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Selection Of The Most Proper 100 Kw Wind Turbine For Electric Generation

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ABSTRACT:- A rising attraction in sustainable power resources, owing to,country level levy inducement and increasing fuel expensesare driving the search toadvance a series of developing novelpower production equipment and unified solutions. The wind energy is one ofthe bestinstances on this issue. Small and micro wind turbine systems can be competitive with conventional energy counterparts. As a result of negative effects of bad emissions and increasing awareness on global warming, there is a rising interestin setting up domesticsmall wind energystations. Small wind turbine systems have a number of advantages: sufficient longevity, high efficiency, low maintenance costs, and straightforward installation.In this study, the AHP approach was applied to choose the most proper 100kW small wind turbine for an electric energy generation system design. Eleven diverse wind turbine brands were analyzed depending on experts' opinions on four groups (environmental, customer satisfaction, technical, and economic) of characteristics of these wind turbines. Wind turbine data used is obtained from the wind turbine manufacturers worldwide.

Keywords*:-Sustainable energy, Small wind turbine choose, Multi-criteria decision making, AHP, Energy efficiency.*

I. INTRODUCTION

Because of progressing countries to carry on their development, their requirement for energy always rises.To balance growth in development countries, wind energy must be used for requirement of electrical energy.In this sense, the wind power ispromising with a rising concern on energy issues. First, it is one of the most environmental power resources in relation to CO_2 emissions. As the CO_2 proportion in air is significantlyassociated with global warming, it will significantly diminish the impacts of power plants and energy resources on global warming. Secondly, the wind power stations have short period of depreciation [1]. The governments back wind power stations with legislative arrangements and use electricity produced from wind power turbines for a conceivable prices[2]. These arrangements are organizedin a way so that the wind power market will increase its participation on country economy and with these prices; it is possible to gainimmense profits from wind energy stations. The cost analysis of operated wind power stations displayed in Figure 1, shows that they provide %25 profit on investment in quarter of a century which is an appealingperspective of wind power.Figure 1 shows cost structure for a wind turbine [3].

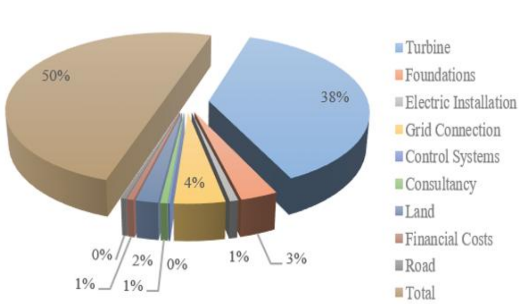


Fig. 1. Cost structure for a wind turbine

The primary concern for wind energy stations is the noise that they produce. But the recent research displays that the noise of wind energy turbines are mostly lower than a busy office or a highway and it is far below them.Noise levels of a few noise resourcesare displayed in Fig. 2 [4].

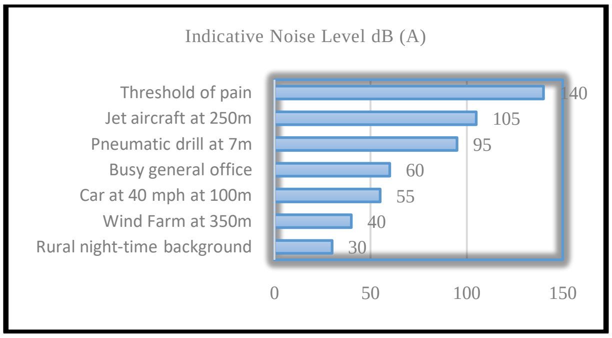


Fig. 2. Noise levels of a few noise resources

For small firms and households, small and privately owned wind turbines are an attractive alternative with the rising interest in renewable energy generation. There has been comprehensive research on the likelihood of integrating wind energy manufactured by small and micro manufacturers into a so-called smart electricity system. With novel government incentive and the fast development of electronic devices, these systems are very much inexpensive compared to a decade ago[5].Fig. 3presents the assessment of wind turbine sector displayed as a function of manufacturing capacity (kW) for the years 1980 to 2020 [6]

