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Potential of geothermal energy resources exploitation using hierarchical decision making method

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ABSTRACT

Decision-making in energy planning must take into account several aspects due to the increasing complexity of social, technological and economic factors. Analytical Hierarchy Process (AHP) is a multi-criterion decision making technique and gin that, the problems are decomposed into a hierarchically structure and are given the weights according to its importance. The output is a priority ranking indicating the overall preference for each decision alternative. This paper describes the application of AHP to select a geothermal prospect in Iran country to be developed in the future. Three major criteria are used and applied into those three prospects: geosciences, infrastructure, and social-culture aspects. The benefits of using AHP are (1) the facts and reasons behind the decision are well documented, (2) able to handle quantitative and qualitative inputs, and (3) able to accommodate environmental and social aspect. Based on the participation of experts, 3 criteria and 20 sub criteria were defined. The results showed that the most relevant criteria were the geology 68.3%, technical 18.8% and social economic 12.9%.

1. Introduction

The rapid growth of technology and the use of fossil fuels have had a devastating effect on the environment, which has led to a new approach to environmental protection among scientists, in this regard; the use of Renewable energy is growing rapidly in the world. Renewable geothermal energy has been around for 4.5 billion years and is available to humans for billions of years (Glassley, 2015). This energy is the result of the stored solar energy accumulation as well as radioactive decay of uranium, thorium and potassium isotopes over many years in the depths of the earth. This type of energy is mainly concentrated in young seismic and volcanic areas and tectonic plates of the earth (Baba et al., 2014).

For the formation and evolution of a geothermal system, the existence of four main factors, heat source, reservoir rock, cover rock and fluid is essential. Therefore, in the initial research and exploration of geothermal resources, the basis is to find areas that have the characteristics of these four main factors together. Heat sources in the earth's crust by thermal processes are caused by the decay of radioactive elements, igneous, volcanic and tectonic activities, as well as the rapid subsidence of sediments in sedimentary basins (Huenges and Ledru, 2010; Gemelli et al., 2013).

Proper reservoir rock is another requirement for the formation of a geothermal system, which can include a sequence of sedimentary or pyroclastic rocks that have the appropriate porosity and thickness to store a large volume of geothermal fluids. From an economic point of view, the existence of a suitable geothermal reservoir depends on the volume of fluid, the permeability of rocks and the presence of a cover rock with a thickness of impermeable or low permeability layers, which is located on the reservoir rock

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and prevents fluid from escaping from the reservoir (Stober and Bucher, 2013). Coating rock usually consists of clay, anhydrite, gypsum or salt rocks. These rocks usually have a low thermal conductivity and are placed on the reservoir rock as a thermal insulator. The presence of geothermal fluid, which is the cause of heat transfer from the reservoirs to the surface, is another major factor in a geothermal system; the source of this fluid supply mainly includes atmospheric waters and sometimes interstitial waters (porous), magmatic waters and waters resulting from alteration and transformation of unstable minerals (Baba et al., 2014; El-Katiri, 2014; Glassley, 2015).

Geothermal energy is directed from different parts of the earth to the surface in various ways, including volcanic eruptions, hot springs, geysers and geysers, due to the reduction of the earth's density and conductivity. One of the challenges of exploiting this energy is to find potential areas where the feasibility of economic implementation of projects can be confirmed by examining technical, economic, social and geological factors. One of the exploiting challenges of this energy, considering the technical, economic, social and geological factors, is to find potential areas to enable the economic implementation of geothermal projects. In the study of the main indicators studied for potential and exploitation of geothermal resources, geological factors including Quaternary structures (Quaternary faults, dynamic folds and active tectonics), alteration, spring hot-springs, mud-springs, volcanoes and large-scale earthquakes are important (Stober and Bucher, 2013). Technical factors also include temperature, pressure, chemical properties, geothermal properties, reservoir storage, gravity properties, magnetic properties, electrical resistance and geothermal slope (Laura, 2014). Economic and social factors also include proximity to place of consumption, climate, population and density rate, which were identified and selected as decision options. In this study, in order to identify previous studies conducted in the application of mathematical models, decision-making methods in the identification and utilization of geothermal energy sources, this research is unique in its kind. In general, most areas with geothermal energy potential of Iran are scattered around volcanoes and Quaternary faults (Wohletz and Heiken, 1992), were presented in Fig. 1. In this study, the proposed model for one of the areas prone to the use of geothermal energy in Iran, which is located around Mount Sabalan which the proposed model for one of the geothermal potential areas, around Sabalan Mountain, is evaluated.

