A Fuzzy DANP Approach to Identifying and Ranking Factors Influencing Location of Renewable Energy Farms

Abstract

Energy consumption, much higher than the global average in developing countries, witnessed a growing and alarming trend in past years. An accepted reality for human communities is that the world's energy demand is hastily increasing, and cheap fossil energy resources will gradually, yet certainly, be exhausted in future decades. To conserve these worthy fossil resources for future generations, prevent environmental damages due to burning these fuels, and respond to the increasing demand for energy, humans should use clean and renewable energies and discover proper locations to generate renewable energies. Today, locating studies prevail to determine the sites of renewable energy farms and reach industrial development. These studies consider various criteria to select the best location for establishing renewable energy farms. The present research attempted to identify and rank factors influencing the location of renewable energy farms using the fuzzy DANP approach.

Keywords: Energy, Renewable Energy, Location, Renewable Energy Farms, Fuzzy DANP

1. Introduction

Technological development and industrial expansion have led to the overuse of fossil fuels. Since the vital pillars of society rely on energy, life without energy is admittedly hard and sometimes impossible for humans (Rashidzadeh et al., 2012). On the other hand, considering the increasing growth of population in the world, energy has become more contributory and oriented humans to employ renewable energies. Fossil fuels, initially as mere energy sources utilized by humans, are exhausting fast, and due to their exhaustibility and contamination, renewable energies are highly privileged. Thus, the current generation should turn to energy sources with long lifetimes and high power and raise their knowledge of their exploitation (Shams et al., 2016).

Renewable energies include diverse resources originating from natural and accessible energies. They reduce the consumption of oil products, create jobs, and decrease environmental pollution. Like other developed countries, using these energies in Iran is drastically significant, such that the government has embarked on the necessary planning in the 5th development program. Thus, developing these energies in Iran to solve these problems and create jobs will be inevitable with respect to global policies (Fakhr Al-Dini et al., 2017).

Owing to the developmental requirements of countries, renewable energies are extensively employed in the world's countries, such that energy consumption is one of the indices of development. According to the plans, this type of energy increasingly contributes to energy supply systems. In this regard, over $120 billion was invested in enhancing capacities, establishing power plants, and engaging in renewable energy R&D projects in 2008. The available capacities of renewable energies had a 3.8% contribution to global electricity production in late 2010 (these figures exclude hydropower since this energy can generate 15 % of the world's electricity by itself). At present, renewable energies supply more than 14% of the world's primary energy. However, they have a negligible contribution in Iran and are an alarm for the country regarding the consumption of fossil fuels (Yousefi et al., 2016).

It seems that three main factors increase market orientation to renewable energies, with the national energy security as the first. Investigations reveal that oil consumption has increased and will soon exceed high domestic production. It will make advanced countries more dependent on oil markets and the economy of Western countries vulnerable to any disorder in oil imports. The fast growth of developing countries imposes incremental pressure on the world's oil markets, such that conditions will worsen and deteriorate over time. Yet, renewable energies will help Western countries rely on domestic energy sources, need fossil fuels less, and slow down consumption (Yousefi et al., 2016).

Nonetheless, it is better to operationalize discussions on the significance of renewable energies. The detrimental impacts of fossil fuels, e.g., meteorological warming and contamination, greenhouse gases, acid rains, and the emission of polluting gases and their consequences, have transformed into a new challenge for humans. Of course, some of these damages stem from the methods used for utilizing these energies. Renewable energies are cost-free and inherently adaptable to the environment, on the one hand, and steer consumption to new energies, on the other hand. Now, since the peripheral environment is the source of these new energies, it is indispensable to discover appropriate locations to establish and exploit renewable energy farms and look for other locations with respect to the certain characteristics of these locations (Yousefi et al., 2016).

