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Potential Assessment of Based on Advantage in the Solar Power plants with Emphasis on FIT (Kerman)

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Abstract

Kerman province has an important advantage of solar energy due to the sun's rays in more than 300 days of the year, which can improve the province's position in the field of clean energy supply as well as attracting foreign investors. In this study, in order to identify, extract, weigh the criteria to measure the technical, spatial, economic, socio-environmental advantages and also to rank the cities of Kerman province using the Delphi, AHP and TOPSIS method. In the next step, simulation of the production capacity of domestic solar power plants has been done using PVSyst software. The results show that the cities of Baft and Rabor have the greatest advantage in generating electricity from the solar system.

Keywords: AHP method, TOPSIS method, Delphi method, Feed in Tariff, Spatial advantage, PVSyst Software.

1. Introduction

One of the most important national assets is the crude oil and natural gas reserves of each country, which unfortunately, their richness in Iran has led to irrational consumption patterns and environmental damage. Renewable energy sources have been considered in many countries to solve environmental problems. To this end, the production and consumption of renewable energy can be proposed as a national policy [1]. One of the most common policies used in the development of renewable energy is the Feed in Tariff (FIT) policy [2]. With average solar radiation of 5 kWh/m2/day, Iran has a high capacity to use solar energy. According to forecasts, by 2050, 34% of the world's total electricity consumption will come from renewable energy [3].

Kerman province, as one of the provinces of the country, has a high potential in solar energy due to its own geographical location and the abundance of sunny hours. Therefore, the study of solar radiation evaluation in this region is considered for potential applications of solar energy. The establishment of solar energy production systems in the province, especially in deprived areas, in order to generate income from energy sales, will create businesses related to solar energy and job creation [4].
Although solar energy is free, solar power generation equipment requires a large initial capital that cannot compete with fossil fuel power plants[5]. Therefore, according to the mentioned points, technical, economic, social and environmental evaluation of solar systems is a way forward for both the public and private sectors for optimal investment.

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2. Materials and Methods

In order to extract the criteria and sub-criteria, the Delphi method has been used and then to define the weighting, the Analytical Hierarchy Process (AHP) method has been used with the help of Expert Choice software. To obtain the economic and socio-environmental criteria, the following relationships and MATLAB software have been used. The technical and spatial sub-criteria have been calculated using PVSyst software.

2.1. Multiple Attribute Decision making

The TOPSIS model is one of the best multiple attribute decision-making models. In this method, m options are evaluated by n indicators and each issue can be considered as a Geometric system consisting of m points in n-dimensional space [6]. In this technique, the selected option should have the shortest distance with the ideal solution (a best possible solution) and the longest distance with the negative ideal (worst case scenario). It is assumed that the desirability of each person is uniformly increasing or decreasing. To solve the problem, the decision involves six steps [7]:

Convert the decision matrix to a non-scale (normal) matrix using the formula:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \quad (1)$$

1- Creating a scale less (normal) matrix Weights with the assumption that the vector is W which is obtained from the opinions of experts:

$$\text{the (weighted) normal matrix} = N_D.W_{n*n} \quad (2)$$

Here N_D is a matrix in which the scores of the indicators are normal and comparable and W_{n*n} is a diameter matrix whose only main diameter elements are non-zero. For the ideal option of A^+ and the negative ideal of A^- are used:

$$A^+ = \left\{\left(\max_i v_{ij} \middle| j \in J\right), \left(\min_i v_{ij} \middle| j \in J' \middle| i = 1,2,3,...,n\right)\right\} \quad (3)$$

$$A^- = \left\{\left(\max_i v_{ij} \middle| j \in J\right), \left(\min_i v_{ij} \middle| j \in J' \middle| i = 1,2,3,...,m\right)\right\} \quad (4)$$

2- Calculate the Separation Measure:

– Ideal Separation

$$S_i^+ = \sqrt{\sum_i^n (v_{ij} - v_j^+)^2} \quad i = 1,2,...,m \quad (5)$$

– Negative-Ideal Separation

$$S_i^- = \sqrt{\sum_i^n (v_{ij} - v_j^-)^2} \quad i = 1,2,...,n \quad (6)$$

3- Calculate the Relative Closeness to the Ideal Solution:

$$Cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})}; o \le Cl_{i+} \le 1; \quad i = 1,2,...,m \quad (7)$$

$$C_i^* = 1 \quad if \quad A_i = A^+$$

$$C_i^* = 1 \quad if \quad A_i = A^-$$

5- Rank the preference order

-A set of alternatives can now be preference ranked according to the descending order of C_i^*