2. AHP-based Evaluations

In this study, in order to create a pattern of identification of geothermal potential areas, the main effective criteria were classified into three branches, which include geological, technical, economic and social factors. In the next step, by identifying the sub-criteria involved in each branch and determining the effective weight of each of those sub-criteria, using a hierarchical decision-making method, an evaluation model was created. The most important feature of this method, in order to better understand, is the process of transforming complex problems into a hierarchical structure. In this method, the decision-making problem is divided into different levels of objectives, criteria, sub-criteria and options so that the decision maker can easily pay attention to the smallest components of the decision. The basic principles of this method include creating a class structure, without limiting the number of levels, establishing preferences from the pairwise comparison method and establishing a logical consistency of the measurements.

2.1. Multi-criteria Decision-making Analysis

Hierarchical analysis was presented as one of the main multi-criteria decision making methods in decision making and management by Saaty (Saaty, 1980). In this method, the decision of an issue is divided into different levels of objectives, criteria, sub-criteria and options, so that the decision maker can easily intervene in the smallest components of the decision. The most important advantage of this method is the facilitation of the decision-making process to determine the relative importance of criteria and options, using pairwise comparisons. The main steps of the hierarchical analysis process include building a hierarchical model based on the main goal, criteria, sub-criteria and options, calculating the weights of each component of the model, and finally calculating system incompatibility. The method of constructing a hierarchical model depends on the type of decision made (Saaty, 2012). Calculating the weight of elements in hierarchical analysis includes two processes of calculating relative weight or relative priority and calculating the final weight (Srdjevic, 2005). To calculate the relative weight in the hierarchical method, the elements of each element are compared to the corresponding element in the higher row in pairs and a pairwise comparison matrix (n×n) is formed in which n is the number of indicators to be compared. The matrix of pairwise comparisons is completed by assigning the relevant numerical scores based on the numbers 1 to 9 and corresponding to their superiority over each other, and the relative weight of the elements is calculated. To calculate the relative weight based on the even comparison matrix, different methods are used such as the least squares method, the logarithmic least squares method and the special vector, but the most accurate method of calculating the relative weight is the special vector method, which in this method W_i (relative weight) Determined to have the following relationship (Saaty, 1980):

$$AW = \lambda W \quad (1)$$

where A and W are the pairwise comparison matrix and the relative weight column vector, respectively, and λ is the eigen value of the pairwise comparison matrix A. While the dimensions of the matrix are larger, calculating these values is very time consuming. Therefore, to calculate λ, the value of the matrix determinants is calculated based on

Eq. 2, and by placing the largest λ value obtained from the mentioned equation, the relative weights of the criteria are estimated (Srdjevic, 2005; Saaty, 2012). The final weight of each option in a hierarchical process is calculated by summing the effects of each criterion on the final goal based on Eq. 3, in Si which the final weight of option i indicates the relative importance of option i over criterion j. Also, in the mentioned relation, the relative weight of the criteria j, m, and n indicates the number of options and criteria, respectively. Stochastic incompatibility index and incompatibility rate indicate the degree of incompatibility between judgments regarding pairwise comparisons, which is calculated based on Eqs. 4 to 6 (Ghodsipour, 2006).

$$A - \lambda I = 0 \tag{2}$$

$$S_i = \sum_{j=1}^{n} a_{ij} \cdot W_j \tag{3}$$

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{4}$$

$$RI = 1.98\left[\frac{n-2}{n}\right] \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

In this regard, CI is the compatibility index, RI is the random index, CR is the compatibility rate, λmax is the largest Eigen value of the matrix and n is the size of the matrix. If the calculated compatibility rate value is less than or equal to 0.1, the system compatibility is acceptable, otherwise the judgment should be reconsidered (Saaty, 2012).

