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A Type-2 Fuzzy-based Multi-criteria Decision-making Method for Sustainable Development of Wind Power Plants in Iran

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Abstract

In the current work, we propose a novel fuzzy-based multi-criteria decision-making method in order to assess the development potential of the wind power plants in a country. The type-2 fuzzy logic is utilized to investigate the simultaneous effects of several technical criteria such as the wind conditions, ambient temperature, and dust activities in a site. Iran is chosen as the case study, considering the various environmental conditions and the lack of thorough investigations in the country. The proposed method could easily be extended to apply to any region. The related technical data for all the 559 synoptic meteorological stations in the country is collected and used as the inputs for the proposed method. Applying two-step interviews with the local experts and reviewing the literature, the leading indicators and their effectiveness are defined. After developing the fuzzy rules and sets, all the sites are scored and ranked using the type-2 fuzzy logic in the proposed method. Based on the final standings, the priority tables are provided, and the top fifty sites for implementing the offshore and onshore wind power plants are introduced. Moreover, the primary analysis of the collected data indicates that the provinces with high energy consumptions and high PM 2.5 levels are in the critical environmental conditions. Thus these provinces require a strict attention and planning for a sustainable energy supply using the renewable energy systems. Based on the results obtained, several recommendations and suggestions are also mentioned in order to organize the investment resources for a more efficient and proper power plant development as well as the future studies.

Keywords: *Potential Assessment, Type-2 Fuzzy, Wind Energy, Multi-Criteria Decision-Making, Technical.*

1. Introduction

The severe rise in the consumption of energy together with its challenges such as global warming as well as greenhouse gas emission have attracted lots of attention toward utilization of either active or passive renewable energy systems over the world [1,2]. Thus several global and regional laws have been passed in order to solve or mitigate such problems [3]. By reviewing the literature, it has been pointed out that the most favorable renewable energy resources around the world are the solar and wind energies [4,5]. Hence, many studies have investigated the feasibility of implementing either multi-generation or hybrid solar/wind-based energy systems in the recent years [6,7]. Likewise, some studies have focused on the challenges of developing such renewable energy systems in diverse environmental conditions and locations [8,9].

Due to the high favorable development conditions for wind power plants, Iran is chosen for a thorough potential assessment analysis. Considering the technical viewpoint, wind energy harnessing is extremely dependent on the local and regional environmental conditions [10]. Earlier studies in the literature have shown that the environmental indicators such as the wind speed [11], ambient temperature [12], and dust activities [13] will affect the output as well as the life time period and O&M costs of a wind power plant. Consequently, these technical parameters play significant roles in a potential assessment analysis. Lately, it has been shown that although the effects of dust on PV systems have been studied -16], its impacts on the wind power plants are mainly neglected in Iran. Still, the level of dust activities

must be accounted for in a comprehensive potential assessment analysis in Iran [17].
In real life, most decisions are made in such conditions where the constraints, goals, and outcomes might not precisely be known [18]. In these conditions, it is recommended to apply fuzzy logic in order to help the decision-making process [19]. Therefore, in this work, to precisely evaluate the potential assessment with various indicators in Iran, fuzzy logic was used in the proposed multi-criteria decision-making (MCDM) framework.
The MCDM approaches have been introduced in the literature as practical methods to solve decision-making problems when various alternatives and different viewpoints with several criteria are involved [20]. In a thorough work [21], Kaya *et al*. have reviewed the various approaches in order to apply the fuzzy-based MCDM methods to solve the problems regarding energy-related decision-making. Several researchers have applied the fuzzy-based methods to analyze the potential assessments in different regions. Turkey and China have the highest number of recorded documents that have considered the fuzzy-based methods to solve the energy-related decision-making challenges [21].
Although in this work, the selected case study (Iran) contains many sites with a very high wind energy potential, numerous obstacles have decelerated the wind power plant implementation. A lack of inclusive potential assessment analysis in the country could be detected by going over the related literature. Additionally, the limited documents regularly investigate a specific location, and not the entire country [11].
In the presented paper, the development potential for wind power plants in Iran was evaluated for the entire country. The novel fuzzy-based approach considered various technical criteria for the analysis. Investigating all the available sites in Iran and with the proposed framework, different sites were ranked and categorized based on the recommended offshore or onshore power plant. Finally, a priority table for the top fifty sites in the country was produced.