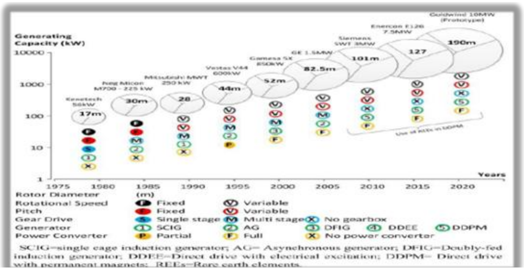


Fig. 3.a)The assessment of wind turbine sectordisplayed as a function of manufacturing capacity (kW) for the years 1980 to 2020

For a wind power station design, the choice of the most effective wind turbine is of extreme significance as the expenses of the wind turbines comprise the biggest percentage of the wind power station' total cost. It can definitely be manufactured after the necessary calculations in detail. The index of wind energy is able to help perform a wind turbine comparison for a specific area to back the selection process of the most appropriate wind turbine [7, 8].For a wind power station, the multi-criteria decision making methodology is essential for making the best decision and appraising various wind turbine brands.In the related literature, it can be seen that there are many papers concerning applications of multi-criteria decision making methods on wind energy station and wind power project planning. The frequently used multi-criteria methods for the assessment are VIKOR, AHP, TOPSIS, ELECTRE, and ANP.All of these methods supply solutions to the systems containing conflicting and multiple objectives. A comparison of the chosen turbines gives a true insight for the best choice among the brands considered with used method [9]. In the last years, researchers have begun to focus on theevolution of equipment related to the sustainable energy.Janke applied multi-criteria decision making and Geographical Information Systems for wind farms site selection [10]. Charabi and Al-Yahyai analyzed site suitability for wind station by using a fuzzy multi-criteria method and local weather conditions [11]. Minguez et al. analyzed the appropriate selection of the most suitable support structures' options for 5.5 MW wind turbine with TOPSIS. They determined the system effectiveness by considering economical, engineering and environmental attributes [12].Xiong and Wang used ELECTRE-TRI and lexicographic order methods for the solution of wind energy station site selection problem [15].Lee et al. composed the comprehensive assessment model, which includes ISM and FANP. With this model, they selected proper turbines for a wind farm [13].To find suitable locations, Parry and Baban defined fourteen criteria such as, land use, memorial and historical sites, slope etc. They used a weighted analysis using Geographical Information Systems to define convenient sites for wind farms in the UK [14]. Aras et al.decided the most suitable site for a wind energy station at a university using AHP [15].Haralambopoulos and Polatidis used a Geographical Information Systems multi-criteria decision makingapproach for wind farms suitability studies [16].In this work, multi-criteria decisionmaking is used to choose the most proper 100kW wind turbine for an electric energy generation system design. The comparative evaluation of eleven diverse wind turbine brands is performed. Each of the wind turbine brands is analyzedbased on four diversemajorgroup of criteria. Within these fourmajorgroups, numerous sub-criteria are obtained; similarly, sub-options are indicated for each of the wind turbine brands. Among selected popular 100kW wind turbine brands, the wind turbinewith the most proper performance is determined.Required data was obtained from actual wind turbine manufacturer.

II. MULTI-CRITERIA DECISION MAKING IN WIND TURBINE SELECTION

In an AHP hierarchy for choosing a wind turbine, the goal would be to choose the best turbine. Technical, economic, environmental, and customer related factors are the four main criteria that are used in majority of the related literature for making a decision. These criteria are often subdivided into several sub-criteria. In this study, the technical criterion is subdivided into output, capacity, rotor diameter, hub height, cut-out wind speed, and nominal wind speed. The cost criterion is subdivided into total cost and state support. The environmental criteria include noise and electromagnetic effects. Finally, the customer satisfaction is measured using service, availability of spare parts, and reliability. Six alternative 100 KW wind turbines are compared using AHP technique. The hierarchy composed of these criteria is constructed as shown in the figure below:

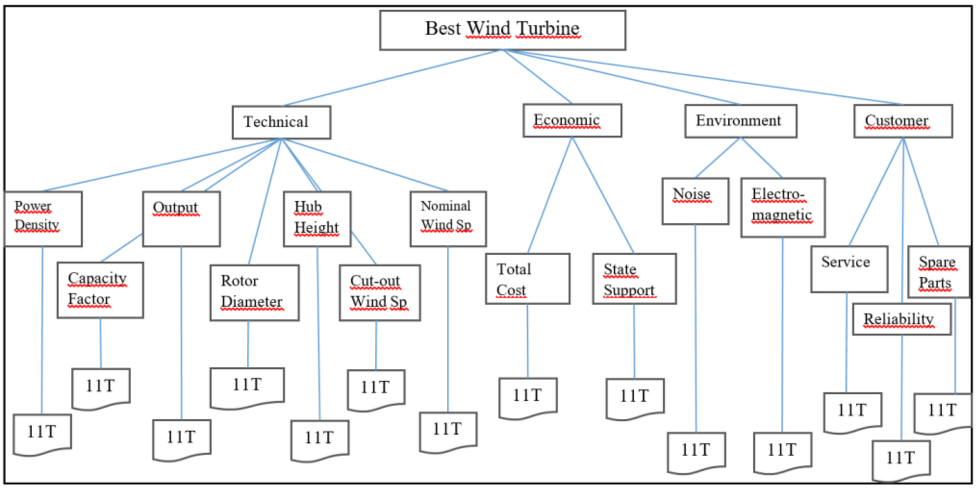


Fig. 4. Hierarchy of Criteria

While measurements for some criteria are readily available, some others like customer satisfaction can only be estimated with respect to other variables. As it is the case in all multi-criteria decision making methods, the relative weights of such criteria need to be determined. In AHP, this is accomplished by pairwise comparison of the elements, starting with the main criteria. Below are the resulting priorities of technical, economic, environmental, and customer related factors.

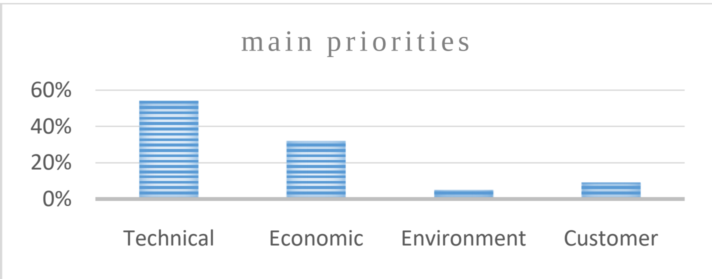


Fig. 5. The resulting priorities of criteria related factors.

In the next step, there are groups of sub-criteria under each main criterion to be compared two by two. In the technical subgroup, each pair of sub-criteria is compared regarding their importance with respect to the technical criterion. Below are the resulting weights for the criteria based on pairwise comparisons.