2.2. Build a hierarchical decision tree

The decision hierarchy in AHP is a tree that has multiple levels depending on the issue under consideration. The first level of the tree represents the purpose of the decision, and the last level represents the options that are compared to each other and compete with each other for choice. Other (intermediate) levels represent the factors (criteria) that are the criteria for comparing the options. The general structure of the decision tree in this paper in Fig. 1 shows the prioritization of criteria (Bellman and Zaden, 1970).

2.3. Coefficient of criteria, sub-criteria and options

Binary comparison method is used to determine the significance coefficient (weight) of criteria and sub-criteria. In this method, the criteria are compared with each other in pairs and the degree of importance of each criterion to the other is determined. To do this, each binary comparison is assigned a number from 1 to 9. The weight and meaning of each number are specified in Table 1. After weighting the parameters, the weights, from the division of each weight, on the sum of the weights of the same column according to the method was normalized (Bowen, 1990; Çimren et al., 2007).

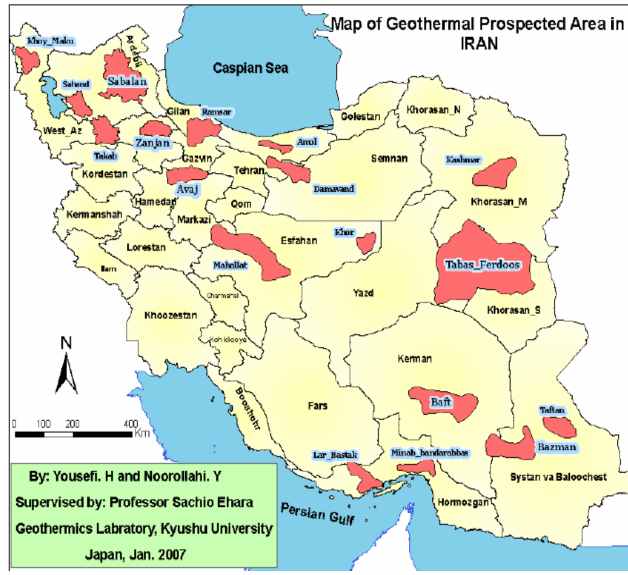

Figure 1. Geothermal potential areas in Iran (Yousefi et al., 2007)

Table 1. ANN model output training data

No	Score	Description
1	1	Equal importance
2	3	Slightly more important
3	5	More important
4	7	Much more important
5	9	Absolute importance
6	2, 4, 6, 8	Intermediate importance

3. Material and Methods

3.1. Geological factors

In the study of the main indicators studied for the potential and utilization of geothermal energy resources, geological factors are considered as the main influential features, including volcanic areas, Quaternary faults (the structure of folds, fractures and tectonics) are alteration zones, hot springs, mud springs and large-scale earthquakes (Huenges and Ledru, 2010).

Hot springs: In almost all areas with potential for geothermal energy extraction, the most important indicator of the potential of the area is the presence of hot springs, which are evidence of the existence of a heat source in the area. The temperature of springs is directly related to the temperature of the source and their presence is an indication of the existence of geothermal energy potential and the possibility of a heat source is much higher than other areas (Gemelli et al., 2013). A study in Japan showed that all geothermal wells are located at a maximum distance of 4 km from hot springs (Amanda et al., 2019). At present, almost all of the electricity generated by geothermal energy comes from such locations. In some areas, rocks can reach temperatures of up to 300°C, providing enormous amounts of heat energy. Therefore, geothermal energy can be formed in places where geological processes have allowed magma to rise close to the earth's surface, or to flow as lava (Stober and Bucher, 2013). Generally, Iranian hot springs are scattered around Quaternary faults and volcanoes, most of which are in the northwest of the country and also the highest temperature is related to Qinarjeh hot spring in the south of Meshkinshahr city in Sabalan geothermal area (Yousefi et al., 2007).