2. Materials and Methods
The current investigation was done in order to evaluate the potentials for installing new offshore and onshore wind power plants in Iran. Figure 1 demonstrates the framework applied in the presented study. Different steps were discussed in greater detail in the later sections.

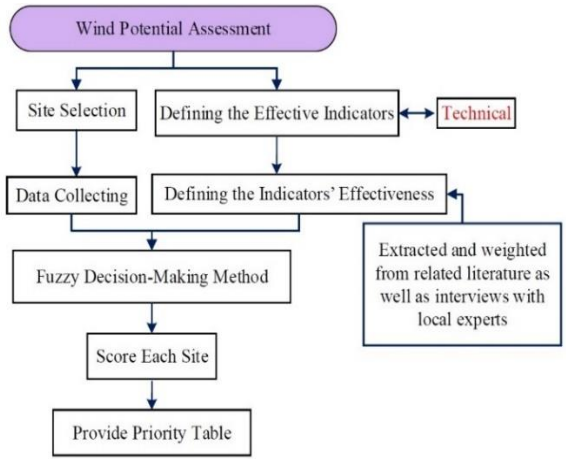

Figure 1. A schematic framework of the present study.

2.1. Defining Proper Indicators
The indicators for this study and the corresponding effectiveness for each indicator were collected using literature reviews and performing interviews with twenty local experts including the researchers in the related fields as well as several EPC (Engineering, procurement, and construction) and O&M (Operations & Maintenance) experts in Iran.
Primarily, they were asked to determine and score any indicator that affected the wind power plant selection. After analyzing the results from the primary interview, the top three indicators with the highest effectiveness scores were chosen for further analysis in the following steps. The chosen effective technical indicators considered in the present study were the local wind speed, ambient temperature, and annual number of dusty days. The extracted effectiveness weights of the indicators are displayed in Table 1.

Table 1. Final extracted effectiveness weights for each indicator.

Criteria	Indicator	Individual weight (%)	Total weight (%)
Technical	Wind speed	68.8	100
	Temperature	13.2	
	Dust	18	

2.2. Site Selection
In the next step, in order to analyze the indicators throughout the entire country of Iran, all the Synoptic meteorological stations in Iran were considered. 559 Synoptic meteorological sites were available, for which all the corresponding technical data was analyzed.

2.3. Data Collecting and Primary Analysis
In this step, the criterion's value was collected for each site in the country of Iran. The available data

from the ground monitoring weather stations in Iran was used for this step. In the case of shortages and missing data, the online databases for Meteonorn and RETScreen software were utilized in order to collect the required information. The primary analysis of the technical data displays a wide changing range for the indicators over Iran. After the primary analysis of all the sites, the top fifty ones with the highest scores were chosen for further analysis. Table 2 lists these sites and the corresponding technical information.

According to Table 2, the long-term annual average of wind speed in the selected sites changes from 6.90 $m.s^{-1}$ in the Zabol station to 3.51 $m.s^{-1}$ in the Kahnuj station. It displays the great potential for the development of wind power plants in Iran. However, the changes in the range of ambient temperature (from 5.12 ˚C in Firuzkuh to 28.96 ˚C in Abumusa Island) and dust activities have also to be taken into account.

The dust particles in the air result in technical problems, and lead to an output reduction. Furthermore, the dust activities in a site lead to an intensive O&M cost increase. Using the primary investigations, the map of Iran's provinces is classified in Figure 2 based on a long-term analysis of the average number of dusty days in a year. These patterns for dust activities depend on the dust origins [17].

