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Financial Appraisal of Meshkinshahr Geothermal Power Plant Assuming Feed in Tariff of Electricity

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Abstract

Despite the high potential of geothermal reservoirs in Meshkinshahr, we only see the government entering the electricity extraction of geothermal energy because the cost of the Meshkinshahr geothermal electricity is higher than the balanced price of the electricity market and the private sector is disadvantaged for entering it. So, the government has adopted a feed in tariff policy for geothermal electricity to encourage private sector investors. This research is aimed at financial appraisal of Maskinshahr geothermal power plant with the assumption of feed in tariff by the government with Equivalent Uniform Annual Worth, Equivalent Uniform Annual Worth, and Equivalent Uniform Annual Cost methods. Equivalent Uniform Annual Benefit is obtained from feed in tariff of government and Equivalent Uniform Annual Cost is determined based on technical and economic components of the geothermal power plant and macroeconomic parameters. The results of the data analysis show that the construction of the geothermal power plant is fully justified with the 14% reduction rate, but if the investor's minimum expected rate exceeds 54%, the construction of the power plant has no economic justification. Also, if the construction of Meshkinshahr geothermal plant takes more than 13 years and 5 months like the government project, the generation of geothermal power is not cost-effective.

Highlights

- The Renewable Energy FIT Policy has been adopted in support of the private sector investor's entry into renewable energy production in Iran.
- The Meshkinshahr area is one of the most susceptible areas in Iran, which can stimulate the private sector's investors in generating electricity by the assumption of FIT.
- A financial appraisal of Meshkinshahr geothermal power plant from the perspective of private sector investment shows that electricity production at the plant is quite economical.
- If the duration of the construction of the plant takes more than 13 years and 5 months, geothermal power generation is not cost-effective

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1. Introduction

Given that one of the reasons for using renewable energy is to reduce environmental pollution, but there are still serious obstacles to the use of this energy in Iran. In Meshkinshahr, according to the geospatial atlas, there is a high potential for the extraction of energy from geothermal sources, which is confirmed by the experts of ENEL Company in Italy. But power generation in this area is restricted to state power plants. Because currently, despite subsidies for electricity sales, the government does not set the price of the electricity market as a criterion for choosing the type of power generation technology, but it invests in the projects which lessen the cost of the production (Motahari et al., 2014). According to the Ministry of Energy Research Center report, the cost of generating geothermal electricity from Meshkinshahr is 4-6 cents per kilowatt-hour at the low level in the spectrum of oil electricity generation, coal, and nuclear energy, and much lower than the cost of generating electricity from other unconventional energy sources (Khosravi, 1997). Comparing the cost of generating electricity itself, can only stimulate the government to generate geothermal electricity, but from the perspective of the private sector investor, the comparison of the price of the electricity market with production costs is the criterion for choosing the type of power generation technology that is currently being limited at non-realistic electricity prices, so the construction of the lowest-cost renewable power plants is not cost-effective. The private sector's entry into renewable energy production, such as geothermal, requires government support. Therefore, the Energy Feed in Tariff (FIT), set by the Ministry of Energy in pursuance of the implementation of Article 44 of the Constitution (reforming the economic structure and participation of the private sector in infrastructure activities) was adopted in 2008. A policy that has worked well in Turkey, Canada, Germany, USA, Spain, and other developed countries.

In the last decade, different countries have adopted FIT policies, Renewable Portfolio Standards (RPS), tendering, biofuel mandates, heat obligations/mandates, and renewable electricity, transport, energy in primary, heating, and cooling targets.

In the meantime, the FIT policy has been welcomed more than the other policies approved in 2018 according to Table 1 at 111 States/provinces/countries. The FIT type is designed to be profitable for private sector investors so that the price of electricity is higher than the usual price of the market.

The world's first and most successful renewable energy development mechanism is electricity FIT; because the private sector investment can be sure about the amount of electricity sold, and carry out feasibility studies of whether the investment in this sector is profitable or not. This is possible by comparing the incomes and costs of generating electricity.

Table 1. Renewable Energy Policies in countries

Policies	2017	2018
Renewable energy targets	179	169
Renewable energy in primary or final energy targets	1	1
Renewable heating and cooling targets	1	1
Renewable transport targets	1	1
Renewable electricity targets	57	65
Heat obligations/mandates	19	18
Biofuel mandates	70	70
Feed-in policies	112	111
RPS/quota policies	33	33
Tendering (held in 2018)	29	48
Tendering (cumulative)	84	98

***Source**: Renewables 2019 Global Status Report*[1]

The government's FIT policy of Iran has been effective in enabling the private sector to enter renewable energy production, so the launch of the first nongovernmental renewable energy plant since 2009, has injected 70.8 MW and more than 502 GW of renewable electricity into the network. The entry of the private sector into the production of renewable electricity, such as heating, requires government support. Therefore, the government's FIT policy has been effective in involving the private sector in the production of renewable electricity. This study seeks to show scientifically whether the production of geothermal electricity in the Meshkinshahr area, assuming FIT policy, is economically justified or not. For this purpose, this research has presented a scientific approach to the subject and examined various issues. In this regard, we will present the literature review in section 2, the theoretical background review in section 3, the materials and methods in section 4, the data and experimental results in section 5, and the conclusions in section 6.