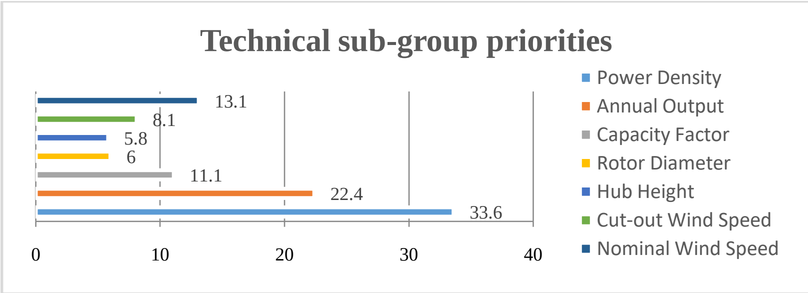
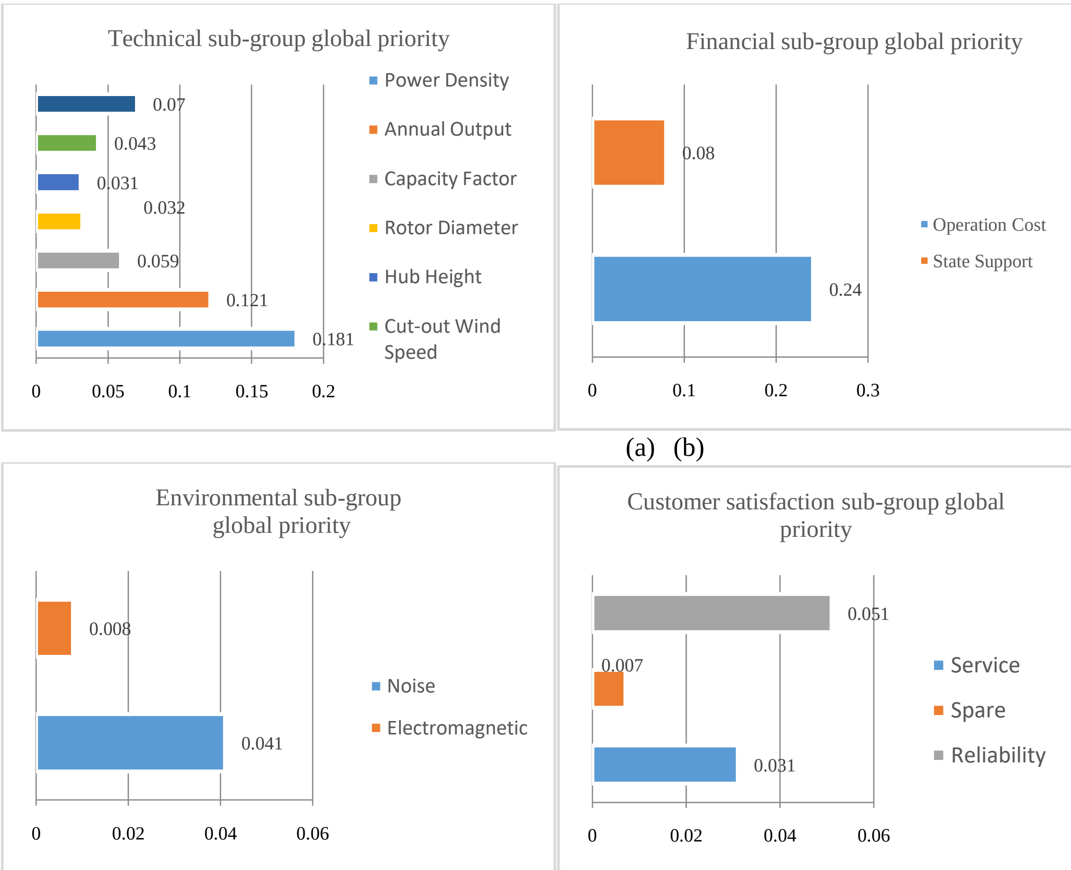


Fig. 6. Technical sub-group priorities

At this point, the comparison for technical criterion has been made, and the AHP method has derived the local priorities for this group. These priorities reflect on how much it contributes to the priority of its parent, thus we need to calculate the global priority of each sub-criterion. That will show us the priority of each sub-criterion with respect to the overall goal. The global priorities throughout the hierarchy should add up to one. The global priorities of each technical sub-criterion is calculated by multiplying their local priorities with the priority of technical criterion which results in the following values.In the economic subgroup, there is only one pair of sub-criteria, namely total cost of investment and state support available. These elements are compared as to how important they are with respect to the economic criterion. Environmental factors considered are noise and electromagnetic effects. Comparison of these elements with respect to the environmental consideration steads to the resulting weights. Finally, there are three sub-criteria in the customer satisfaction subgroup, namely service, spare parts, and reliability. These elements are compared as to how they add value towards the customer satisfaction.



(c) (d)

Fig. 7. The resulting weights are based on the principal eigenvector of the decision matrix.

III. PAIRWISE COMPARISON OF THE ALTERNATIVES WITH RESPECT TO THE CRITERIA

After determining the priorities of each criterion with respect to the overall goal of selecting the best wind turbine and priorities of sub-criteria with respect to their associated main criteria, the turbine alternatives need to be compared two by two with respect to each sub-criterion. The technical properties of the selected 100 KW wind turbines are presented in the table below:

Table 1. Technical Properties

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Annual Output	270	255	252	265	273	277	254	259	262	265	258
Capacity Factor	30.8	29.0	28.8	30.2	31.1	31.6	29.0	29.5	30.0	30.0	29.5
Nominal Rotor Diameter	24	19	17.9	21	26	29	18	21	24	20.7	18
Hub Height	23/38	20/35	18/30	23/38	40	30/50	18/24	23/40	25/36	29/37	20/30
Cut-out Wind Speed	20.0	20.0	24.0	25.0	26.5	25.0	20.0	25	20	25	26
Nominal Wind Speed	10.0	10.0	16.0	14.5	11.5	10	14.5	12	9.5	15	12
Power Density	4.53	2.84	2.52	3.47	5.31	6.61	2.55	3.47	4.53	3.37	2.55