Quaternary faults: One of the most important evidences of the presence of geothermal energy in an area is the existence of faults and fractures that play an important role in accelerating the flow of groundwater, charging and stability of reservoirs. In 2000, Hanon investigated the effect of faults on the natural properties, fluid flow and heat conduction of geothermal reservoirs and concluded that faults play a role in secondary permeability in geothermal reservoirs (Stober and Bucher, 2013). Secondary permeability plays the most important role in fluid transfer in most of the world's geothermal fields. In 2003, Belwitt examined the location of geothermal power plants and production wells in the Great Basin geothermal field in the United States and proved that the location of geothermal power plants with internal faults and fractures is in line with the flow of geothermal fluid in the geological layers controlled by faults and fractures (Glassley, 2015). Amanda et al. (2019) studied 430 geothermal wells in two Northern provinces of Japan and concluded that more than 95% of the production wells in geothermal fields are located at a maximum distance of 6 km from the faults.

Alterations: The distribution of altered rocks in an area is an indicator of the presence of geothermal energy sources and alteration by hot water can be dependent on the geothermal system. The possibility of geothermal resources in areas containing metamorphic rocks is more than other areas and the presence of altered rocks can be a reason for the existence of heat and fluid source (Stober and Bucher, 2013; IGA Service GmbH, 2013). Geological structure and type of minerals metamorphic rocks in geothermal areas by physical condition; the chemical composition of the heating system depends on the temperature, pressure, rock type, permeability, and chemical composition of the fluid. Thus, analysis of the location and type of altered rocks can provide us with information about the events of geothermal resources in the past and present (Brady and Brown, 2010).

Earthquakes: Investigating the depth of large earthquakes and their location is used to map major fractures and faults and the path of groundwater within reservoirs. On the other hand, most geothermal systems are located along tectonic plates where large earthquakes are centered (Slemmons, 1975). In addition, small earthquakes occur in geothermal fields far more often than in other areas. The nature of earthquakes in geothermal areas is not different and their magnitude is not large, while outside the geothermal areas, earthquakes of larger and deeper magnitude occur (Simiyu and Keller, 1998; Duffield and Sass, 2003; IGA Service GmbH, 2013).

Domes and volcanic rocks: Examination of geothermal fields has shown that in most of them volcanic rocks have a wide surface distribution and young active or inactive volcanic craters are still exchanging energy with the surrounding geological layers. These volcanic craters and the presence of volcanic rocks in an area can be considered as a heat source of geothermal fields (Huenges and Ledru, 2010; Gemelli et al., 2013; Stober and Bucher, 2013; Baba et al., 2014; Glassley, 2015). A look at the map of volcanic rocks in Iran (Yousefi et al., 2007), shows that these rocks are found along the two mountain ranges of Alborz, Zagros and around the volcanic mountains of eastern Iran. The area covered by these rocks covers 146,000 square kilometers and about 9% of the whole country (Stober and Bucher, 2013).

Flower sprayer: Golfers are a combination of water and volcanic ash, water and clay, or dissolved water and rocks which may form during volcanic activity, earthquakes and tsunamis and flow like magma. The presence of volcanoes in an area can be a reason for the existence of a deep heat source. Ten volcanoes are located in the Makran region in southeastern Iran, and two are located in the city of Gonbad Kavous near the east of the Caspian Sea (Yousefi et al., 2007; Stober and Bucher, 2013; Glassley, 2015).

3.2. Technical factors

Technical factors include fluid temperature, chemical properties, geothermal properties, fluid pressure, reservoir storage, gravity properties, magnetic properties, electrical resistance and geothermal slope that influence the decision to use their energy (Baba et al., 2014).

Source temperature: In order to use the heat in the earth intelligently, heat sources must be carefully identified and evaluated (Stober and Bucher, 2013). Heat in geothermal sources can be transferred by two basic mechanisms as follow (Glassley, 2015):

- Heat transfer through rocks,
- Through the movement of fluid (groundwater and gases).

Usually, high temperature areas should be at a depth that is accessible by drilling wells and the volume of transfer fluid should be high. Currently, only in areas with young Quaternary volcanoes are high temperature springs found at shallow depths (Huenges and Ledru, 2010). Geothermal sources in terms of source temperature are divided into two categories of low temperature reservoirs: 10-94°C and high temperature reservoirs: 94°C< (Gemelli et al., 2013). Table 2 shows the classification of geothermal resources by temperature.