2. A Review of the Related Literature

The review of researches on the financial appraisal of renewable power plants such as wind, solar and geothermal shows that most studies have focused on calculating the cost of producing electricity from renewable energy plants and comparing it with the cost of other conventional power plants. In these studies, LCA and Levelized Electricity Cost Assessment (LCOE) are used to compare the cost of generating electricity from power plants.

Technical-economic assessment of geothermal and fossil-fuels power plants show that the cost of geothermal power generation is about 4-6 cents per kilowatt-hour, which is the lowest in the spectrum of electricity costs from oil, coal, and nuclear energy sources, and far below the cost of generating electricity from other unconventional sources (Khosravi, 1997).

[1] https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf.

El-Kordy et al. (2002) have analyzed the useful life for electricity generation by conventional and renewable systems in Egypt. In this research, the cost of external impacts has been considered to compete with solar and wind power converters with conventional power generation systems. The results indicated that as time passed, environmental standards will be strengthened, fossil fuels will be reduced and the cost of conventional systems will increase, so renewable plants will be able to compete with conventional power plants.

Fitzgerald (2003) analyzed geothermal electricity with binary cycle technology as a financial appraisal of the return of capital. In this research, factors affecting the costs and incomes of power generation were considered, which can be considered as the discharge flow from the geothermal reservoir and electricity market prices. Eventually, the return on capital was extracted from the changes in the price of electricity, and the comparison of the time of the return on investment of the investor with the long-term return on capital gained determines the economic justification of geothermal electricity.

Roth and Ambs (2004) compared the cost of electricity generation in 14 technologies. In this study, considering the cost of external impacts on the cost of electricity generation, suitable alternatives for fossil power plants have been proposed; the results indicate the economic justification of renewable power plants.

Elíasson and Valdimarsson (2005) analyzed the generation of electricity from the geothermal reservoir by pure net worth and internal return rates. In this study, the parameters of the discharge flow, reservoir temperature, investment cost, repair and maintenance costs, and electricity prices are included in the calculations. Finally, the economic conditions of production were determined for each of the parameters, assuming the stability of the other variables.

Sener et al. (2009) examined the economic prospect of geothermal electricity in the West American Electricity Market. In this study, price fluctuations, tax effects, and factors affecting electricity prices were considered. A Stochastic Geothermal Cost Model (SGCM) was used to compare the cost with those of past prices and future expectations. The results were based on the economic justification of geothermal electricity under certain conditions.

Taheri fard and Shahab (2010) calculated the fixed and operating costs of Meshkinshahr geothermal electricity generation for the three scenarios of lowest, average, and highest cost in the upstream sector and power plant. The results show that the cost of producing each kilowatt-hour of geothermal electricity in the field of geothermal power plants is very risky and requires serious government support.

Lin et al. (2014) assessment the FIT and ETS policies for achieving China's renewable energy. The results show that ETS policy doesn’t provide sufficient incentive for renewable energy development in China.

Barimani and Ka'abi Nejadian (2014) considered the economic justification of private renewable hydroelectric, solar, and wind power plants with the assumption of FIT policy in the form of annual uniform value. In this study, electricity generation costs were calculated using LCOE. The results indicate the economic justification of electricity generation from wind and hydroelectric technologies and the lack of justification for the production of electricity from photovoltaic technology.

Hasan and Wahjosudibjo (2014) review the policy of FIT for geothermal energy in Indonesia. They conclude that to develop geothermal and other renewable resources should be the law and regulation are better.

Taylor et al. (2015) examine the levelized cost of power generation technologies in different parts of the world. In this report, the average cost of geothermal electricity is around 7 cents per kilowatt-hour in 2014 around the world, which is in a better position than other renewable and fossil fuels power plants.

Bolurian et al. (2015) compared the cost of electric power stations for wind and fossil power plants under two scenarios: a one percent increase in global fuel prices, regardless of the global price increase of fuel, at both discount rates of 6% and 8%, in terms of export and import prices of the fuel. The results show that in the exclusion of the global fuel price increase scenario if the fuel price is calculated based on the price of export fuel, the geothermal power plant is at a discount rate of 6%. In the scenario of applying a 1% increase in fuel prices, the cost of the geothermal power plant is at a discount rate of 6% and 8% lower than the steam power plants. Also, the geothermal power plant is more affordable compared to other renewable energy sources such as wind power.

Arash and Ghasemzade Khyabi (2015) examined the most common power generation systems in geothermal power plants. The financial appraisal of these power plants is done through effective factors in creating the cost of calculating the total investment cost and production cost and the effect of various parameters such as the capacity discount rate on production cost are examined and compared with steam power plant production cost fossil fuels.