2.2. Analytical Hierarchy process (AHP)

The method is used to calculate the Local priority. Local priority is obtained from the Taking pairs matrix, while Overall priority is the final rank of each option, which is calculated from the combination of Local priority. Here, too, the purpose of using AHP is simply to calculate the priority of the indicators [8].

To prioritize the components of an issue, the first step is to make a Taking pairs. The scale of the AHP is shown in Table.1 [9] .

Table 1.Process scale AHP [10]

Value	Comparison status
1	Equally Preferred
3	Moderately Preferred
5	Strongly Preferred
7	Strongly Preferred
9	Extremely Preferred
2.4.6.8	Between

When comparing the index a with b, one of the numbers in the table above is assigned to it, but in comparison b with a, the inverse value of that number is assigned. The results are recorded in a square column whose row and column are made up of indicators. Therefore, the weight of each index is [11]:

$$W_i = \frac{1}{\lambda} \sum_{j=1}^{n} a_{ij} w_j; i = 1,2,...,n \quad (8)$$

The above matrix can also be written as $A \times W = \lambda.W$; That A is the same as the matrix comparison pair and W is the weight vector and λ is a constant number. Consistency should also be calculated after Taking pairs. If the Consistency number is greater than 0.1, the Taking pairs matrix is inconsistent. If the Consistency number is 0, the Taking pairs matrix is exactly consistent and if equal 0/1 then is acceptable [12, 13].

2.3. Economic Evaluation

The goal of economic analysis of renewable projects is to allocate better resources to increase investment and develop renewable resources [14].Here, net present value (NPV), internal rate of return (IRR) and payment payback (PP) are used to assess the economic performance of home photovoltaic systems.

3. Results & Discussion

3.1. Identify the sub-criteria using the Delphi method

In the first step, using library studies and scientific resources in the field of solar energy, 4 main criteria and 15 sub-criteria have been extracted as indicators of measuring spatial, technical, economic, socio-environmental advantages. Table.2 introduces these criteria and sub-criteria. In the next step, the statistical population, including 7 people, was selected to use their opinions, which was extracted through a multivariate questionnaire of the most important criteria.

Table 2 . Introduction of criteria and sub-criteria

criteria	sub-criteria
Spatial advantage	Solar radiation, temperature, altitude, wind speed, humidity
Technical advantage	production rate
Economic advantage	NPV, IRR,PP, opportunity cost
Social advantage	Unemployment rate, household income, carbon dioxide emissions, water consumption, migration

In the first stage, 11 sub-criteria have an average above 3.5 and 4 sub-criteria have an average below 3.5, so these sub-criteria were removed. The Delphi technique for the remaining sub-criteria shows that all of the above sub-criteria had a mean grade above 3.5. Therefore, the Delphi technique was stopped and these sub-criteria were considered as the input of the AHP method.

3.2. AHP results for weighting the sub-criteria

Using AHP, the weight of all criteria and sub-criteria and prioritization of cities in Kerman province were determined based on the advantages provided in Table 2. The results are shown in Table.3. The results show that the economic advantage criterion has the highest weight among the other criteria. In the next rankings, respectively, are the criteria of spatial advantage, technical advantage, and finally the socio-environmental advantage.

Table 3. The final weight of the sub-criteria using AHP method

weight	criteria	Sub-criteria	weight	Final weight
0.268	Spatial advantage	Solar radiation	0.141	0.037788
		temperature	0.02	0.00536
		altitude	0.013	0.003484
0.08	Technical advantage	production rate	0134	0.1072
0.613	Economic advantage	NPV	0.232	0.142216
		IRR	0.265	0.162445
		PP	0.077	0.047201
0.04	Social advantage	Unemployment rate	0.05	0.002
		household income	0.045	0.0018
		carbon dioxide emissions	0.015	0.0006
		water consumption	0.007	0.00028

Source: The research results

The results of the calculation of the weight of the sub-criteria show that the sub-criterion for the amount of solar radiation has the highest weight in the criterion of spatial advantage. Also, among the sub-criteria of economic advantage, the sub-criterion of IRR has the highest weight. The unemployment rate sub-criterion has the highest weight in the socio-environmental advantage. The rest of the sub-criteria are listed in Table.3.