Table 2. Geothermal resource classification (Huenges and Ledru, 2010)

Classification (°C)	Muffler and Cataldi (1978)	Hochstein (1990)	Benderitter and Cormy (1990)	Nicholson (1993)	Axelsson and Gunnlaugsson (2000)
Low enthalpy sources	< 90	< 125	< 100	< 150	< 190
Medium enthalpy sources	90 – 150	125 – 225	100 – 200	-	-
High enthalpy sources	150 <	225 <	200 <	150 <	190 <

Concentration of anions and cations: The chemical composition of geothermal fluids is affected by the fluid-mineral balance in hydrothermal systems. In a high enthalpy system, the concentration of solute depends on the temperature, gas volume, heat source, rock type, permeability, age of the hydrothermal system, and fluid source. Geothermal fluids contain the cations Mg, Ru, Cs, Mn, Fe, Na, k, Li, Ca and the anions of sulfate, chlorine, bicarbonate, F, Br, I, natural silica, arsenic, boron and ammonia (Bowen, 1990).

Fluid pressure: Fluid pressure is a function of source depth and fluid density and is one of the factors that play an effective role in exploiting a geothermal source. Fluid pressure can be normal, sub-normal and super-normal based on the hydrostatic slope. Abnormal fluid pressure is a pressure higher than the hydrostatic slope, which is often due to the high temperature of the fluid (Huenges and Ledru, 2010).

The amount of tank storage: The economics of a geothermal reservoir depend primarily on the volume of fluid in the system (Bowen, 1990). Estimating reservoir reserves is one of the critical factors in decision making and planning for the exploitation of a geothermal resource. Reservoir reserves are usually estimated based on geological data and exploratory studies conducted in the area as well as numerical modeling. Naturally, the higher the reservoir reserve is the better the geothermal source for exploitation (Baba et al., 2014).

Magnetic properties: In the exploration of geothermal resources, magnetic property is a common application. In addition to identifying deep faults and structural discontinuities, the depth of the blind spot and the temperature of blindness are also identified. At the point of blindness, the material will change from ferromagnetite to paramagnetite, and the efficiency of the geothermal power plant is estimated based on the blindness temperature of the surface material of the site. Titanium magnetite, for example, is a common material in geothermal areas with a blinding temperature between 570 and 200 degrees Celsius. Simple geometric anomalies modeled at different depths are used to estimate the depth of blindness (Amanda et al., 2019).

Electrical resistance: The change in the electrical resistivity of the fluid-rock volume is the most important change in physical properties due to the presence of a hydrothermal system. Ion mobility and electrical conductivity increase with increasing temperature up to about 300°C. Ion conductivity increases with increasing porosity, salinity and the amount of some minerals such as clays and zeolites. Geothermal systems can generally be identified by one or more of these characteristics, which are seen in high conductivity or low resistance anomalies (Amanda et al., 2019). Low-strength geophysical anomalies in most geothermal systems are among the most useful exploratory targets, and a better and deeper study of the structural strength of geothermal systems has shown that the lowest resistance is usually in a zone above the reservoir (Huenges and Ledru , 2010).

Porosity and permeability of rocks: Permeability plays an essential role in mass and heat transfer to define a geothermal reservoir (Huenges and Ledru, 2010). The presence of reservoir rock is one of the main requirements in the formation of a geothermal system and can consist of a series of sedimentary or pyroclastic rocks with special characteristics and different thicknesses. Such rocks have considerable porosity, permeability and thickness and can store huge volumes of geothermal fluids. In the formation of geothermal reservoirs, the permeability factor plays an important role and in case of low permeability, it is not possible to extract and exploit these fluids economically (Bowen, 1990).

3.3. Economic and social factors

Infrastructures: Infrastructure is interpreted as the basic physical and organizational structure required carrying out the operations of an organization or a society, which provides a framework for the development of all other structures and can be considered as one of the elements of a country's development. Infrastructure comes in both soft and hard infrastructures. Hard infrastructure includes transportation, water management, communications, solid waste management, monitoring network, and land measurement. Soft infrastructures include governance, economic, socio-cultural, sports and entertainment (Wohletz and Heiken, 1992; Duffield and Sass, 2003).