In line with the implementation of Article 44 of the Constitutional of Iran, the reform of the economic structure and the participation of the private sector in infrastructure activities are known as important and effective acts. The requirements for implementing it in the country's electricity industry, are restriction to create a healthy environment for competition, privatization, optimal allocation of resources, improving the quality of services, and, consequently, increasing the general welfare, which the private sector, in addition to satisfying the profits, will have a position for investment in this sector. In this context, the government's FIT policy can be the main and most important means of attracting private sector investors to the electricity industry.

Wang et al. (2015) are studied four scenarios for feed-in-tariff for Photovoltaics (PV) power as residential electricity generators, and residential appliances. The results show that the FIT mechanism effective the electricity consumption.

Pita et al. (2015) review the impact of Adder and FIT policy on retail electricity price in Thailand. The results show that subsidy on FIT and adders will be about 48,873 and 53,416 million Baht respectively.

Kavadias et al. (2019) assessment the optimum sizing of a geothermal power plant and a solar field to cover the energy needs of an isolated island. The results show that the proposed operation can support energy with economic efficiency.

In Iran, since the beginning of the Renewable Energy FIT Policy, base purchasing prices for different renewable technologies have been the same (13.13 and 9.10 cents per kilowatt-hour, for peak hours and normal hours respectively). This base price is not attractive to the private sector investor and leads to the lack of their desire for investment. Over time, this has been considered by policymakers that the cost and investment of electricity generation vary from technology to technology, so the same purchasing prices cannot be set for different technologies. Because, the same FIT prices prevent the balanced development of various renewable technologies and lead the investments in more beneficial technologies, which hinders the development of other options. In recent years, FIT base prices have changed, due to the volume of investment, the price of energy conversion in the electricity market, the cost of saving fuel, and the cost of saving Emission, and annually announced by the high authority of the Ministry of Energy.

A review of research on the financial appraisal of renewable power plants such as wind, solar and geothermal shows that most research has focused on calculating the cost of electricity generation of renewable power plants and comparing it with the cost of other conventional power plants. Therefore, comparing the cost of electricity generation can only motivate the government to produce geothermal electricity, but from the point of view of the private sector investor, comparing the electricity market price with production costs is the criterion for choosing the type of electricity generation technology that currently has unrealistic electricity prices. Therefore, this study seeks to show scientifically whether the production of geothermal electricity in the Meshkinshahr area, assuming FIT policy, is economically justified or not.

3. Theoretical Background

3.1 Definition of Geothermal Power Plant

Geothermal energy is renewable energy that derives from the heat extracted from the hot melting masses and the destruction of the radioactive materials in the depths of the earth. Unlike other renewable energy sources such as the wind, sun, waves, etc., this source of energy is a continuous energy source and the electricity and heat can be produced uninterrupted, 24 hours a day. Most of the renewable resources are seasonal and time-dependent and are based on specific situations. Geothermal electricity refers to the generation of electrical energy from geothermal energy. Geothermal resources are usually used to generate baseload and only in certain circumstances they are used to generate peak load. There are several methods for converting geothermal energy into electricity, such as dry steam systems and instantaneous expansion vapor as old methods, as well as two-dimensional cycle systems and periodic separation as new technologies (Moghaddas Tafreshi, 2014).

3.2 Financial Appraisal and Decision

What attracts the attention of economists about the nature of the decision, is the quantitative values and goals of a decision. Economists have focused their attention on the activities of financial and economic markets, where there are many services and goods and are often valued by a measure of money. Using the most logical methods of decision making and choosing the most suitable options and solutions based on financial and economic criteria is one of the most important tasks of managers, engineers, and experts. The economics of engineering is a set of mathematical techniques to examine the economic justification of projects. Correct decision-making is the main task and responsibility of scientific research and financial appraisal techniques are guidelines for proper decision-making (Oskounejad, 1989). In this research, for economic decision-making, we used two indicators: uniform annual net value and internal return rate, which assess the economic justification of Mashkinshahr private geothermal power plant and identifies the justified economic conditions for the private sector investor.

3.2.1 Equivalent Uniform Annual Worth (EUAW)

Equivalent Uniform Annual Worth (EUAW) is Equivalent Uniform Annual Benefit (EUAB) minus Equivalent Uniform Annual Cost (EUAC). This economic indicator reflects the steady profitability of a project's investment over its useful life; so, the benefits and costs in each year, are converted into equivalent benefits and costs, with a discount rate after the transition to the base year. The difference in benefits and costs reflects the acceptance or rejection of the proposed economic plan. If the value is positive, this means that the equivalent uniform annual benefit is greater than the equivalent uniform annual cost, and the plan has an economic benefit, and vice versa if the value is negative, the equivalent uniform annual benefit is less than the equivalent uniform annual cost and the investor will bear losses (Newnan et al., 2004). In calculating the ratio of equivalent uniform annual benefit to equivalent uniform annual cost, it is also possible to accept or deny the economic plan. In this case, if the ratio of benefit to cost, exceeds 1, the plan has an economic benefit, and if the ratio of benefit to cost is less than 1, the investor will bear losses (**Error! Reference source not found.**). $\text{EUAW} = \text{EUAB} - \text{EUAC}$