2. Research background

Domestic studies

- **Dashti et al. (2021)** investigated and determined influential criteria in locating different types of power plants. The criteria were categorized into three groups based on their performance: Technical-environmental, economic-social, and environmental constraints. Generally, all criteria and sub-criteria were associated with locating different power plants (steam, gas, combined cycle, nuclear, hydropower, pumped storage, wave, tidal, wind, solar, geothermal, biomass, diesel, and magneto-hydrodynamic). Finally, the characteristics of a power plant were outlined according to some criteria, e.g., the energy source of power plants, the usability and accessibility of the source, cost, desirable or undesirable impacts on the human environment, and generation power.
- **Pourfayaz et al. (2020)** embarked on locating and assessing wind energy to establish wind farms in Fars province. They employed a Multiple Criteria Decision-Making Support system to measure the potential of wind energy in Fars province in the south of Iran and assessed suitable locations for constructing a wind power plant. The paramount barrier to the extensive development of renewable energies in Iran was the price of fossil fuels, being the lowest in the world. The government has recently decided to eliminate fossil fuel subsidies, implying that their prices will elevate and renewable energies will become more attractive. The first step of this study employed the Geographic Information System (GIS) to locate wind energy in Fars Province and explained the Multiple-Criteria Decision-Making (MCDM) method and the criterion for selecting suitable locations for the examined region. The decision criteria were categorized into technical-economic and environmental-geographic groups. The technical-economic criteria involved wind velocity, distance from power transmission lines, distance from link roads, and steepness. Likewise, the second group included geographic and environmental phenomena, e.g., rivers, protected areas, faults, and residential regions. First, unsuitable regions were eliminated by the constraint method, and the remaining regions were ranked into four groups by the multiple criteria AHP decision method and the weighting of every criterion. According to the evaluation of the outcomes, the north and northwest of the province were the most suitable regions for constructing a wind power plant.
- **Nissani et al. (2019)** evaluated suitable locations for solar farms in East Azerbaijan Province using GIS data and MCDM methods. These researchers could identify suitable locations for establishing a solar power plant in East Azerbaijan using GIS data and the fuzzy AHP technique as one of the MCDM methods. According to the results, highly suitable, desirably suitable, and moderately suitable lands covered 6.60%, 18.31%, and 27.10% of the province area for installing a solar power plant. However, 47.99% of the lands in the province lacked the necessary utility to construct a solar power plant. The west and southwest of the province were generally the maximally suitable regions, and the north and northeast were the minimally suitable areas for installing a solar power plant. Furthermore, the sensitive analysis of the

obtained weights from the fuzzy AHP method revealed that the GHI and PVOUT criteria were highly significant in determining suitable regions for exploiting solar energy.

Foreign studies

- **Geovanna et al. (2022)** examined the location of photovoltaic farms using GIS systems with MCDM methods and considering energy regulations in Ecuador. They sought to discover suitable sites for installing photovoltaic solar farms based on the energy regulation of Ecuador by combining GIS data with MCDM techniques. Thus, they employed nine factors and four constraints for their analysis and weighted the factors by the AHP method. After weighting, seven MCDMs were used to select sites with solar potential. The seven results were examined by the Pearson correlation coefficient before the absolute error analysis. The Pearson coefficient reflected methods with high correlation and numerous pixels with similar values independent of geographic situations. Considering the results, Luzha and some areas of the central provinces of the country's north (Pichincha, Santo Domingo de Los, Tsáchilas, and Cotopaxi) were the most suitable for cooling solar panels due to their temperature, global solar radiation, and wind velocity.
- Montusiewicz et al. (2022) examined optimal locations for wind farms. At present, wind energy pioneers renewable energies. One of the many advantages of developing renewable energy resources is their trivial harm to the environment. Yet, some barriers to installing wind power plants should be overcome. One of the steps to constructing a wind turbine is to design its fit location, which is a complex process necessitating an analysis of some criteria that are often hard to compare and even contradictory. This paper employed multiple criteria optimization methods to explain the concept of locating wind farms.
- **Pradas et al. (2020)** embarked on a locating, feasibility, and territory analysis for the sustainable development of solar photovoltaic energy using GIS bases. They combined legal, political, and environmental criteria, including solar radiation intensity, local geophysics, environment, and climate, as well as location criteria, e.g., distances from roads and the nearest power substations. In addition, the GIS data (solar radiation time series, Digital Elevation Models (DEMs), land cover, and temperature) were utilized as the input parameters. Every site was assessed separately by a distinctive and integrated approach for the selection of the fittest locations for developing solar farms in Valencia, a Spanish region in the east of Spain.
- **Gašparovi´ et al. (2021)** investigated the optimal locations of solar power plants based on GIS and remoting sensing methods in Croatia. This research employed climatic, spatial, environmental, and geomorphological parameters and considered socioeconomic factors, population, unemployment, and the number of tourist nights and electricity consumption. Rasters of all parameters were developed by the spatial analysis and Grass GIS software. The analytic hierarchy process was used to assign the calculated rasters with weight coefficients, and the sum of all those rasters displayed the final result of optimal locations for the construction of solar power plants in Croatia. Sensitivity analysis with different weight coefficients of the parameters was used to test the accuracy of the results. The sensitivity analysis outcomes, histogram, and statistical indicators of the three rasters illuminated that the F1 raster rendered the best results. The strongest parameters in determining optimal locations of solar power plants were GHI, land cover, and distance to the electricity network.
- **Lind et al. (2020)** examined the optimal locations of renewable energies. They displayed that with mandatory electricity transmission constraints, feed-in premiums should differ across locations. They employed a numerical energy system model (TIMES) to investigate the potential welfare cost of a non-coordinated development of grids and wind power production capacity in the energy system of Norway. Their results indicated that grid investment costs could be considerably higher when the location decisions were based on uniform feed-in premiums compared to geographically different premiums. However, the difference in the sum of the grid