3.3. The results of the measurement of economic advantage sub-criteria by ranking TOPSIS method

The investment cost is 85 million Rial/kW, the maintenance and repair cost is 10% of the investment with a discount rate of 17% and taking into account the adjustment rate and FIT rate of 8000 Rial/kW over a period of 20 years. The results of the TOPSIS method for other sub-criteria are presented in Table.4.

Table 3. The results of the Topsis method for economic advantage sub-criteria

county	d+	d-	CI
Anar	0/008	0/017	0/657
Anbarabad	0/019	0/007	0/27
Baft	0/002	0/023	0/901
Bam	0/012	0/013	0/506
Bardsir	0/09	0/016	0/638
Fahraj	0/016	0/009	0/368
Faryab	0/012	0/013	0/508
Ghalehganj	0/021	0/004	0/187
Jiroft	0/013	0/012	0/492
Kahnooj	0/024	0/002	0/088
Kerman	0/009	0/016	0/632
Kouhbanan	0/008	0/017	0/659
Manoojān	0/026	0/001	0/062
Narmashir	0/014	0/011	0/433
Orzueeyeh	0/01	0/015	0/579
Rabor	0/001	0/025	0/94
Rafsanjan	0/013	0/012	0/477
Ravar	0/009	0/016	0/628
Rigan	0/022	0/003	0/142
Rudbar	0/024	0/002	0/074
Shahrbabak	0/008	0/017	0/688
Sirjan	0/018	0/007	0/277
Zarand	0/009	0/016	0/634

Source: The research results

The results of the calculation of economic advantage sub-criteria show that NPV is positive for all cities, most of which are related to the city of Rabor and the least related to the city of Manojan. The average IRR is 23% and the PP is 7 years & 9 months, depending on the discount rate.

3.4. The results of the measurement of technical advantage sub-criteria by ranking TOPSIS method

The annual production rate of the cities of Kerman province has been calculated as a sub-criterion of technical advantage using PvSyst software. In this simulation, a 5 kW polyclinic panel is used. The results show that the highest amount of production is related to Rabor and the lowest amount of production is related to Manoojān and this is while the average production in Kerman province is 9529 kWh. The results of the TOPSIS method for other sub-criteria of technical advantage are presented in Table.5.

Table 4. The results of the TOPSIS method for technical advantage sub-criteria

county	**d+**	**d-**	**CI**
Anar	0/00127	0/016	0/638
Anbarabad	0/018	0/007	0/277
Baft	0/00031	0/007	0/27
Bam	0/021	0/004	0/187
Bardsir	0/00135	0/009	0/368
Fahraj	0/024	0/002	0/074
Faryab	0/026	0/001	0/062
Ghalehganj	0/009	0/016	0/634
Jiroft	0/00182	0/025	0/94
Kahnooj	0/012	0/013	0/508
Kerman	0/00136	0/002	0/088
Kouhbanan	0/00126	0/013	0/506
Manoojān	0/014	0/011	0/433
Narmashir	0/009	0/016	0/628
Orzueeyeh	0/00156	0/017	0/659
Rabor	0/00002	0/017	0/657
Rafsanjan	0/013	0/012	0/477
Ravar	0/00138	0/016	0/632
Rigan	0/022	0/003	0/142
Rudbar	0/01	0/015	0/579
Shahrbabak	0/00116	0/023	0/901
Sirjan	0/008	0/017	0/688
Zarand	0/00135	0/012	0/492

Source: The research results

3.5. The results of the measurement of Spatial advantage sub-criteria by ranking TOPSIS method

The average amount of solar radiation in Kerman province is 2137 kWh per square meter, the average temperature is 21 degrees Celsius and the average altitude is 1201 meters. The results of this section are presented in Table.6.