$\text{EUAW} = \text{EUAB} - \text{EUAC}$

$$\text{EUAW} = \text{EUAB} - \text{EUAC} \qquad \text{Equivalent Uniform Annual Worth} \quad (1)$$

$$\frac{B}{C} = \frac{\text{EUAB}}{\text{EUAC}} \qquad \text{The Ratio of Benefit to cost} \quad (2)$$

$$\text{EUAW} \geq 0 \;\Leftrightarrow\; \frac{B}{C} \geq 0 \;\Rightarrow \text{EUAB} \geq \text{EUAC} \qquad \text{Project Acceptance} \quad (3)$$

$$\text{EUAW} \leq 0 \;\Leftrightarrow\; \frac{B}{C} \leq 0 \;\Rightarrow \text{EUAB} | \leq \text{EUAC} \qquad \text{Project Rejection} \quad (4)$$

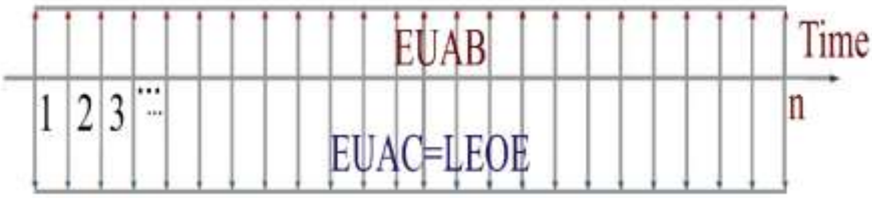

Figure 1. Equivalent Uniform Annual Worth (EUAW)= Equivalent Uniform Annual Benefit (EUAB)- Equivalent Uniform Annual Cost (EUAC)
***Source**: Research Calculations*

3.2.2 Internal Rate of Return Index (IRR)

The rate of discount, for which the equivalent uniform annual benefit and equivalent uniform annual cost are equal, is called the internal rate of return. The comparison of the internal rate of return with the Minimum Attractive Rate of Return (MARR) also determines the acceptance or rejection of the economic plan. If the investor's minimum rate is higher than the internal rate of return, the economic plan will be accepted and otherwise rejected (Gessinger, 2009).

$$EUAW(r\%) = 0 \Rightarrow EUAB(r\%) = EUAC(r\%) \Rightarrow r = i\% \quad IRR \tag{5}$$

$$MARR \geq IRR \quad \text{Project Acceptance} \tag{6}$$

$$MARR \leq IRR \quad \text{Project Rejection} \tag{7}$$

3.3 Equivalent Uniform Annual Cost (EUAC)

The economic assessment of private-sector electricity generation requires that FIT be combined with production costs. The costs of generating electricity from renewable sources are determined based on the technical-economical components of the power plant and the macroeconomic parameters. To this end, the use of the Levelized Cost of Electricity (LCOE) algorithm or the equivalent uniform annual cost of electricity is common in the world. The Levelized Cost of Electricity includes investment, repair and maintenance, fuel, and emissions costs. The output of Levelized Cost of Electricity algorithm is the final cost of electricity, which stays the same throughout the lifetime of a power plant. Levelized Cost of Electricity is calculated according to (9)-(13) equations (Mousavi et al., 2012).

EUAC (Equivalent Uniform Annual Cost)=LCOE (Levelized Cost of Electricity) (8)

$$LCOE = C_k + \left[\sum_{t=0}^{pL} \frac{C_{O\&M} \times (1+e_{O\&M})^t}{(1+r)^t} + \sum_{t=0}^{PL} \frac{C_{Fuel} \times (1+e_{Fuel})^t}{(1+r)^t} \right] \times \frac{r(1+r)^{PL}}{(1+r)^{PL} - 1} + C_{EC} \tag{9}$$

$$C_K = \frac{DR \times TPC(1+r)^{CL}}{HY \times CF} \tag{10}$$

$$C_{O\&M} = \frac{FOM}{HY \times CF} + VOM \tag{11}$$

$$C_{Fuel} = FC \times HR \quad (12)$$

$$C_{EC} = EF \times HR \times VED \quad (13)$$

According to (9), costs are transferred to the current year costs to calculate the current value of the project. Multiplying the current value of maintenance and repair costs variables and the cost of fuel with $\frac{r(1+r)^{PL}}{(1+r)^{PL}-1}$ factor converts them into an annual uniform cost.