investment and production costs was extensively low since locations based on uniform feed-in premiums enhanced capacity in regions with better wind conditions.

- **Lígia et al. (2021)** explained the social acceptance of renewable energies through location-related factors in Portugal and analyzed the public perceptions of renewable energies based on objective location-related factors. Personal location-related factors can originate in the involvement of individuals with renewable energy sources. Regional location-related factors reflect the significance of renewable energy sources in the residential district relative to other renewable energies. The researchers implemented a questionnaire concerning the public perceptions of renewable energy sources by the general population in mainland Portugal and completed respondent-level responses with renewable energy district data. Regression analysis displayed that the objective location-related factors, both personal and regional, helped explain public perceptions of renewable energies. Hence, they found empirical support for the proposed approach. Their results can inform and direct policy-makers in addressing future social acceptance issues of renewable energy policies toward lower carbon emissions and less contaminating energy generation.
- **Almutari et al. (2021)** attempted to determine suitable locations for developing renewable hydrogen using MCDM methods. The purpose was to employ MCDM approaches to find the best location for producing hydrogen from wind energy. The criteria were weighted by the Stepwise Weight Assessment Ratio Analysis (SWARA). The most significant criteria were the average wind velocity, number of regional refineries, and wind power density with 0.2780, 25.70, and 0.1570 values. Then, the Weighted Aggregated Sum Product Assessment (WASPAS) method was used to rank the locations. Finally, three other techniques, i.e., Evaluation Based on Distance from Average Solution (EDAS), Complex Proportional Assessment (COPRAS), and Weighted Sum Model (WSM), were employed for result validation. The eastern province of Saudi Arabia was known as the best location for hydrogen development in this country. With a nominal capacity of 900kW, this province was predicted to generate 1863MWh energy and 30.16 tons of hydrogen per year.
- **Obadia et al. (2020)** investigated energies in potential renewable energy farms in Tanzania for sustainable development. Developing renewable energies is now emphasized for sustainable development. To attain sustainable development objectives at a global level, Tanzania, like other developing countries, attempts to adopt different approaches to ensuring cost-effectiveness and accessibility to supply energy to its political and socioeconomic sectors and develop renewable energies. To supply cost-effective and accessible energy, renewable energies are substituted as alternative energy sources due to being environmentally friendly. Renewables will help remove energy problems in Tanzania if produced and utilized in a sustainable and modern way. Hence, this research attempted to obtain sustainability, select suitable locations for renewable energy farms in Tanzania, and examine the challenges of renewable energy development.
- **Ghiani et al. (2020)** explored the effect of renewable energy resources and energy storage technologies on smart distribution grid planning. Renewable Energy Sources (RES) become increasingly significant in distribution systems, and it is predicted that they will play paramount roles in the near future. Indeed, new generations of power plants are annually connected to distribution grids and can, seemingly, no longer be regarded as negative connection loads. (فراموشی؟؟). Connection to power distribution networks with the increasing number and capacity of RES installations means overcoming several technical challenges ahead of distribution network operators, though it is assumed that RES systems engender problems for power systems. This chapter presents an exact outlook of the effects of RES and energy storage technologies on future distribution networks, considering their planning, management, and exploitation.
- **Duncan et al. (2021)** examined the location, variable values of renewable energies, and demand-side efficiency of resources.