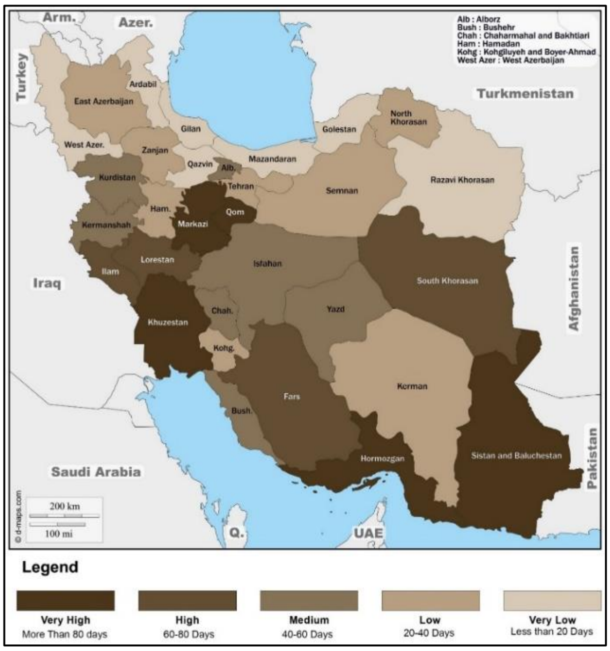

Figure 2. Map of Iran's provinces produced using a long-term analysis of the average number of dusty days in a year.

Table 2. Collected technical data for the fifty selected sites of Iran in this study.

Site name	Site location	V_W [$m.s^{-1}$]	T_{am} [°C]	Dust [day]
Abumusa Island	(25.87, 55.01)	4.12	28.96	139
Aligudarz	(33.41, 49.70)	4.98	13.01	69
Ardebil (airport)	(38.33, 48.42)	5.59	9.49	11
Birjand	(32.89, 59.28)	3.96	17.05	61
Dorud	(33.52, 49.00)	3.69	17.22	69
Dastjerd	(34.57, 50.21)	3.65	14.34	113
Firuzkuh (gaw)	(35.70, 52.59)	4.81	5.12	24
Fariman	(35.65,59.83)	4.03	12.91	11
Gilanegharb	(34.13, 45.93)	5.06	20.09	48
Gharqabad	(35.11, 49.83)	5.68	15.78	84
Izadkhast	(31.53, 52.13)	4.05	15.66	73
Imam Khomeini	(35.42, 51.17)	4.28	18.30	24
Jirandeh	(36.71, 49.80)	5.31	11.38	4
Jajarm	(36.95, 56.33)	4.48	15.03	23
Khaf	(34.58, 60.15)	4.56	18.55	11
Kahnuj	(27.99, 57.71)	3.51	27.03	23
Komijan	(34.71, 49.31)	4.11	15.04	84
Khark Island	(29.27, 50.32)	4.30	26.96	52
Kuhin	(36.37, 49.64)	4.39	10.54	20
Lavan Island	(26.81, 53.35)	4.50	28.25	139
Lalehzar	(29.52, 56.83)	3.74	11.84	23
Manjil	(36.73, 49.41)	4.53	17.39	4
Malekan	(37.15, 46.08)	3.58	15.55	28
Meymeh	(33.43, 51.17)	3.41	14.53	50
Maragheh	(37.35, 46.15)	3.64	14.43	28
Naein	(32.85, 53.08)	3.56	17.53	50
Nadooshan	(32.00, 53.56)	4.02	15.50	53
Nir	(38.04, 48.03)	3.71	9.03	11
Namin	(38.42, 48.49)	4.39	10.22	11
Omidiyeh	(30.74, 49.69)	4.18	26.73	127
Raz	(37.94, 57.10)	3.97	13.61	23
Rayn	(29.58, 57.43)	3.60	14.86	23
Rudbar	(36.82, 49.42)	3.57	18.25	4
Rezvan	(37.18, 55.79)	5.88	12.47	27
Sabzevar	(36.21, 57.65)	3.54	18.63	11
Saman	(32.44, 50.87)	3.91	12.89	42
Salafchegan	(34.48, 50.47)	3.84	17.36	113
Sahand	(37.93, 46.12)	3.81	12.48	28
Siri Island	(25.90, 54.55)	4.55	28.88	139
Sarbisheh	(32.62, 59.78)	3.62	13.88	61
Sonqor	(34.78, 47.58)	3.70	13.50	48
Torbat-e-Jam	(35.29, 60.56)	3.85	16.59	11
Tang Torkaman	(37.94, 56.92)	3.57	14.89	23
Tabriz (east)	(38.05, 46.33)	4.71	13.00	28
Tazehabad	(34.75, 46.15)	3.88	16.36	48
Zabol	(31.09, 61.54)	6.90	22.86	85
Zahak	(30.90, 61.68)	5.32	25.19	85
Zanjan airport	(36.77, 48.37)	3.94	13.95	31
Zaboli	(27.13, 61.67)	4.39	24.00	85
Zahan	(33.42, 59.82)	3.55	15.03	61

