the warmth of the Earth's crust which has a temperature of around 13°C regardless of freezing winter or a sweltering summer occurring on the surface. According to the implications, below 15–20 m depth, everything can be accepted as geothermal energy and the relatively negligible initial capital compared to the conventional geothermal plants, the application in everywhere, the provided heating cooling residential lead the shallow geothermal energy to become one of the leading renewable energy sources in the world (Johnston, Narsilio, & Colls, 2011; Narsilio & Aye, 2018).

Compared to the effects of nonrenewable energy resources on the environment, geothermal energy is considered a clean energy resource because some environmental degradations such as CO_2, NO_X, and SO_X emissions are significantly low. Regarding other types of renewable energy resources, the weather conditions such

as sunny days, gale-force play a vital role in energy efficiency achieved from solar and wind, whereas weather conditions seem to be insignificant factors impacting the geothermal resources. In other words, the geothermal energy is accepted all year long. Therefore, geothermal will be able to meet the demands of human activities because geothermal energy is a very predictable and reliable source. Furthermore, although geothermal energy–requiring temperatures are more than 150°C to turn the turbines effectively, heating and cooling are always provided by shallow geothermal energy because the earth is more immune to seasonal temperature changes than air. Additionally, the earth only a few feet below the surface can provide the geothermal source via shallow geothermal development. Many scholars have investigated heating and cooling, and they show the amount of energy consumption per capita for heating and cooling, their future trends, their effects on the environment, and economy (Daioglou, Van Ruijven, & Van Vuuren, 2012; Isaac & Van Vuuren, 2009; Labriet et al., 2015). According to IEA (2015), it is measured that the amount of residential energy consumption per capita in developed and developing countries accounts for about 20% of global energy consumption. Besides, Gi, Sano, Hayashi, Tomoda, and Akimoto (2018) claim that the heating and cooling demand in 2050 worldwide becomes at least three times higher than the amount in 2010 considering all climate change simulations. Another essential utilization of geothermal is greenhouse heating. Agriculture depends on the weather conditions, and plant-freezing and plant-growth inhibition are some of the most unintended problems impacting agriculture production. Therefore, the greenhouse plays a vital role in protecting agricultural products via a good plant-growth environment (Adaro, Galimberti, Lema, Fasulo, & Barral, 1999). Various energy sources provide the heating greenhouse, and the number of heating costs for greenhouse sometimes can increase the total cost of the agriculture products by 40–80% (Devrim Elvan & Turker, 2013; Kendirli & Çakmak, 2010). In addition to heating and cooling residential and buildings, shallow geothermal and conventional geothermal energy can reduce agriculture production costs and sustain agriculture productions to meet world populations.

In terms of the cost side, it can be said that geothermal projects require a relatively significant initial capital investment while their annual operating cost is negligible. The total initial costs of the geothermal projects involve the project development costs, the exploration costs consisting of seismic surveys and test wells, and the drilling and injection wells. Besides, field infrastructure, disposal system, and fluid collection are also factors impacting the initial capital investment of the geothermal projects. Therefore, the initial capital may be several million dollars. Nevertheless, the initial capital fossil fuel system is needed for central boiler and distribution lines, and their annual operation and maintenance costs are similar to the conventional geothermal projects. Furthermore, the geothermal project seems to be superior to the fossil fuel system in terms of the fuel cost because the fossil fuel system recapitulates to pay for the fuel at an ever-increasing rate. Still, the payment for fuel in the geothermal is stable. (IRENA, 2020; Lund, 2010).

Soltani et al. (2021) made a study to examine the environmental, economic, and social consequences of the geothermal energy method, and they endeavor to reach valid evidence about the relative importance of geothermal energy resources. Regarding the comparison of geothermal energy resources' environmental impacts against nonrenewable resources and other renewable energy resources, air emissions, land usage, geological hazard, noise, water use, solid/fluid waste, and pollution, biodiversity can be considered as important indicators. In terms of air emissions, geothermal reservoirs contain quantities of dissolved gases involving CO_2, H_2S, and CH_4, and when depressurization and cooling process induce these dissolved gases to release. At this time, the type of the geothermal plants becomes important because dry-steam plants do not produce mineral-laden brine and binary plants operating in closed-loop mode. Therefore, dry-steam plants and binary plants are better than flash-steam geothermal plants. However, the total amount of emission generated by the geothermal plants is 10 times less than plants gas-fired powered, 20 times less 10 against oil and plants coal-powered. Concerning renewable resources, geothermal energy induces lower emissions than solar and biomass. However, geothermal energy is also preferred in terms of land usage because geothermal plants need much less space than other power plants. The effects of biodiversity, waste heat, fluid/solid waste, and pollution generated by geothermal energy plants rely on management, supervision, control, laws, and implementation obeyed by the managers. According to Soltani et al. (2021), along with essential management measures, the economic footprint of geothermal energy resources becomes minimum, and the geothermal energy resource will be increasingly regarded as an essential alternative against nonrenewable energy resources.

1.3 New Perspectives on Geothermal Energy Investments

In this chapter, it is aimed to identify new perspectives of geothermal energy investments. For this purpose, studies that have an expression of "geothermal energy" on their titles are taken into consideration. These manuscripts are selected from the journals that are indexed in social science citation index and science citation index. These studies are evaluated with the help of text mining approach. In this framework, most frequently stated words, two words and three words are identified. Within this context, some unnecessary words are removed from the analysis. Table 1.1 gives information about the analysis results.

Table 1.1 describes the most frequently used words regarding the geothermal energy investments. It is possible to reach some important results by considering these words. Firstly, technological development with respect to the geothermal energy is an important issue in this framework. The studies include mainly the words of "technology," "energy technology," and "geothermal energy technology." In addition to this issue, risk is another important factor in this regard because the words of "risk" and "environment risk geothermal" are used in these studies. Finally, new implications regarding the geothermal energy are also

Table 1.1. Most Frequently Stated Words.

Number of the Words	Name of the Words	Number of Uses
1 word	Technology	45
	Heat	31
	Potential	31
	Environmental	28
	Risk	28
	Policy	27
	Economic	26
2 words	Heating cooling	8
	Deep geothermal	7
	Shallow geothermal	7
	Energy technology	4
	Energy heating	4
	Economic feasibility	3
	Climate change	3
3 words	Deep geothermal energy	16
	Shallow geothermal energy	15
	Geothermal energy technology	5
	Environmental risks geothermal	4
	Geothermal energy heating	4
	Ground heat exchanger	4
	Risk-induced seismicity	3

considered by the researchers. For instance, "shallow geothermal" and "shallow geothermal energy" are among the most frequently used words.

1.4 Conclusion

In this study, it is aimed to determine the current applications for geothermal energy. In this framework, all studies on geothermal energy published in qualified journals were included in the review. The most frequently used words were evaluated in the summary sections of these studies. It is found that technological development with respect to the geothermal energy is an important issue in this framework. After that, it is also determined that risk is another important factor in this regard. Finally, new implications regarding the geothermal energy are also considered by the researchers.