3. Theoretical foundations

3.1. Renewable energies

Renewables are useful energies originating from renewable resources and are naturally replaced on a human-temporal scale, e.g., carbon-neutral resources with zero carbon emissions, such as sunlight, wind, rain, tides, waves, and geologic warming. This term usually encompasses biomass, which is discussed for its neutral carbon state. This type of energy source lies opposite to fossil fuels, with consumption rates much faster than their renewal. Wind, sunlight, and hydropower are three sources of renewables that often supply energy for four chief domains: power, air and water heating and cooling, transportation, and rural energy services (off-grid) (Sheikh Aghaei).

According to the report of REN21 (2017), renewable energies contributed to 19.3% and 24.5% of humans' global energy consumption and power generation in 2015 and 2016. In this respect, traditional biomass, thermal energy (modern biomass, geological, and solar heat), and hydropower had 8.9%, 4.2%, and 3.9% shares in this energy consumption. Besides, 2.2% of energy was generated by wind, the sun, geologic sources, and other forms of biomass. Global investment in renewable energies exceeded $286 billion in 2015 and amounted to $179.8 billion in 2017. China allocated 45% of the global investment to itself. Likewise, the United States and Europe invested $40.5 and $40.9 billion in renewable energies. Globally, 10.5 million jobs are associated with renewable energy industries, wherein solar photovoltaic is the biggest employer. Renewable energy systems become more efficient and cheaper quickly, and their contribution to the total consumed energy is growing. Over two-thirds of the newly installed electricity capacity all over the world was of a renewable type in 2019. The growing consumption of coal and oil may terminate until 2020 due to the increasing application of renewable energies and natural gas (Movagati et al., 2013).

Table 1. Types of renewable energies

Energy source	Energy conversion and application method
Fluid power	Power conversion
Modern biomass	Power generation and heat, pyrolysis, and gas conversion, absorption, and digestion processes
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Home solar systems, solar dryers, solar cookers
Direct sunlight	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generator, water pumps, windmill
Wave	Various designs
Tide	Dam construction, tidal flows

Source: Naji et al. (2017)

2.2. Significance of using renewable energies

Today, attaining energy resources that are suitable alternatives to fossil fuels and environmentally friendly and can supply domestic demand for electric, thermal, and transportation energies is a significant issue with which collective thought of different countries is involved and a paramount reason for attending to new energies in the country (Shams et al., 2016).

1) The significance of diversity in energy resources and surge of energy security

Access to energy is one of the main components of national security in every country, and any arising problem imports extensive damage to its different sectors. An investigation shows that an outage of 1kWh will bring an $8 destruction to the national economy, while the supply cost is just 8 cents. Thus, it is one of the primary strategies for diversifying resources and not depending on one or two fuel types (John et al., 2017).

2) Limitations for using fossil fuel resources while protecting them

Using the energies of renewable power plants enables conserving fossil fuels and protecting them for future generations.

3) Creating business opportunities and new jobs

Many technologies linked to renewables experience their incipient phases of technology development. Therefore, our country can cater to some of its energy demand and contribute as a primary producer of the region using the internal potential (Sheikh Aghaei, 2014).

4) Creating jobs and developing remote regions

Developing fossil power plants creates more job opportunities compared to conventional power plants. Besides, considering the dispersion of the resources, renewable power plants can easily penetrate remote areas and prevent the migration of villagers to cities.