The west of Iran is much more likely to suffer from dust storms than the other areas due to the differences in soil and weather. This region is severely affected by the dust storms blown from the great deserts of Iraq, Saudi Arabia, and Syria every year. In many cases, in the bare desert, the sandy areas (such as those found on the Arabian land) do not create dust storms, and the areas with silt- and clay-rich soils (that are most common in Iran and Iraq) are responsible for the dust storms [22]. In a recent detailed study [17], Gholami *et al*. have reviewed the most prominent research works regarding the impact of dust on the photovoltaic systems in Iran. Figure 3 shows the main arid and semi-arid areas in the interior of Iran overlaid on the source regions of dust near the border of Iran. It could be obtained from Figures 2 and 3 that the SW of Iran, especially near the border of Iraq, Saudi Arabia, and UAE, are considered to have dust storms more frequently. Iraq, with vast deserted regions, around 40% of the country is regarded as one of the chief external dust sources. Several factors including the extreme drought in 1990, destructive war effects, deforestation, and improper political decisions, have increased the desertification process in the recent years [23-25].

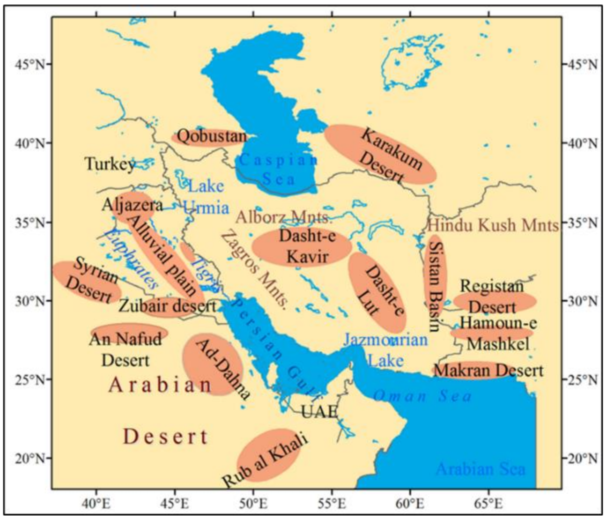

Figure 3. Map of Iran's provinces produced using a long-term analysis of the average number of dusty days in a year.

Besides the number of dusty days that results in several technical problems, the amount of PM 2.5 for each province was collected. Several studies have proposed a direct link between exposure to PM 2.5 and lung or cardiac diseases [26]. These particles come from various sources such as conventional power plants, motor vehicles, airplanes, and dust storms. Therefore, beside the technical aspects, this indicator should be considered to prioritize the provinces for a renewable energy system development. The classification is based on the air quality standards for particle pollution published by the U.S. Environmental Protection Agency (Table 3) [27].

Table 3. Level of PM 2.5 (μg/m^3) based on the air quality standards for particle pollution.

$PM_{2.5}$	Air Quality Index	$PM_{2.5}$ Health Effects	Precautionary Actions
0 to 12.0	Good 0 to 50	Little to no risk.	None.
12.1 to 35.4	Moderate 51 to 100	Unusually sensitive individuals may experience respiratory symptoms.	Unusually sensitive people should consider reducing prolonged or heavy exertion.
35.5 to 55.4	Unhealthy for Sensitive Groups 101 to 150	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
55.5 to 150.4	Unhealthy 151 to 200	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion.
150.5 to 250.4	Very Unhealthy 201 to 300	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
250.5 to 500.4	Hazardous 301 to 500	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

Figure 4 shows the classification of Iran's provinces based on the levels of PM 2.5. Respectively, Hormozgan, Markazi, Khuzestan, Bushehr, and Isfahan with the PM 2.5 levels of 168, 109, 94, 84, and 82 μg/m3 suffer the most, while the Zanjan province has the lowest PM 2.5 level of 13.78 μg/m3. The majority of the provinces in the country are in the moderate PM 2.5 level (12.1-35.4 μg/m3). However, it should be considered that none of the provinces in the country has an air quality index of good. This is one of the driving forces in the country for renewable energy system development.