In (13), the CEC represents the costs imposed to the community (the cost of external effects) by polluting gases. The emission factor shows the amount of emission in a fuel consumption unit. HR is the heat rate of power plants and VED represents the value emission damage. Emission factor (EF) and heat rate (HR) are physical values that can be calculated, while VED can be calculated by estimating direct costs or reducing costs or their composition. VED is an important parameter for analyzing the regulations, but it is difficult to calculate. The cost of external effects in the electricity unit produced is directly calculated by using these factors and entering them into the LCOE formula.

As seen above, LCOE can be determined based on the total cost of capital, repairs and maintenance, fuel costs, and external influences. Since LCOE is the criterion for measuring the cost of generating electricity over the life cycle of a power plant, then all costs should be included in the calculation of the final cost. To calculate the levelized cost, the technical-economic components of the power plant and the macro-economic parameters of the economy are needed.

Table 2 lists the variables used in the above equations.

Table 2. Definition of Levelized Cost of Electricity Equation Parameters

Parameter	Unit	Variable
Capital Cost	$/kwh	CK
Depreciation Rate	%	DR
Total Plant Cost	$/Kw	TPC
Construction Life	Year	CL
Discount Rate	%	R
Hours Per Year	Hours	HY
Capacity Factor	%	CF
Total O&M Cost	$/kWh	CO&M
Escalation Rate of O&M Cost	%	eo&m
Total Fixed O&M Cost	$/kwYear	FOM
Total Variable O&M Cost	$/kWh	VOM
Heat Rate	BTU/kWh	HR
Plant Life	Year	PL
Fuel Cost	$/MBTU	FC
Escalation Rate of Fuel Cost	%	eFUEL
avoiding emission cost	$/kWh	CEC
Value emission damage	$/gr	VED

Table 2 (Continued). Definition of Levelized Cost of Electricity Equation Parameters

Emission Cost	gr/BTU	EF
Levelized Cost of Electricity	$/kWh	LCOE

Source: *(Roth & Ambs, 2004) and (Mousavi et al., 2012)*

4. Materials and Methods

In the present study, for financial appraisal of Meshkinshahr Geothermal power plant, Equivalent Uniform Annual Worth (EUAW) is used, which is Equivalent Uniform Annual Benefit (EUAB) minus Equivalent Uniform Annual Cost (EUAC). Equivalent uniform annual benefits are provided from government FIT, and equivalent uniform annual costs are calculated using the LCOE algorithm. The levelized cost of electricity is the fixed rate of benefit that can cover all project costs over a service life per sales unit.

$$\mathrm{EUAW}(\$/\mathrm{KWh}) = \mathrm{Tariff}(\$/\mathrm{KWh}) - \mathrm{LCOE}(\$/\mathrm{KWh}) \quad (14)$$

Determining the sign of equivalent uniform annual worth (EUAW), according to (14), determines the economic justification of geothermal electricity from the perspective of the private sector. In this case, the amount of EUAW represents a steady gain in the lifetime of the project, which is achieved by the investor for one kilowatt-hour of electricity production. The ratio of benefits to electricity generation costs also determines the economic justification of geothermal power generation. In this case, the ratio of benefits to costs is compared to 1, if the result is greater than 1, it means that the FIT from geothermal electricity generation is more than the costs and vice versa.

$$B/C = \frac{\mathrm{Tariff}}{\mathrm{LCOE}} \quad (15)$$

Since private sector investors are taking steps in production to reach MARR, IRR calculation is important to determine the economic range of MARR. Equation (16) represents the economic range of MARR.

$$\mathrm{Tariff} = \mathrm{LCOE}(r\%) \Rightarrow r = \mathrm{IRR} \Rightarrow 0 \le \mathrm{MARR} \le \mathrm{IRR} \quad \text{Economic range of MAR} \quad (16)$$

The duration of the construction affects the investment cost and the levelized cost of electricity. According to (10), project postponement will exponentially increase the cost of investment. Therefore, it is important to determine the economic time of construction for a geothermal power plant. This importance is evident in (18) so that the sensitivity of the levelized electricity cost to the construction of the power plant is a function of the CL in the long run. Excel software has been used to ease the calculation of the economics of engineering and to determine the economic range for each of the parameters.

$$\mathrm{Tariff} = \mathrm{LCOE}(\mathrm{CL}) \Rightarrow \mathrm{CL} = \mathrm{cl} \Rightarrow 0 \le \mathrm{CL} \le \mathrm{cl} \qquad \text{Economic Range of CL} \quad (17)$$

$$\frac{\partial \mathrm{LCOE}}{\partial \mathrm{CL}} = C_k (1+r)^{\mathrm{CL}-1}$$

5. Empirical Results

To calculate the levelized cost of electricity, the technical-economical components of Meshkinshahr geothermal power plant and macroeconomic parameters are needed. The technical and economic data of Meshkinshahr geothermal power plant have been gathered from Office (2011), Tavanir (2013), and Office (2016). The macroeconomic data such as the discount rate and the fluctuations in the cost of maintenance and repairs are considered about the general inflation rate and economic conditions of the country in recent years and with the field information of economic analysts. The technical and economic components and macroeconomic parameters of Meshkinshahr geothermal power plant are presented in Table 3.