5) Solving the problem of urban wastes

Promoting the strategic position in energy diplomacy in the international environment

2.4. Determining ecologic power to find locations for constructing renewable energy farms

Optimally and principally exploiting the natural resources of lands and organizing their use based on their ecologic capacity play significant roles in managing the environment, preventing environmental destruction, and attaining sustainable development. Ecologic capacity assessment is one of the approaches to determining the optimal land uses. For this purpose, environmental units are first mapped by the integration of elevation class maps, slope, slope direction, soil, and vegetation cover. Second, the capacity of different uses is evaluated by the systemic analysis of sustainable and unsustainable ecologic factors of lands. GIS systems are employed to map the environmental units of watersheds. After the maps are integrated and updated through the comparison of mathematical models, the ecologic capacity of land uses, e.g., agriculture, pasturing, forestry, urban and rural development, centralized and extensive recreation, aquaculture, and environmental unit conservation, is assessed and classified. Afterward, the uses are ranked for the selection of the best alternatives in land units and the organization of uses, and the class map of use capacity is prepared. The best location is selected by the comparison of the use criteria if the purpose is to determine suitable sites for constructing power plants and renewable energy farms (Sheikh Aghaei, 2014).

4. Research method

Fuzzy DANP combines the fuzzy DEMATEL technique with the Analytical Network Process (ANP) and provides examined participants’ opinions to obtain the indices of relationships. Fuzzy DANP can be employed to develop a fuzzy weight supermatrix indicating the rate of penetration into relationships. In these types of studies, researchers collect case data and determine requisite indices via questionnaires after developing models. They then analyze the data by the fuzzy DANP-MCDM technique and rank effective factors in locating renewable energy farms.

4.1. Data collection tools and approaches

The below approaches were used for data collection:

- Library studies: Library sources, papers, books, and the global information network were used to collect data on theoretical foundations and respective research literature.
- Field studies: Domestic and foreign studies were extensively investigated for the identification and extraction of effective criteria and factors in locating renewable energy farms.

4.2. Topical, temporal, and spatial scopes of the research

Temporal scope: This research was conducted in September 2022.

Topical scope: Identifying and ranking effective factors in locating renewable energy farms by the fuzzy DANP method

Spatial scope: This research was implemented in the Renewable Energies and Energy Efficiency Organization.

4.3. Introducing the research population and sample

The examined population consisted of all individuals with expert knowledge of renewable energies and energy efficiency in Tehran province.

Sample size: A total of 200 renewable energy experts and specialists in Tehran province participated in the study.

Sampling method: A non-randomized (purposeful-judgmental) method was used for sampling since the number of experts was finite for questionnaire completion due to several factors, e.g., the specialty of the questions and the researcher's prior familiarity with these individuals. The sample size was determined by Cochran's formula. Thus, 132 individuals were selected as samples, considering the number of the statistical population.

$$n=\frac{\frac{Z^2 pq}{d^2}}{1+\frac{1}{N}\left(\frac{Z^2 pq}{d^2}-1\right)}$$

Where N is the size of the population, p indicates the ratio of individuals with the examined trait, and q stands for the percentage of individuals lacking the examined trait. It is worth noting that if p and q values are not defined, the maximum values, i.e., 0.5, are used. Besides, z equals 1.96 at the error level of 5% (z = t), and Z^2 equals 3.8416.

The d-value indicates the difference between the real proportion of the trait in the population and the researcher's estimation of the presence of that trait. Sampling precision depends on this factor, and the maximum value of d, i.e., 0.05, should be utilized for a sampling with the highest accuracy.

4.4. Data analysis

The data were analyzed by the fuzzy ANP and DEMATL MCDM techniques.

4.4.1. Fuzzy DANP

Fuzzy DENP is an MCDM technique combining DETAMEL and ANP methods. To mix DEMATEL with ANP, we conventionally obtain the complete relationships matrix of fuzzy DEMATEL and attain the model network using threshold values and omitting some insignificant relationships. We then insert this network into the fuzzy ANP to acquire the weights of criteria and sub-criteria. This approach usually zeros weights in the ANP supermatrix. In this technique, we proceed until the complete relationships matrix of fuzzy DEMATEL develops and, then, obtain the final weights of the indices by implementing fuzzy DANP steps.