Besides the PM 2.5 levels, the total energy consumption, the energy consumption per capita, and the consumer type indicators for each province are presented in Figure 5. The total energy consumption of each province reflects the distribution and density of the country's consumption. Moreover, this indicator can be used to reduce the pressure on transmission lines and power supply at the desired points. The Tehran, Khuzestan, and Isfahan provinces have the highest annual energy consumptions with, respectively, 35366, 31128, and 23588 million kWh/year. However, due to the industry developments as well as other factors, Hormozgan, Yazd, and Khuzestan have the highest energy consumption per capita.

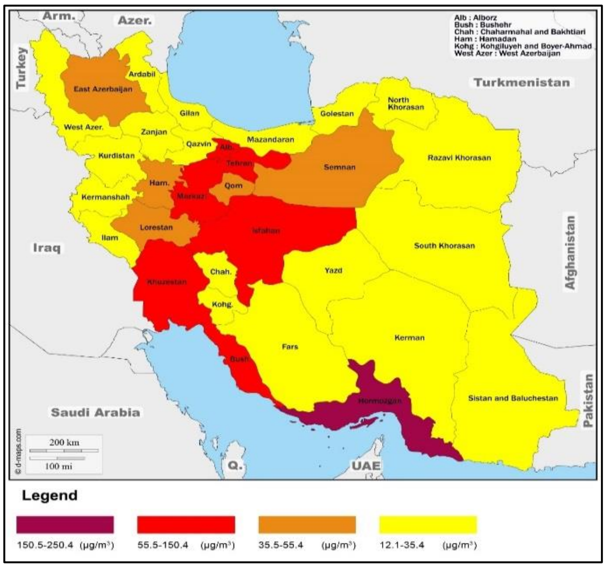

Figure 4. Map of Iran's provinces classified by the amount of PM 2.5.

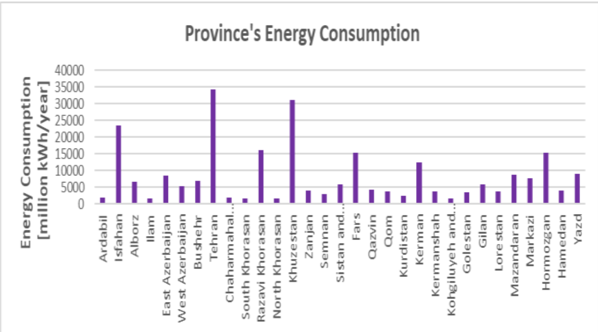

Figure 5. Province's energy consumption of Iran.

In the current work, the prioritization of the available sites in the country was done based on the technical indicators. However, based on the primary analysis regarding the energy consumption and PM 2.5 level in different provinces, several recommendations have been proposed to develop wind power plants in the country.

2.4. Type-2 Fuzzy for Analyzing

Type-2 fuzzy logic is an improvement and generalization of the type-1 fuzzy one. The type-1 fuzzy sets define the ambiguity in the decision-making process. Nevertheless, they do not model the proper uncertainty. In the type-2 fuzzy sets, the uncertainties memberships include abounded regions that are called the footprints of uncertainty (FOU). In a decision-making system based on the experts' knowledge, these sets with FOU result in a better uncertainty modeling. In a multi-criteria decision-making system such as the one in the current work, various ideas might lead to diverse the membership functions. Hence, in the presented work, the type-2 fuzzy sets were applied to obtain a single model. An interval type-2 fuzzy set is a specific case of a type-2 fuzzy set (T2FS), where a classic set represents the membership degree. Figure 6 shows the sample interval type-2 membership functions. The type-2 fuzzy steps applied in the current work for analyzing the decision-making process are presented in Figure 7.