Table 5. The results of the TOPSIS method for Spatial advantage sub-criteria

county	d+	d-	CI
Anar	0/008	0/017	0/657
Anbarabad	0/019	0/007	0/27
Baft	0/002	0/023	0/901
Bam	0/012	0/013	0/506
Bardsir	0/009	0/016	0/638
Fahraj	0/016	0/009	0/368
Faryab	0/012	0/013	0/508
Ghalehganj	0/021	0/004	0/187
Jiroft	0/013	0/012	0/492
Kahnooj	0/024	0/002	0/088
Kerman	0/009	0/016	0/632
Kouhbanan	0/008	0/017	0/659
Manoojān	0/026	0/0014	0/062
Narmashir	0/014	0/011	0/433
Orzueeyeh	0/01	0/015	0/579
Rabor	0/001	0/025	0/94
Rafsanjan	0/013	0/012	0/477
Ravar	0/009	0/016	0/628
Rigan	0/022	0/003	0/142
Rudbar	0/024	0/002	0/074
Shahrbabak	0/008	0/017	0/688
Sirjan	0/018	0/007	0/277
Zarand	0/009	0/016	0/634

Source: The research results

3.6. The results of the measurement of Social - Environmental advantage sub-criteria by ranking TOPSIS method

In order to generate electricity per kilowatt, about 4.16 liters of water is used in steam power plants and 1.13 liters of water is used in combined cycle power plants. Therefore, according to the amount of electricity consumption of each city from the power plants of the province, the total amount of water consumed has been estimated. On the other hand, for each kilowatt of electricity produced in steam power plants and combined cycle power plants, 900 grams and 425 grams of carbon dioxide gas are released, respectively. As a result, according to the amount of electricity consumption of each city from the power plants of the province, the total amount of carbon dioxide emitted for electricity generation has been obtained. The results show that the highest sub-criterion is related to carbon dioxide emissions and Kerman city with 891184.2324 tons has the highest and Rabor city with 10086.1398 tons has the lowest carbon emissions. In sub-criterion of water consumption, Kerman city with the amount of 8135008597 liters has the highest and Rabor city with the amount of 92069440.86 liters has the lowest water consumption. According to the unemployment rate sub-criterion, Faryab city with 16.57 has the highest unemployment rate and the lowest value is related to Fahraj city with 6.18.

Table 6. The results of the TOPSIS method for Social - Environmental advantage sub-criteria

county	**d+**	**d-**	**CI**
Anar	0/009	0/016	0/638
Anbarabad	0/018	0/007	0/277
Baft	0/019	0/007	0/27
Bam	0/021	0/004	0/187
Bardsir	0/016	0/009	0/368
Fahraj	0/024	0/002	0/074
Faryab	0/026	0/0014	0/062
Ghalehganj	0/009	0/016	0/634
Jiroft	0/001	0/025	0/94
Kahnooj	0/012	0/013	0/508
Kerman	0/024	0/002	0/088
Kouhbanan	0/012	0/013	0/506
Manoojān	0/014	0/011	0/433
Narmashir	0/009	0/016	0/628
Orzueeyeh	0/008	0/017	0/659
Rabor	0/00002	0/017	0/657
Rafsanjan	0/013	0/012	0/477
Ravar	0/009	0/016	0/632
Rigan	0/022	0/003	0/142
Rudbar	0/01	0/015	0/579
Shahrbabak	0/002	0/023	0/901
Sirjan	0/008	0/017	0/688
Zarand	0/013	0/012	0/492

Source: The research results

The highest value of household income sub-criterion is related to Ravar city with 156 number and the lowest value is related to Rudbar city with 75.6 number. The results for other cities are presented in Table.7.

3.7. Illustration of ranking results

In order to illustrate the results on the map of Kerman province, the cities have been classified according to the formula k = √n (n is the sample size) [15]. In Figure 1, cities are categorized by technical advantage. As can be seen, the city of Baft and Rabor have the most advantage.