Investment in infrastructure is part of the accumulation of capital needed for economic development, and the impact of infrastructure on economic growth is always one of the fundamental issues in project economics. Vital infrastructure is built and managed by governments, and the operation of the basic structures of society, such as the economy, is possible and necessary for its implementation, and can include the following (Demirtas, 2013):

- Production, transportation and distribution of electricity,
- Production, transportation and distribution of oil and gas,
- Communications and communication lines,

- Water supply sources including drinking water as well as sewage and surface water,
- Agriculture and structures of agricultural products,
- Heating tools, equipment and tools including oil and gas fuel natural and public health,
- Rail, air, port and inland transport systems,
- Financial services systems and banks,
- Security systems include police forces and military structures.

Proximity to the place of consumption: The direct application of geothermal energy is the direct exploitation of geothermal energy. In this case, the geothermal energy is not converted into electrical energy, but only its thermal energy is used. Obviously high heat tanks are mostly used to generate electricity. Geothermal energy is used for heating buildings, agriculture, animal husbandry, snowmelt on roads, etc., and considering the above and the conditions of facilities and operation and proximity to the place of consumption is also one of the parameters under study.

Weather: In the study of exploration and exploitation of geothermal reserves, the weather conditions in constructions should be considered from two perspectives and its effects should be considered in the initial decisions and planning as difference between the temperature of the place and the temperature of the geothermal source and its application.

4. Results and Discussions

In this study, economic and social, geological and technical criteria were considered as the main criteria. Each of these main indicators has a number of sub-criteria, Table 3. The effect of these sub-criteria on geothermal energy has been discussed earlier. In order to prioritize and evaluate the impact of each of the factors affecting geothermal energy, pairwise comparative matrices were used. According to Tables 3 to 5 of geological factors, Quaternary faults in technical factors, temperature and in technical and economic factors, infrastructure, had the largest share in influencing geothermal energy. In this regard, by influencing the weight of each of the main criteria in the sub-criteria, the number related to each of the criteria and sub-criteria, which show their impact on the prioritization of susceptible areas, was obtained. Table 6 is presented the results of AHP classification for studied prioritizations.

Given that the CR in each of the tables is less than 0.1, so it can be concluded that the calculations are correct and logical. Figures 2 to 6 is presented the results of the main criteria's based on AHP evaluations. According to Figure 2, the geological factor is the most important among the main factors and according to Figure 3, the temperature index and Quaternary faults are most important factors in prioritizing geothermal energy prone areas.

In Fig. 6, considering that geological factors had the highest share, therefore, the sub-indices related to geological factors also have the highest share among all sub-indices. Among these factors such as Quaternary faults and hot springs are of the highest importance.

Table 3. Prioritization matrix under economic and social criteria

Criteria	C1	C2	C3	C4	C5	C6	Result
C1	1	2.00	1.50	1.50	2.00	1.75	0.248
C2	0.50	1	0.50	1.75	1.75	2.50	0.178
C3	0.66	2.00	1	2.00	1.50	1.75	0.217
C4	0.66	0.57	0.50	1	1.25	2.00	0.139
C5	0.50	0.57	0.66	0.80	1	1.50	0.121
C6	0.57	0.40	0.57	0.50	0.66	1	0.095
λ_{max}		RI		CI		CR	

Table 4. Prioritization matrix under geological criteria

Criteria	C1	C2	C3	C4	C5	C6	Result
C1	1	1.10	2.00	1.50	2.00	2.95	0.252
C2	0.90	1	0.50	1.60	1.70	2.60	0.189
C3	0.50	2.00	1	1.50	1.70	2.85	0.218
C4	0.66	0.62	0.66	1	2.00	2.25	0.159
C5	0.50	0.58	0.58	0.50	1	1.75	0.111
C6	0.33	0.38	0.35	0.44	0.57	1	0.072
λ_{max}		RI		CI		CR	

Table 5. Prioritization matrix under technical criteria

Criteria	C7	C8	C9	C10	C11	C12	C13	C14	Result
C7	1	0.67	1.20	0.50	1.20	0.77	1.30	0.67	0.100
C8	1.50	1	2.00	0.33	1.20	1.30	1.80	2.00	0.148
C9	0.83	0.50	1	0.50	0.50	0.59	1.10	0.67	0.080
C10	2.00	3.00	2.00	1	2.00	3.00	1.50	2.00	0.233
C11	0.83	0.83	2.00	0.50	1	0.63	1.10	0.42	0.098
C12	1.30	0.77	1.70	0.33	1.60	1	1.40	0.59	0.113
C13	0.77	0.56	0.90	0.67	0.90	0.71	1	0.80	0.091
C14	1.50	0.50	1.5	0.50	2.40	1.70	1.25	1	0.137