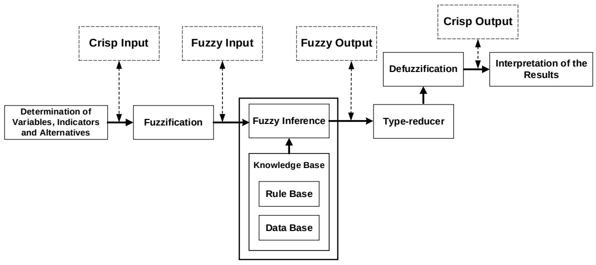

Figure 6. Algorithm and steps in the fuzzy decision-making method.

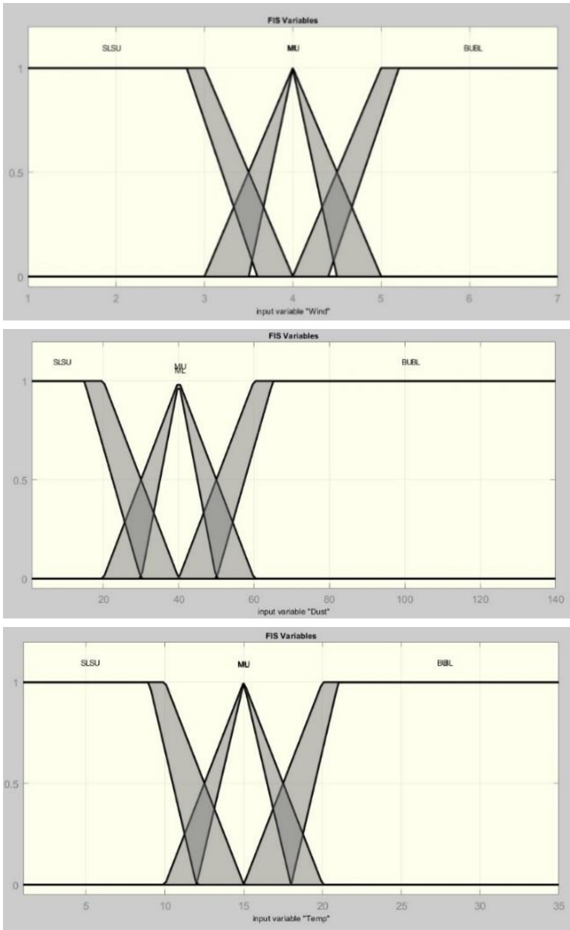

Figure 7. (Top) Wind input membership function, (Middle) dust input membership function, (Bottom) temperature input membership function.

First, the variables, indicators, and alternatives are determined. Then during the fuzzification phase, the actual variables for wind power plants transform into the linguistic ones. After that, the universe (i.e. every possible value as well as the changing range of the indicators) will be set for each one of the indicators. Based on the defined universe in the work, all the collected technical data was normalized to be considered as the fuzzy inputs in the next step. In the present work, three linguistic variables (High (H), Medium (M), and Low (L)) with either negative or positive effects have been introduced. These fuzzy rules explain the system's natural and actual behaviors under different conditions (Table 4). The coefficient weight of each rule was determined by applying each indicator's effectiveness index based on Table 1.

Table 4. Input indicator membership functions and their ranges.

Indicators	Membership function		
Wind speed	L (-) Trapmf	M Trimf	H (+) Trapmf
Temperature	L (-) Trapmf	M(+) Trimf	H (-) Trapmf
Dust	L (+) Trapmf	M Trimf	H (-) Trapmf