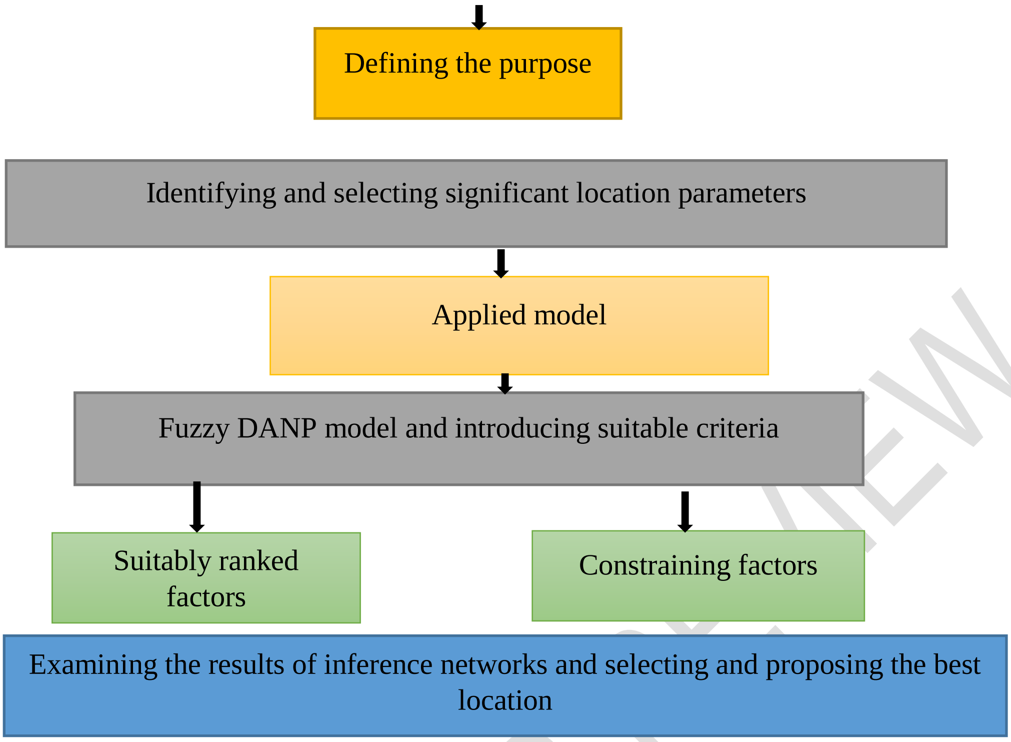

Figure 1. Data collection, preparation, and implementation phases of research

Source: The researcher (2022)

4.4.2. Effective criteria and components in locating renewable energy farms

Table 2. Effective indices in locating renewable energy farms

Main index	Sub-indices	Symbol
Physical factors	Earth form	EF
	Soil and earth	SE
Biological factor	Vegetation and land use	VE
	Water range	WR
	Environmental range	ER
	Population range	PR
Social and economic factors	Communication ways	CW
Technical factors	Power transmission	PW
	Energy Capture	EC
Infrastructures	Special Facilities	FS
	Power Units	PU

Data analysis and results

1.1.1. Initial decision matrix

The initial decision matrix is extracted from the simple average of all individuals’ opinions. The initial, normalized, and complete relationships matrix of the indices are displayed in Tables 3,4 and 5.