Table 3. Technical and Economic Specifications of Meshkinshahr Geothermal Power Plant

Technical-economic components	Unit	Geothermal
Primary Costs	$/KW	4100
Construction time	Year	4
Depreciation rate	%	3.3
Discount rate	%	14.5
Capacity factor	%	85
Lifetime	Year	30
Number of access hours	Hour	7446
Fixed repair and maintenance cost	$/KWY	84
Variable repair and maintenance cost	$/KWY	9.6
Fluctuations in the cost of repair and maintenance	%	2
Heat rate	Million BTU/KWH	0.009
Fuel cost (natural gas)	$/Million BTU	-
Fluctuations in fuel prices	%	-

Source: *(Office, 2011)*

The geothermal emissions indicator is derived from the Administration (2013) in Table 4. According to (13), this index is the result of the multiplication of emission factor (EF) with the heat rate of the power plant (HR). According to

Table 5, VED is based on World Bank (2009) on the power plants. Thus, the cost of external effects of the power plant is calculated.

Table 4. Greenhouse Gases (GHG) emissions in geothermal power plant (g / kWh)

Type of Greenhouse Gases	CH4	CO2	PM	SO2	NOx
Geothermal power plant	0.000	102.627	0.000	0.078	0.000

Source: *(Administration, 2013)*

Table 5. Damage cost of power plant (cents per gram)

Type of Greenhouse Gases	CH4	CO2	PM	SO2	NOx
Damage cost of power plant	0.0335	0.00161	0.6923	0.2936	0.0965

Source: *(World Bank, 2009)*

The FIT of renewable and clean power plant approved by the government in 2016 is presented in Table 6. The base FIT of a geothermal power plant is calculated at 490 Toman per kilowatt-hour.

Table 6. FIT Base Price for Renewable and Clean Power Plants

Renewable electricity	Description of the scope and framework	FIT Base Price (Toman/ kWh)
Biomass	Landfill	270
	Anaerobic digestion of animal and agricultural waste and sewage	350
	Waste burner and garbage gas-burner	370
Wind Farm	With more than 50 MW capacity	340
	With a capacity of 50 MW or less	420
Solar farm	With a capacity of over 30 MW	320
	With a capacity of 30 MW or less	400
	With a capacity of 10 MW or less	490
Geothermal	Includes drilling and equipment	490
Power generation from thermal waste recycling	In industrial processes	290
Small Hydro (with the capacity of 10 MW or less)	On the river and dam side accessories	210
	On water pipelines	150
Wind	With a capacity of 1 MW or less	570
Solar	With a capacity of 100 KW or less	700
	With a capacity of 20 KW or less	800

Source: *Research Calculations*

Since many equipment and facilities of the geothermal power plants are imported, the cost of production is based on the international currency (USD), and each USD is assumed to be on average 42,000 Rials[2].

[2] The currency previously allocated to the Ministry of Energy for the construction of a state-owned geothermal power plant in Meshkinshahr to import equipment including a turbine was 35,000 Rials, but Currently, the government allocates currency of 35,000 Rials to the private sector to set up renewable power plants due to providing the growing demand for electricity and staying committed to the 2015 Paris Agreement on "carbon dioxide reduction".

Table 7. Results of data analysis under economic indicators

Index	Unit	Meshkinshahr Geothermal Power Plant
LCOE	¢/KWh	5.2
Tariff	¢/KWh	14
EUAW	¢/KWh	8.8
B/C	-	2.69
IRR	%	53.9

Source: *Research Calculations*

The results of the data analysis show that the cost of the Maskinshahr Geothermal Power plant is 5.2 cents per kilowatt-hour at the level of global geothermal power plants. According to Table 7, EUAW and the ratio of benefits to costs (B/C) of Meshkinshahr geothermal power plant indicate that the construction of this power plant is completely economically justified from the standpoint of the private sector investor. The internal rate of return is 53.9%, which indicates that if MARR is less than that, then the construction of the power plant would be cost-effective.

Sensitivity analysis is a kind of review to an economic assessment. Sensitivity analysis is the repetition of the calculation of a financial process by changing the main parameters and comparing the results to the initial information. If a small change in a parameter causes a significant change in the results, it is said that the design is sensitive to that parameter and it is a sensitive parameter. In Fig 2, EUAW sensitivity to the discount rate is presented.

As seen in Fig 2, EUAW is negatively affected by values greater than 53.9%, which means that if MARR is greater than this, the plan is not economically justified.

The construction of a state-run geothermal power plant in Meshkinshahr region began in 2004 and will be exploited in 2018 due to lack of financing, according to the Minister of Energy. While experts from the New Energy Organization in Iran believe that the construction of this plant by financing will take maximum of 4 years. The CL is a sensitive component of the design, which has great importance when analyzing the sensitivity of EUAW to it. According to Fig 3, if like the government, the construction of Meshkinshahr geothermal power plant takes more than 13 years and 5 months, the generation of electricity from the perspective of the private sector investment is not economically justifiable.