After applying a fuzzy analysis on the inputs, the output values will be obtained. Then during the defuzzification step, they will be changed accordingly. In the final step, the results obtained were utilized in order to prepare the priority tables for wind power development potential in Iran.
Here, Interval Type-2 Fuzzy Logic Systems (IT2-FLSs) were applied for the analysis. The main implementation structure of IT2-FLS is the same as the type-1 counterpart. A type-2 membership function is defined as [28]:

$$\mathbf{\mu_{\tilde{x}}(x, u) | x \in X, u \in [0\ 1]} \tag{1}$$

where the rule structure of TSK type IT2-FLS constructed from *m* rules is as follows:

$$\mathbf{R^l\text{: if } x_1 \text{ is } \bar{A}_1^l \text{ and ... and } x_n \text{ is } \bar{A}_n^l\text{, then } y \text{ is } B^l} \tag{2}$$

where $l = 1, 2, \dots, m$ and $\bar{A}_i^l (i = 1, \dots n)$ are the antecedent, and $B^l = [\underline{b}^l, \bar{b}^l]$ are the consequent membership functions. $\underline{b}^l$ and $\bar{b}^l$ can be crisp consequents as follow:

$$\mathbf{\underline{b}^l = \underline{c}_0^l + \underline{c}_1^l x_1 + \dots + \underline{c}_n^l x_n} \tag{3}$$

$$\mathbf{\bar{b}^l = \bar{c}_0^l + \bar{c}_1^l x_1 + \dots + \bar{c}_n^l x_n} \tag{4}$$

For the crisp input $x' = [x'_1, x'_2, \dots, x'_n]$, the output can be computed as follows.

1. Compute $\left[\underline{\mu}A_i^l,\ \bar{\mu}A_i^l\right]$:

For $i = 1,2, \dots, n \text{ and } l = 1, 2, \dots, m$

2. Compute firing strength:

$$\mathbf{\underline{f}^l = \left[\underline{\mu}A_1^l(x'_1) * \underline{\mu}A_1^l(x'_2) \dots * \underline{\mu}A_1^l(x'_n)\right]; \; l = 1, \dots, m} \tag{5}$$

$$\mathbf{\bar{f}^l = \left[\bar{\mu}A_1^l(x'_1) * \bar{\mu}A_1^l(x'_2) \dots * \bar{\mu}A_1^l(x'_n)\right]; \; l = 1, \dots, m} \tag{6}$$

3. Compute the output:

$$\mathbf{Y(x') = \frac{\sum_{i=1}^{m} y_i f^l}{\sum_{i=1}^{m} f^l} = [y_L, y_R]} \tag{7}$$

Where

$$\mathbf{y_L(k) = \frac{\sum_{i=1}^{L} \underline{y}^l \bar{f}^l + \sum_{i=L+1}^{m} \underline{y}^l \underline{f}^l}{\sum_{i=1}^{L} \bar{f}^l + \sum_{i=R+1}^{m} \underline{f}^l}} \tag{8}$$

$$\mathbf{y_R(k) = \frac{\sum_{i=1}^{R} \bar{y}^l \underline{f}^l + \sum_{i=R+1}^{m} \bar{y}^l \bar{f}^l}{\sum_{i=1}^{R} \underline{f}^l + \sum_{i=R+1}^{m} \bar{f}^l}} \tag{9}$$

Where *L* and *R* are the switching points that can be found via the iterative Karnik–Mendel (KM) algorithm, and

$$\mathbf{y^* = \frac{y_L(k) + y_R(k)}{2}} \tag{10}$$

3. Results and Discussion

Based on the type-2 fuzzy analysis, the final rank for the selected sites in the country for wind power plant development in the country, their final technical scores, and the suggested power plant type for implementation for the selected sites are presented in Table 5.
Base on the technical analysis, it could be seen that that, respectively, the Jirandeh, Rezvan, Ardebil, Gharqabad, Jajarm, and Aligudarz sites had the highest development priority, while the Naein, Abumusa Island, and Meymeh sites had the least priority in this regard.
The technical assessment implies that even though Iran has promising wind potentials in numerous sites, other indicators including dust activities and ambient temperature will affect the wind power plants' electrical outputs and performance. Consequently, supplementary investigations are crucial for Iran's climatology in this regard.
Furthermore, the primary analysis indicated that the provinces with higher energy consumption rates and PM 2.5 levels were the most vulnerable

provinces in the country and the best ones for developing renewable power plants. Therefore, further investigations are required in these regards.

Table 5. Final technical position of the selected sites for wind power plant development.