Table 3. Initial decision matrix of indices

		EF	SE	VE	WR	ER	PR	CW	PW	EC	FS	PU
	EF	0	0.55	0.68	0.65	0.55	0.35	0.65	0.55	0.65	0.75	0.85
	SE	0.63	0	0.55	0.75	0.45	0.35	0.62	0.35	0.45	0.60	0.75
	VE	0.86	0.65	0	0.36	0.55	0.45	0.55	0.65	0.55	0.55	0.65
	WR	0.68	0.34	0.55	0	0.62	0.55	0.45	0.65	0.55	0.45	0.75
	ER	0.7	0.55	0.46	0.44	0	0.55	0.42	0.75	0.45	0.55	0.65
	PR	0.59	0.86	0.81	0.65	0.20	0	0.40	0.40	0.35	0.65	0.85
	CW	0.94	0.66	0.45	0.65	0.45	0.65	0	0.22	0.35	0.65	0.55
	PW	0.69	0.56	0.55	0.55	0.75	0.35	0.65	0	0.25	0.45	0.65
	EC	0.85	0.65	0.65	0.45	0.55	0.45	0.55	0.45	0	0.65	0.75
	FS	0.59	0.46	0.35	0.35	0.55	0.75	0.45	0.35	0.45	0	0.85
	PU	0.85	0.75	0.85	0.65	0.85	0.55	0.65	0.75	0.65	0.75	0

Table 4. Normalized decision matrix of indices

	EF	SE	VE	WR	ER	PR	CW	PW	EC	FS	PU
EF	0	0.5	0.6	0.6	0.4	0.3	0.4	0.5	0.6	0.7	0.8
SE	0.6	0	0.5	0.7	0.5	0.3	0.4	0.4	0.5	0.7	0.6
VE	0.8	0.8	0	0.4	0.6	0.4	0.5	0.6	0.6	0.5	0.6
WR	0.6	0.3	0.6	0	0.6	0.5	0.4	0.6	0.6	0.6	0.7
ER	0.6	0.7	0.5	0.6	0	0.5	0.3	0.7	0.5	0.6	0.6
PR	0.6	0.9	0.8	0.6	0.1	0	0.5	0.5	0.4	0.6	0.8
CW	0.9	0.6	0.6	0.2	0.5	0.6	0	0.3	0.6	0.6	0.5
PW	0.6	0.5	0.8	0.7	0.8	0.3	0.6	0	0.3	0.4	0.6
EC	0.8	0.6	0.5	0.6	0.7	0.4	0.5	0.4	0	0.6	0.7
FS	0.4	0.4	0.3	0.5	0.7	0.6	0.4	0.3	0.4	0	0.8
PU	0.9	0.8	0.7	0.5	0.9	0.4	0.6	0.7	0.6	0.7	0

Table 5. Complete relationships matrix

	EF	SE	VE	WR	ER	PR	CW	PW	EC	FS	PU
EF	0	0.097	0.095	0.093	0.093	0.094	0.085	0.093	0.094	0.095	0.094
SE	0.000	0	0.000	0.000	0.000	0.000	0.000	0.093	0.000	0.095	0.093
VE	0.000	0.000	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WR	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ER	0.092	0.090	0.095	0.093	0	0.090	0.090	0.091	0.093	0.094	0.095
PR	0.000	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000	0.000
CW	0.000	0.000	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
PW	0.099	0.085	0.084	0.088	0.083	0.096	0.095	0	0.093	0.097	0.095
EC	0.097	0.096	0.085	0.083	0.095	0.083	0.097	0.086	0	0.084	0.093
FS	0.096	0.094	0.097	0.095	0.099	0.094	0.092	0.097	0.096	0	0.098
PU	0.099	0.099	0.103	0.105	0.109	0.103	0.100	0.101	0.104	0.105	0

The last step was to estimate the extent to which every factor influenced and was influenced (Table +6) by adding up each row and column of the complete matrix. Then, the affectability and influence diagram, as the decision basis, was drawn. Vectors D and R represent the sum of the rows and columns of the matrix. The value of D + R indicates the significance of the respective criterion in the entire system. Factors with larger D + R values correlate with other factors strongly. On the other hand, criteria with positive D-R values fall into the cause group and transfer effects to other criteria. In contrast, criteria with negative D-R values fall into the effect group and are influenced by the other criteria.