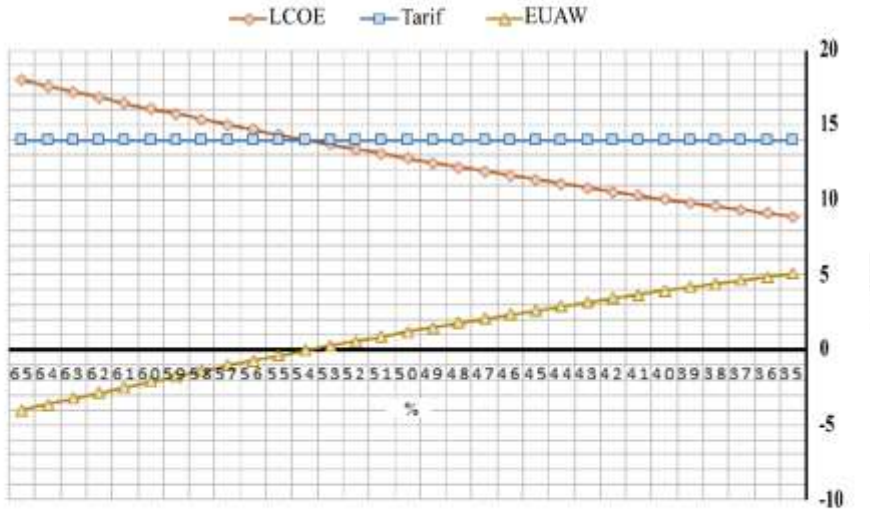

Figure 2. EUAW Sensitivity to the Discount Rate
Source: *Research Calculations*

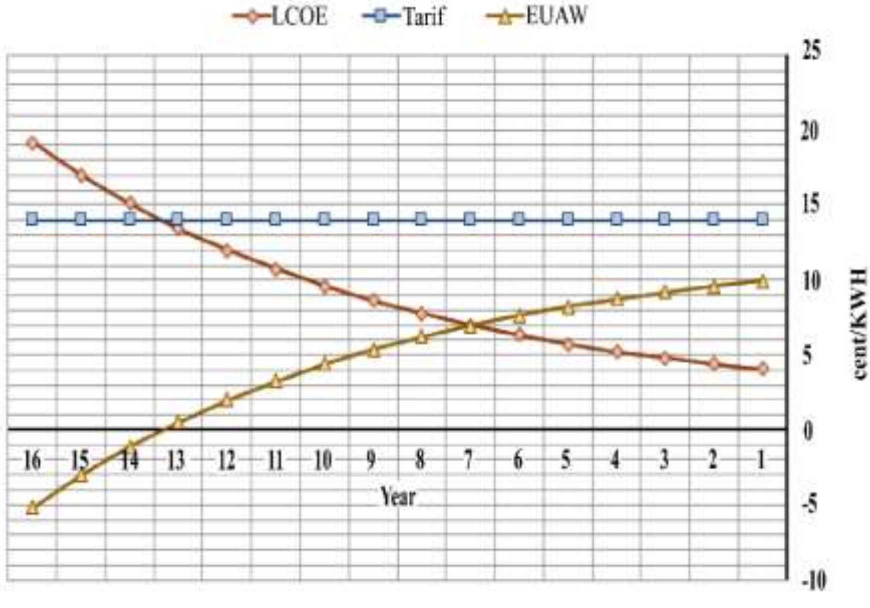

Figure 3. EUAW Sensitivity to the Construction Duration of Meshkinshahr Geothermal Power Plant
Source*: Research Calculations*

6. Concluding Remarks

Restructuring and privatization of the electricity industry are possible when the private sector is satisfied with the electricity generating benefit. In Iran, the Renewable Energy FIT Policy has been adopted in support of the private sector investor's entry into renewable energy production. In this regard, the Meshkinshahr area is one of the most susceptible areas in Iran, which can stimulate the private sector's investors in generating electricity by the assumption of FIT. A financial appraisal of Meshkinshahr geothermal power plant from the perspective of private sector investment, under the parameters of EUAW, the ratio of benefits to costs (B/C) and IRR shows that electricity production at the plant is quite economical and can satisfy MARR. Sensitive parameter sensitivity analysis shows that if the duration of the construction of the plant, like the government project, takes more than 13 years and 5 months, geothermal power generation is not cost-effective.

According to the results of this study, the cost of generating each kilowatt hour of geothermal electricity is associated with a lot of uncertainty and investing in geothermal power plants is very risky and requires serious government support.