Station	Type	Score	Rank
Jirandeh	Onshore	0.9286	1
Rezvan	Onshore	0.9150	2
Ardebil	Onshore	0.9	3
Gharqabad	Onshore	0.8413	4
Jajarm	Onshore	0.8239	5
Aligudarz	Onshore	0.8132	6
Firuzkuh	Onshore	0.8113	7
Manjil Gilan	Onshore	0.803	8
Tabriz	Onshore	0.7959	9
Gilanegharb	Onshore	0.7849	10
Khaf	Onshore	0.7844	11
Zahak	Onshore	0.75	12
Zabol	Onshore	0.75	13
Kuhin Qazvin	Onshore	0.7014	14
Imam Khomeini	Onshore	0.6895	15
Namin	Onshore	0.6808	16
Fariman	Onshore	0.6347	17
Siri Island	Off/Onshore	0.6232	18
Torbat-E-Jam	Onshore	0.6139	19
Raz North	Onshore	0.6124	20
Lavan Island	Off/Onshore	0.61	21
Rayn	Onshore	0.5810	22
Tangeh Torkaman	Onshore	0.5742	23
Zanjan	Onshore	0.5563	24
Maragheh	Onshore	0.5441	25
Khark Island	Off/Onshore	0.5337	26
Malekan	Onshore	0.5331	27
Sahand	Onshore	0.5271	28
Rudbar Gilan	Onshore	0.5233	29
Komijan	Onshore	0.5194	30
Nadooshan	Onshore	0.518	31
Nir	Onshore	0.518	32
Sabzevar	Onshore	0.513	33
Lalehzar	Onshore	0.5123	34
Zaboli	Onshore	0.5103	35
Saman	Onshore	0.5066	36
Izadkhast	Onshore	0.5036	37
Tazehabad	Onshore	0.5026	38
Sonqor	Onshore	0.4728	39
Birjand	Onshore	0.4626	40
Dastjerd	Onshore	0.4507	41
Salafchegan	Onshore	0.4489	42
Kahnuj	Onshore	0.444	43
Omidiyeh	Onshore	0.4384	44
Sarbisheh	Onshore	0.4330	45
Zahan	Onshore	0.4304	46
Dorud	Onshore	0.4268	47
Meymeh	Onshore	0.4257	48
Abumusa Island	Off/Onshore	0.4243	49
Naein	Onshore	0.4084	50

4. Conclusions and Recommendations

A growing demand for energy supply and related environmental challenges lead to a substantial leaning toward implementing renewable energy systems and, in particular, solar or wind power plants. Besides these matters, the limited available investment and technical resources should be organized and developed to attain the maximum and the most environmentally friendly available outputs. Hence, comprehensive potential assessment analyses are essential.

In this paper, we proposed a novel multi-criteria method in order to evaluate the technical potentials for developing wind power plants. Iran was chosen as the case study with considerable wind potential and diverse techno-environmental conditions and a shortage of thorough investigations. The proposed multi-criteria potential assessment method was applied to this country.

Using the related literature and interviews with the experts, the leading indicators and criteria for the assessment were determined, and the top three were chosen for further analysis. The values of each criterion were collected using the available data from all the 559 synoptic meteorological stations in Iran and other databases. These sites were analyzed using fuzzy logic in decision-making in the proposed method, and the top fifty sites with the highest technical scores were selected for further analysis. All the chosen 50 sites were ranked in the final step, and their recommended power plant types were defined.

The results obtained confirmed that just considering the wind speed for such potential assessments results in misleading outcomes. Thus to improve the precision of the analysis, all the technical indicators must be taken into accounts.

Besides, it was shown that several provinces with high energy consumption and high PM 2.5 levels are in critical environmental conditions. Therefore, these provinces are favorable locations for the development of renewable power plants. Moreover, it is recommended that for future analyses, the social and eco-environmental criteria should also be considered. The results of the current paper imply that equal energy laws over the entire country might decrease the legislation's impacts. Thus in order to reach a better and quicker progress in Iran, the government ought to codify the related energy legislation based on the local conditions.

The introduced framework in this work can be extended and applied with no trouble for other energy-related analyses in the future. Therefore, the proposed framework is suggested to be applied to other regions or renewable energy resources for future investigations.

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6. References

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