Table 6. Prioritization matrix of main criteria

Criteria	Geology	Economic /social	Technical	Result
Geology	1	3.50	5.50	0.67
Economic/social	0.28	1	1.40	0.188
Technical	0.18	0.71	1	0.129

4.1. Evaluation of Meshkinshahr geothermal area

The Meshkinshahr geothermal zone located in Ardabil province in Iran was studied to evaluate the hierarchical algorithm. According to the studies of the Geothermal Energy Office of the New Energy Organization of Iran (SANA), Meshkinshahr is the best place to use the capacity of geothermal energy in the country and the temperature of geothermal fluid in Meshkinshahr area in different layers of the reservoir is estimated between 2 to 4 C^{o}. The first Meshkinshahr geothermal exploration well was drilled vertically in 1981 with a depth of 3,200 meters and a temperature of 250°C.

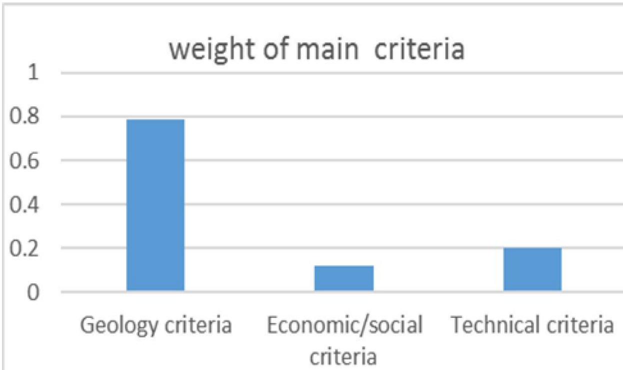

Figure 2. The weight of main criteria

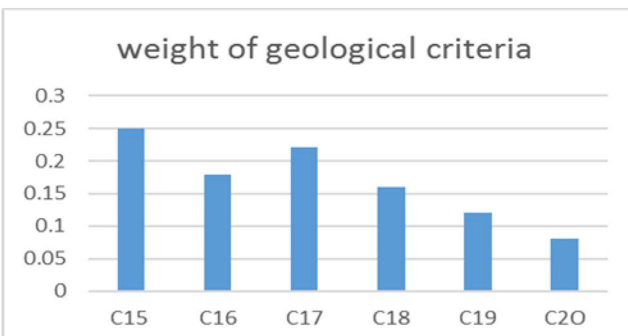

Figure 3. The weight of geological criteria

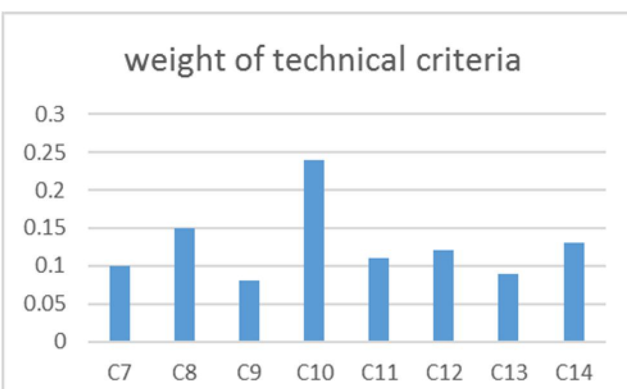

Figure 4. The weight of technical criteria

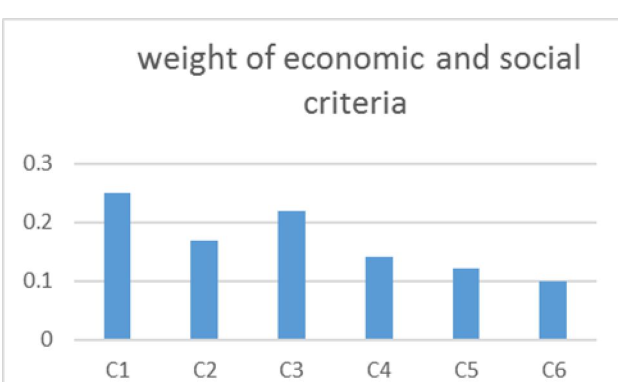

Figure 5. The weight of economic and social criteria

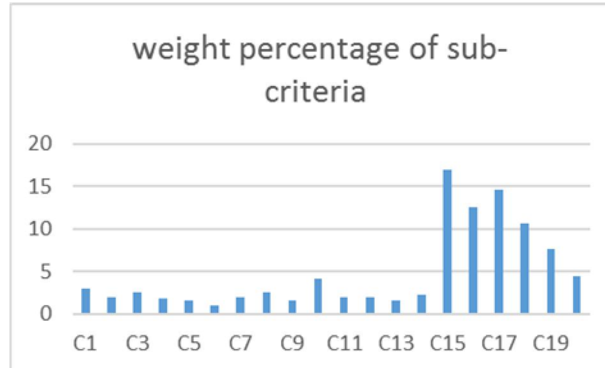

Figure 6. The weight percentage of sub-criteria

The second exploratory well was drilled in 1983 at a depth of 3,177 meters, the temperature at the end of which is 140°C, and then the third exploratory well was diverted to a depth of 2,265 meters at a temperature of 211°C was excavated. Out of a total of 17 wells planned for this power plant, 11 wells have been drilled so far and three wells have successfully passed the steam outflow test stage, and planning for the construction and operation of a geothermal power plant with a nominal capacity of 100 MW in this The area is done. To implement the algorithm presented in this paper, first by evaluating the main economic and social, technical and geological indicators using study models and a survey of experts in this field, the sub-indicators were scored. The results are given in Table 7.

5. Conclusion