Cut-In Wind Speed and Turbine Output values for all turbines are kept constant while the remaining values are used to compare the alternatives. The economic properties of the alternatives are presented in the following table:

Table 2. Financial Properties

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Total Cost	653	645	640	655	700	750	632	667	724	645	620
Support of Government	0.31	0.30	0.28	0.29	0.32	0.32	0.28	0.30	0.30	0.29	0.29

Table below shows the environmental effects of the turbines. Noise level and the electromagnetic effects are chosen as the differentiating elements among different turbine alternatives.

Table 3. EnvironmentalProperties

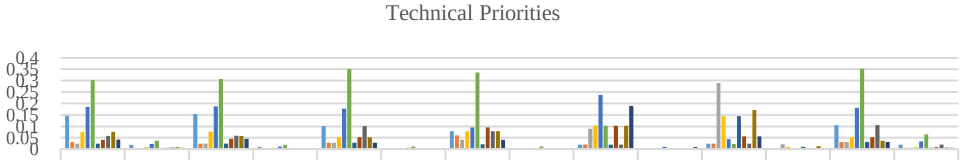
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Max. sound power (dB)	93.2	87.8	88.0	95.2	96.6	95.7	89	90.5	95.2	89.1	88.0
Electromagnetic effects	7-12	7-13	6-16	6-19	7-13	6-15	6-12	6-16	7-15	6-16	7-14

In order to measure the customer satisfaction towards the wind turbines, three sub-criteria is defined: customer service, spare parts available, and the reliability of the company. Service is evaluated to be positively related to the number of branches available for each company. Spare parts are measured by the inventory levels of the companies while the reliability is measured by their market shares and sales. The companies are ranked from 1 to 11 to be able to generate a medium of comparison.

Table 4. Customer Service Properties

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Service support	4	7	9	3	2	1	11	6	5	8	10
Spare part	3	7	10	4	1	2	11	6	5	8	9
Reliability	4	8	9	5	1	2	10	6	3	7	11

The next step in applying the AHP technique is two by two comparisons of the turbine alternatives with respect to each sub-criterion. In order to design an objective scheme for this purpose, the maximum and minimum values of the alternatives for each sub-criterionare determined. This range is divided into nine even classes since AHP requires pairwise comparisons on a scale from 1 to 9. Finally, each alternative is placed in one of these classes based on their values to compare them with each other. Remainder of this section presents the priorities obtained under each subcategory using this scheme.

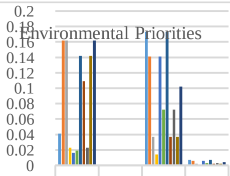


	Annual Output		Capacity Factor		Nominal Rotor Diam.		Hub Height		Cut-out Wind Speed		Nominal Wind Speed		Power Density	
T1	0.147	0.018	0.153	0.009	0.101	0.003	0.078	0.002	0.019	0.001	0.023	0.002	0.104	0.019
T2	0.03	0.004	0.023	0.001	0.028	0.001	0.06	0.002	0.019	0.001	0.023	0.002	0.03	0.005
T3	0.023	0.003	0.023	0.001	0.028	0.001	0.04	0.001	0.089	0.004	0.291	0.021	0.03	0.005
T4	0.076	0.009	0.077	0.005	0.052	0.002	0.078	0.002	0.102	0.004	0.144	0.01	0.052	0.009
T5	0.184	0.022	0.188	0.011	0.178	0.006	0.095	0.003	0.238	0.01	0.044	0.003	0.18	0.033
T6	0.303	0.037	0.306	0.018	0.351	0.011	0.335	0.011	0.102	0.004	0.023	0.002	0.352	0.064
T7	0.023	0.003	0.023	0.001	0.028	0.001	0.021	0.001	0.019	0.001	0.144	0.01	0.03	0.005
T8	0.041	0.005	0.045	0.003	0.052	0.002	0.095	0.003	0.102	0.004	0.056	0.004	0.052	0.009
T9	0.057	0.007	0.058	0.003	0.101	0.003	0.078	0.002	0.019	0.001	0.023	0.002	0.104	0.019
T10	0.076	0.009	0.058	0.003	0.052	0.002	0.078	0.002	0.102	0.004	0.171	0.012	0.037	0.007
T11	0.041	0.005	0.045	0.003	0.028	0.001	0.04	0.001	0.189	0.008	0.056	0.004	0.03	0.005