Table 6. Effect and affectability of every factor

	D	**DR**	**D+R**	**D-R**
EF	0.98	0.86	2.4	08
SE	0.42	0.29	1.5	-0.3
VE	0.81	0.66	2.6	0.6
WR	0.49	0.39	1.9	-0.2
ER	0.29	0.18	0.2	-0.5
PR	0.62	0.49	2.5	0.3
CW	0.22	0.16	0.3	-0.5
PW	0.71	0.59	2.2	0.4
EC	0.48	0.44	1.7	-0.3
FS	0.29	0.18	1.2	-0.3
PU	0.16	0.07	0.05	-0.7

Regarding the extent to which every factor influenced and was influenced by the location of renewable energy farms (Table 6), earth form, vegetation and land use, and power transmission strongly correlated with other factors. Making effective policies in locating renewable energy farms can impact locating strategies. The survival of these cases depends on successful R&D activities and modern technology use. In particular, companies implementing locating strategies and optimization foreground this domain extensively.

1.2. Objective-based estimation of the relative weight of indices with fuzzy ANP

The relative weight of every index was determined based on Saaty's 9-point scale for pairwise comparison with regard to the objective of the problem. Lastly, a column vector representing the relative weight of the indices was developed and used as the objective-based relative weight matrix of the indices in the supermatrix.

Table 7. Objective-based relative weight matrix of indices

	EF	SE	VE	WR	ER	PR	CW	PW	EC	FS	PU
EF	0	0.07	0.09	0.08	0.05	0.06	0.05	0.07	0.06	0.03	0.04
SE	0.08	0	0.06	0.07	0.09	0.05	0.03	0.04	0.04	0.06	0.03
VE	0.07	0.05	0	0.05	0.06	0.07	0.04	0.09	0.06	0.07	0.06
WR	0.06	0.07	0.08	0	0.04	0.05	0.04	0.03	0.05	0.06	0.06
ER	0.09	0.06	0.04	0.04	0	0.07	0.08	0.04	0.06	0.04	0.05
PR	0.07	0.06	0.09	0.06	0.03	0	0.05	0.07	0.08	0.03	0.08
CW	0.04	0.08	0.06	0.06	0.04	0.09	0	0.06	0.06	0.07	0.07
PW	0.05	0.03	0.07	0.08	0.05	0.07	0.04	0	0.07	0.05	0.06
EC	0.03	0.04	0.04	0.07	0.07	0.05	0.06	0.08	0	0.04	0.09

FS	0.08	0.09	0.05	0.06	0.08	0.04	0.08	0.09	0.04	0	0.06
PU	0.04	0.05	0.03	0.04	0.06	0.09	0.04	0.03	0.06	0.05	0

The importance coefficients of the indices were determined by the fuzzy ANP technique for the purpose of weighting and ranking criteria. This study attempted to identify and rank effective factors in locating renewable energy farms. Decisions lied on the top level of the diagram, and the criteria, including earth form, soil and earth sciences, vegetation and land use, water ranges, environmental ranges, population ranges, communication ways, power transmission, energy capture, special facilities, and power units, were at the next level. Every criterion was weighted according to the experts' opinions and considering the knowledge of the problem. The weighting and calculations led to the final weights, where earth form, vegetation and land use, and power transmission were the factors with the highest weights. The factors selected by the fuzzy ANP agreed with the chosen factors in the DEMATEL method (Table 8).

Table 8. Final objective-based ranking of indices

Alternatives	Total	Ranking
EF	0.28	1
SE	0.18	6
VE	0.17	2
WR	0.17	5
ER	0.12	8
PR	0.12	4
CW	0.09	10
PW	0.15	3
EC	0.11	7
FS	0.09	9
PU	0.09	11

Conclusion

Considering the theoretical foundations, literature review, and energy-sector experts' opinions elicited by means of questionnaires, earth form, soil and earth sciences, vegetation and land use, water ranges, environmental ranges, population ranges, communication ways, power transmission, energy capture, special facilities, and power units constituted 11 factors influencing the location of energy farms. The mixed DEMATEL and fuzzy ANP method, presented in the table, was used for the pairwise comparisons of the criteria to the research objective and alternatives to the criteria and the pairwise comparisons of sub-criteria and sub-alternatives and, finally, the alternatives were ranked. The estimation results indicate that the highest weights belong to the earth form, vegetation and land use, and power transmission.

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