References

Arash, A., & Ghasemzade Khyabi, G. (2015). Technical-economic evaluation of Meshginshahr geothermal power plants and their applications in environmental cycle National Conference on Technology. *Energy and Data with Electrical and Computer Engineering Approach, Kermanshah, https://civilica.com/doc/395962/.*

Barimani, M., & Ka'abi Nejadian, A. (2014). Renewable energy and sustainable development in Iran. *Renewable and Innovative Energies*, 1(1), 21-26.

Bolurian, A. H., Seyed Hosseini, S. M., & Jalali Majidi, M. (2015). Evaluation of economic aspects of geothermal energy in comparison with wind energy and other renewable energies for the construction of power plants. *The first National Conference on New and Clean Energy Management, Hamedan, https://www.civilica.com/Paper-ENERGYBON01-ENERGYBON01_024.html.*

El-Kordy, M., Badr, M., Abed, K., & Ibrahim, S. M. (2002). Economical evaluation of electricity generation considering externalities. *Renewable Energy*, 25(2), 317-328.

Elíasson, L., & Valdimarsson, P. (2005). Economic evaluation of power production from a geothermal reservoir. *Proceedings World Geothermal Congress, Antalya, Turkey*.

Fitzgerald, C. D. (2003). An economic evaluation of binary cycle geothermal electricity production.

Gessinger, G. H. (2009). *Materials and innovative product development: Using common sense*. Butterworth-Heinemann.

Hasan, M., & Wahjosudibjo, A. S. (2014). Feed-in tariff for Indonesia's geothermal energy development, current status and challenges'. *In Proceedings of Thirty-Ninth Workshop on Geothermal Reservoir Engineering Stanford University*, 24-26.

Khosravi, K. (1997). Economic-technical assessment of geothermal power plants. *12th International Power System Conference, Tehran. https://www.civilica.com/Paper-PSC12-PSC12_092.html.*

Kavadias, K. A., Alexopoulos, P., & Charis, G. (2019). Techno-economic evaluation of geothermal-solar power plant in Nisyros island in Greece. *Energy Procedia*, 159, 136-141.

Lin, W., Gu, A., Liu, B., & Wang, X. (2014). Emission trading scheme and feed-in tariff policy in China: alternative or integrated? *Energy Procedia*, 61, 1323-1326.

Moghaddas Tafreshi, S. M. (2014). *Sources of electricity generation in the 21st century*. K.N.Toosi University of Technology .

Motahari, S. A. A., Ahmadian, M., Abedi, Z., & Ghaffarzadeh, H. R. (2014). Economic evaluation of wind power development in Iran considering the effect of energy price liberalization policy. *Iranian Energy Economics*, 3(10), 179-200.

Mousavi, S. M., Ghanbarabadi, M. B., & Moghadam, N. B. (2012). The competitiveness of wind power compared to existing methods of electricity generation in Iran. *Energy Policy*, 42, 651-656.

Electricity and Energy Macroeconomic Planning Office (2011). *Planning the structure of the electricity supply and set up the required database*.

Electricity and Energy Macroeconomic Planning Office (2016). *The Energy balance sheet of 2014.*

Newnan, D. G., Eschenbach, T., & Lavelle, J. P. (2004). *Engineering economic analysis (Vol. 2)*. Oxford University Press.

Oskounejad, M. M. (1989). *Engineering economy or economic evaluation of industrial projects*. The Amirkabir University of Technology.

Pita, P., Tia, W., Suksuntornsiri, P., Limpitipanich, P., & Limmeechockchai, B. (2015). Assessment of feed-in tariff policy in Thailand: Impacts on national electricity prices. *Energy Procedia*, 79, 584-589.

Roth, I. F., & Ambs, L. L. (2004). Incorporating externalities into a full cost approach to electric power generation life-cycle costing. *Energy*, 29(12-15), 2125-2144.

Secretariat, R. (2019). *Renewables 2019 global status report*. Rep. Paris: REN21.

Sener, A. C., Van Dorp, J. R., & Keith, J. D. (2009). Perspectives on the economics of geothermal power. *GRC Trans*, 33, 29-36.

Taheri fard, A., & Shahab, M. (2010). Case study: Meshkinshahr geothermal power plant and study of technical-economic aspects of electricity. *Energy Economics*, (125), 31-39.

Tavanir. (2013). *Detailed statistics of Iran's electricity industry*.

Taylor, M., Daniel, K., Ilas, A., & So, E. Y. (2015). *Renewable power generation costs in 2014*. International Renewable Energy Agency: Masdar City, Abu Dhabi, UAE.

U.S. Energy Information Administration (EIA) (2013). *Annual energy outlook 2013*.

Van Kooten, G. C. (2013). *Economic analysis of feed-in tariffs for generating electricity from renewable energy sources*. In Handbook on Energy and Climate Change. Edward Elgar Publishing.

Wang, G., Zhang, Q., Tian, R., & Li, H. (2015). Combined impacts of RTP and FIT on optimal management for a residential micro-grid. *Energy Procedia*, 75, 1666-1672.

World Bank (2009). *Environmental cost evaluation for Iran power generation sector*.