Fig. 8. Technical Priorities

	Total Cost		Support of Government	
	Local	Global	Local	Global
T1	0.097	0.023	0.122	0.01
T2	0.122	0.029	0.067	0.005
T3	0.122	0.029	0.02	0.002
T4	0.097	0.023	0.036	0.003
T5	0.034	0.008	0.265	0.021
T6	0.014	0.003	0.265	0.021
T7	0.151	0.036	0.02	0.002
T8	0.07	0.017	0.067	0.005
T9	0.02	0.005	0.067	0.005
T10	0.122	0.029	0.036	0.003
T11	0.151	0.036	0.036	0.003

	Max Service support		Spare part		Reliability	
T1	0.0	0	0.0	0	0.0	0
T2	0.0	0	0.0	0	0.1	0.0
T3	0.1	0.0	0.2	0	0.1	0.0
T4	0.0	0	0.0	0	0.0	0
T5	0.0	0	0.0	0	0.0	0
T6	0.0	0	0.0	0	0.0	0
T7	0.2	0.0	0.2	0	0.2	0.0
T8	0.0	0	0.0	0	0.0	0
T9	0.0	0	0.0	0	0.0	0
T10	0.1	0	0.1	0	0.0	0
T11	0.2	0.0	0.1	0	0.2	0.0



	Max. sound power (dB)		Electromagnetic effects	
T1	0.041	0	0.173	0.007
T2	0.162	0.001	0.141	0.006
T3	0.162	0.001	0.037	0.002
T4	0.023	0	0.014	0.001
T5	0.016	0	0.141	0.006
T6	0.019	0	0.072	0.003
T7	0.142	0.001	0.173	0.007
T8	0.109	0.001	0.037	0.002
T9	0.023	0	0.072	0.003
T10	0.142	0.001	0.037	0.002
T11	0.162	0.001	0.102	0.004

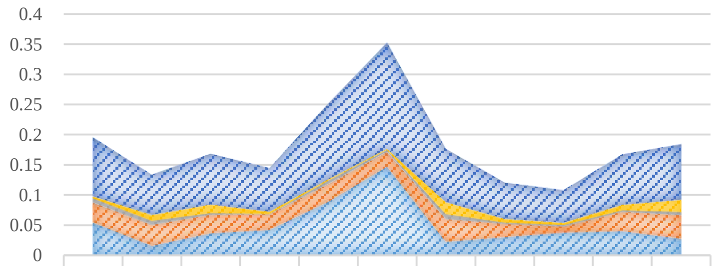
(a) (b) (c)

Fig. 9. (a) Financial, (b) Environmental, and (c) Customer Priorities

IV. CONCLUSIONS

The wind is apower source that countries must profit from and with improving industry most of its drawbacks will disappear as well. Though there are some environmental-safety concerns and there is a performance restrict, wind power can still be favored to most of other powerresources both sustainable and non-sustainabledue to its profits such as being ability to gain profits, its small cost, and clean relatively compared to other power resources.

Fig.10. Wind turbine comparison



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Total	0.0977	0.0667	0.0841	0.0722	0.1257	0.1762	0.0881	0.0602	0.0539	0.0836	0.092
Customer	0.0029	0.0092	0.014	0.0033	0.0018	0.0018	0.0196	0.0056	0.003	0.0088	0.0199
Environment	0.0076	0.0072	0.0029	0.0008	0.006	0.0032	0.0084	0.0024	0.0032	0.0027	0.0056
Economic	0.0331	0.0347	0.0309	0.0261	0.0294	0.0244	0.0378	0.0221	0.0102	0.0322	0.0391
Technical	0.0541	0.0157	0.0363	0.042	0.0885	0.1468	0.0222	0.0301	0.0375	0.0399	0.0274

This study aims to find the most effective 100 KW wind turbine brand based on various criteria exist in the literature. A list of criteria is evaluated and divided into four groups. Each criterion is appointed a relative weight as a result of expert evaluations. Finally, AHP method is applied to the resulting scheme. Based on the calculations above, the relative priorities corresponding to the attractiveness of each wind turbine about all factors of technical, financial, environmental and customer satisfaction are presented in Figure 10.
The obtained results indicate that the model T6 with a global priority of 0.1762 is the alternative that contributes the most to the goal of choosing the best wind turbine that satisfies all the criteria selected.