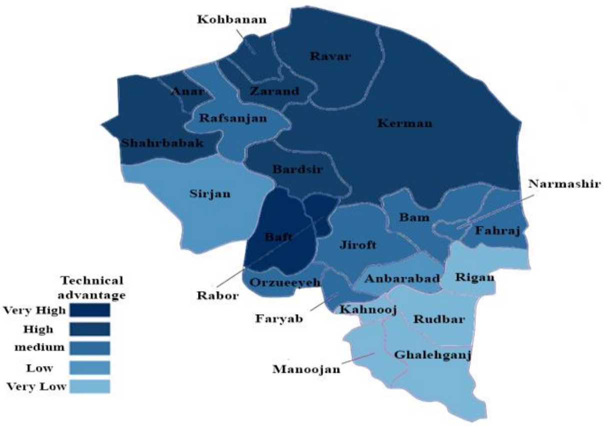

Figure 1: Category of cities based on technical advantage

Figure 2 show the cities are categorized by Economic advantage.

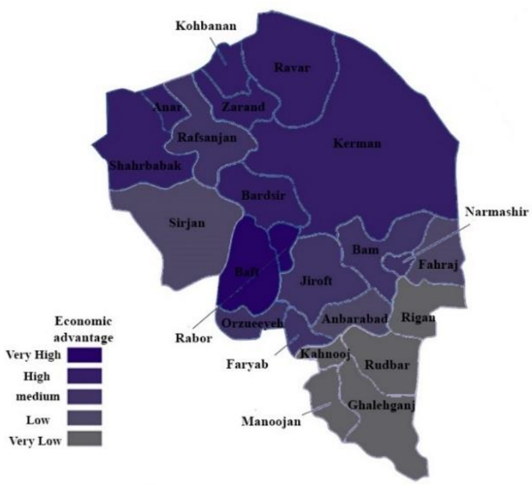

Figure 2: Category of cities based on economic Advantage

As can be seen, the cities of Rigan, Kahnooj, Rodbar, Manoojan and Ghaleganj have the least economic advantage. The classification of cities is shown in Figure 3 based on the socio-environmental advantage.

Figure 3: Category of cities based on Social-Environmental advantage

As can be seen, the lowest advantage is only related to the city of Rabor. In Figure 4, cities are categorized based on spatial advantage.

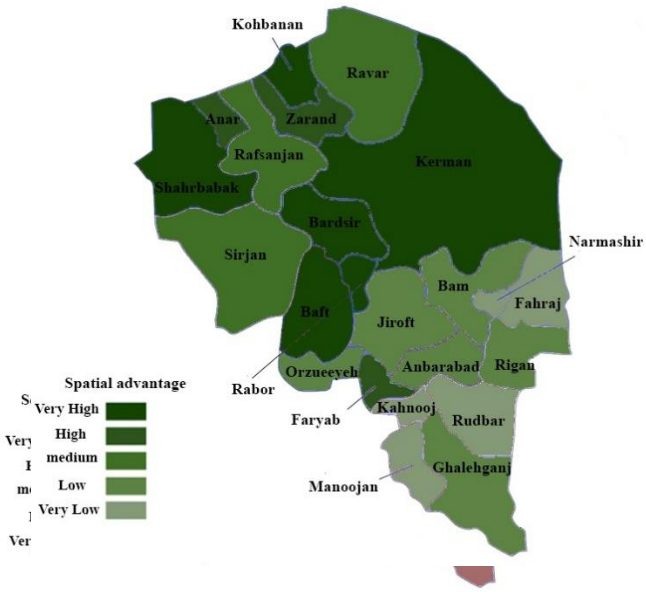

Figure 4. Category of cities based on Spatial advantage

Based on spatial advantage, the number of cities with high advantage increases compared to previous advantages.

4. Conclusion

The classification of the cities of the province based on the combined advantage shows that the cities of Rabor and Baft have a higher potential than other cities of Kerman province in terms of all 4 spatial, technical, economic and socio-environmental advantages, so as the best place to build solar power plants 5 KW is recommended, also due to their high competitiveness, it is the best place in Kerman province to export solar energy.

In order to achieve the goals of sustainable development, especially poverty alleviation, one of the policies proposed to the government in deprived and less developed areas is to use a guaranteed floating purchase rate. Since the potential for solar power generation is also different in all areas in terms of location, technical, economic, and socio-environmental, it is recommended that the guaranteed purchase rate be different. In other words, in areas with lower energy efficiency, the government has bought electricity at a higher rate so that investment in these areas is profitable. It is suggested that domestic equipment be used in the construction of solar power plants so that by law, the government can purchase up to 30% more electricity.

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