Renewable energy is produced from natural resources such as geothermal heat creating new businesses and employment. A selection among the renewable energy alternatives has been made using AHP methodology. Analytic Hierarchy Process, which developed for solving the multi-criteria decision making problem, is a widely used method in determining the best alternative. (Kaya and Kahraman 2010; Lior, 2010). The paper presents a framework for the use of the Analytic Hierarchic Process (AHP) to define a scale of values in the geothermal prospect in Iran country.

In summaries, several advantages by using AHP can be mentioned such as (1) the facts and reasons behind the decision are well documented, (2) able to handle quantitative and qualitative inputs, (3) able to accommodate environmental, social and other influences, and (4) able to handle subjective judgments of individuals. In addition, AHP application for geothermal prospect selection may be extended into multicriteria decision making at a group level Three major criteria are used and applied into those three prospects: geosciences, infrastructure, and social-culture aspects. Based on the participation of experts, 3 criteria and 20 sub criteria were defined. The results showed that the most relevant criteria were the geology 68.3%, technical 18.8% and social economic 12.9%.

Table 7. Scoring indicators of Meshginshahr geothermal area based on AHP model

Criteria	Sub-Criteria	ID	Score for each criteria	General score
Economic and social	Infrastructure	C1	12.4	1.6
	Consumer market	C2	8.01	1.04
	Proximity to the place of consumption	C3	8.68	1.12
	Population and its density rate	C4	4.90	0.63
	Local laws and customs of residents	C5	6.66	0.83
	Weather	C6	2.85	0.36
	Total		43.5	5.58
Geological	Quaternary faults	C7	18.9	12.9
	Domes and volcanic rocks	C8	18.0	12.3
	Hot springs	C9	19.53	13.32
	Flower springs	C10	13.52	9.27
	Earthquake	C11	7.77	5.32
	Alteration	C12	5.37	3.67
	Total		83.09	52.60
Technical	Gravitational and magnetic properties of the area	C13	7.00	1.33
	Tank storage rate	C14	12.58	2.38
	Electrical resistance	C15	5.20	0.98
	Fluid temperature	C16	20.97	3.96
	Porosity and crushing of rocks	C17	7.35	1.35
	Concentration of anions and cations	C18	7.91	1.47
	Geothermal drilling slope	C19	7.28	1.36
	Fluid pressure	C20	10.28	1.95
	Total		52.60	14.77

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