REFERENCES

[1] Chong Li*, Youying Liu, Gang Li, Jianyan Li, Dasheng Zhu, Wenhua Jia, Guo Li, Youran Zhi, Xinyu Zhai**,** Evaluation of wind energy resource and wind turbine characteristics at two locations in China, Technology in Society 47 (2016) 121-128.

[2] A. V. Da Rosa, Fundamentals of Renewable Energy Processes, California: Academic Press, 2009.

[3] J. F. Manwell, J. G. McGowan and A. L. Rogers, Wind Energy Explained, West Sussex: John Wiley & Sons Inc, 2002.

[4] "Noise from Wind Turbines - The Facts," 2010. [Online]. Available: http://www.bwea.com/ref/noise.html. [Accessed December 2011].

[5] [5] J. Bukal, K. Damaziak, H.R. Karimi, K. Kroszczynski, M. Krzeszowiec, J. Malachowski, Modern small wind turbine design solutions comparison in terms of estimated cost to energy output ratio, Renewable Energy 83 (2015) 1166e1173

[6] K. Ortegon, Loring F. Nies, John W. Sutherland, The Impact of Maintenance and Technology Change on Remanufacturing as a Recovery Alternative for Used Wind Turbines, Procedia CIRP 15 (2014) 182 – 188.

[7] A. Uçar, F. Balo, Investigation of wind characteristics and assessment of wind-generation potentiality in Uludağ-Bursa, Turkey, Applied Energy, 86 (3), 333-339, 2009.

[8] A. Uçar, F. Balo, Investigation of wind turbine characteristics and wind potential assessment of Ankara, Turkey, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33(13), 1291 -1303, 2011

[9] M. Collu, A. Chahardehi, FP. Brennan, MH. Patel. A multi-criteria decision making method to compare support structures for offshore wind turbines. In: European Wind Energy Conference, Warsaw, 2010.

[10] JR. Janke. Multi-criteria GIS modeling of wind and solar farms in Colorado. Renew Energy 2010;35:2228–34.

[11] S. Al-Yahyai, Y. Charabi. Assessment of large-scale wind energy potential in the emerging city of Duqm (Oman). Renew Sustain Energy Rev 2015;47:438-447.

[12] E. Lozano-Minguez,A.J. Kolios, F.P. Brennan, Multi-criteria assessment of offshore wind turbine support structures,Renewable Energy,Volume 36, Issue 11, November 2011, Pages 2831–2837 [15] JM. Sanchez-Lozano, MS. García-Cascales, MT. Lamata. Identification and selection of potential sites for onshore wind farms development in Region of Murcia, Spain. Energy 2014;73:311-324

[13] A. H.I. Lee, Meng-Chan Hung, He-Yau Kang, W.L. Pearn, A wind turbine evaluation model under a multi-criteria decision making environment, Energy Conversion and Management, Volume 64, December 2012, Pages 289–300, (IREC 2011, The International Renewable Energy Congress).

[14] RV. Van Haaren, V. Fthenakis. GIS-based wind farm site selection using spatial multi-criteria analysis (SMCA): evaluating the case for New York State. Renewable Sustain Energy Rev 2011;15:3332–40.
[15] A. Haydar, Ş. Erdoğmuş, E. Koç, Multi-criteria selection for a wind observation station location using analytic hierarchy process, Renewable Energy, Volume 29, Issue 8, July 2004, Pages 1383–1392
[16] L. I. Tegou, H. Polatidis, & D. A. Haralambopoulos. Environmental management framework for wind farm siting: Methodology and case study. Journal of Environmental Management, 91, 2134–2147. (2010).