# Application of Literature and Expert based Delphi Analysis on identifying Most Important Parameter in Selection of Location for Installation of Wind Energy Power Plant

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*Abstract:* The increase in population and advance in technology have enhanced the amount and frequency of energy demand.As fossil fuel is a finite source of power, possible alternatives are now widely researched to substitute the conventional forms of energy.But the irregularity observed in the availability of non-conventional energy resources and cost of converting the potential into utilizable form has prevented wide scale application of the renewable. It was observed that the selection of a location for installations of renewable energy power plants is extremely critical in maximum utilization of the available potential under minimum expenditure. Sometimes hybridization of two renewable or with the conventional energy sources become more successful compared to the individual installations. But here also location selection plays an important role. Again the selection of location depends on various factors having a different level of significance on the desired objective. The present investigation aims to conduct an Individual Component Analysis (ICA) where the most important parameter has to be selected with the help of Literature and Expert based Delphi Analysis (LEDA) which have maximum significance in the selection of an ideal location for a Wind-Wave Hybrid Renewable Power Plant (WWHRPP).If the most important parameter (MIP) can be identified the available locations can be sorted and the most optimal location (MOL) can be earmarked. MCDM is an objective method of decision making which can give an unbiased estimation of importance for the related parameter in a relative scale. The results encourage further application of the study.

*Keywords:* Wind energy power plant, Delphi Analysis, Individual component analysis

## I. INTRODUCTION

The shortage of electricity is a big concern for the whole world because the source of energy is limited. Most of the power is generated by nonrenewable energy source so there is a need of renewable energy system which can be used for the alternatives for the source of power. In this aspect, the hybrid renewable energy system could be a very good alternative for power generation.

A hybrid renewable energy system is the integration of two or more renewable energy system together to provide a continuous supply of energy for increased system efficiency as well as greater balance in energy

supply. The hybrid renewable energy type system comes into the practice because one type of renewable energy system is not able to generate the continuous amount of electricity so in this paper two type of renewable energy resources taken into the account one is wind energy system and other is wave energy system.

## 1.1. Global Renewable Energy Scenario-

The study has shown that the total wind energy resources available in the atmosphere are roughly 200 times the current global energy demand. Compare to another source of wind energy wind energy, therefore, comes 2nd after solar power which is by far the dominant renewable energy resource. Not all the wind energy potential in the atmosphere can be harnessed. more realistic study have shown if we placed a wind turbine infeasible location then the wind energy resources is still 40 times larger than the current energy demand. However, a scientist in the field do believe that wind power can provide a quarter of the total energy demand worldwide.in 2015 wind energy reaches a new milestone where over 60gw new turbine were installed. The cumulative effect over last 20 year is over 400gw of installed wind power capacity [1].



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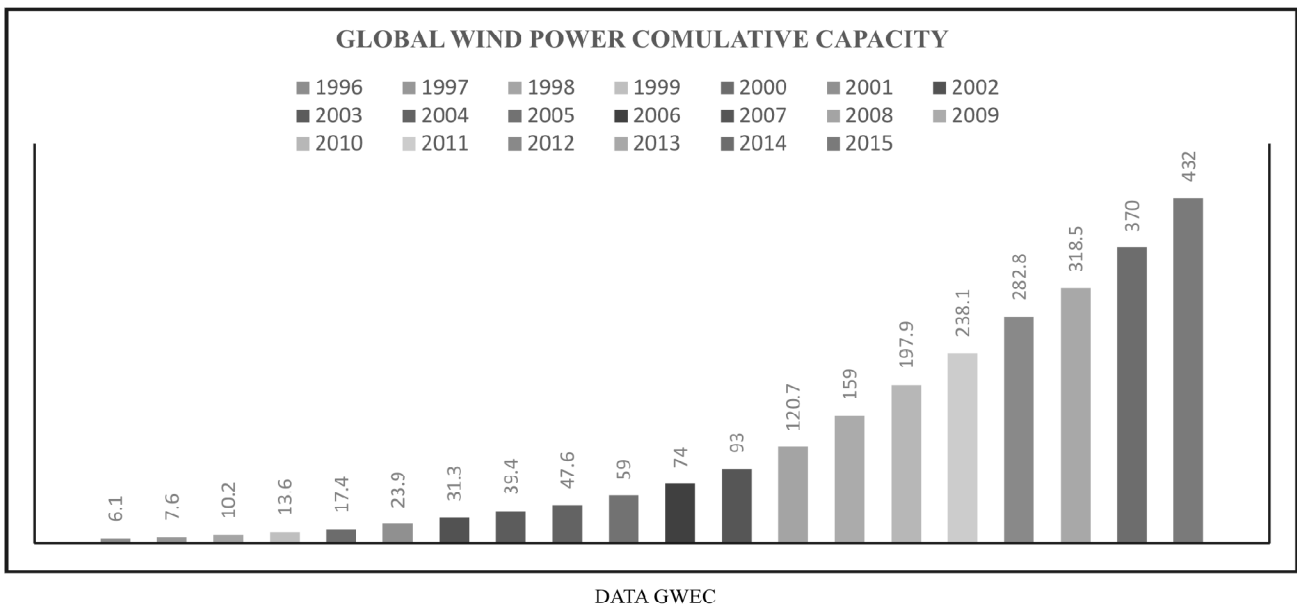
## 1.2. Importance of Wind

As it is known there is a continuous increment in consumption of energy, depletion of natural resources and bad impact on the environment this thing indicate there is a requirement of some renewable energy resources.in this aspect, the wind energy could be a very good alternative because of the advantage of wind energy like the wind is free no fossil fuel required to generate electricity and these system uses less space to generate electricity and it is compatible to make the hybrid energy system along with the another source of energy[2].

Besides this wind energy also have a commercial advantage like home was grown, local land possessor, small businesses can make a setup of a single turbine or group of the turbine.it doesn't even release pollutant and also doesn't contaminant water body. Some hazardous gasses like greenhouse gas which is produced by the conventional source of energy like coal, fuel etc. affect the environment adversely whereas wind energy produces none of them.

## 1.3. Why Location Selection is important?-

In this type of renewable energy, resource location must be suitable because the availability of energy source is not same at all location. Some locations have the high potential of wind because of their climate condition and

some places have poor potential so the selection of suitable location is very important. In other words efficiency of the plant depends on the winds; if the intensity of the wind is high then efficiency also will be high and vice-versa.

## 1.4. A Literature Review on Delphi Analysis

There is general agreement that it was first used in technology forecasting studies initiated by the RAND (Research and Development) Corporation for the American military in 1944 (Gupta and Clarke, 1996). Delphi technique is commonly used to seek the data from the expert within their domain of expertise. In this technique first, communicate to the expert of the issue and gathered the relevant data regarding the issue from them. This technique can be used in the area like to determine the policy and make the assessment etc. This technique can also be used to gain consensus by the survey in which question is asked by the surveyor to the expert according to the requirement of the issue. Basically, there are three types of Delphi technique are widely used and the names are Classical Delphi, policy Delphi, decision Delphi.

Classical type of Delphi based on five-factor anonymity, iteration, controlled feedback, statistical group response and stability.in this Delphi technique expert give their opinion to predict the desired solution.In policy type Delphi technique study the effort is not to move towards the exact solution but the developer tries to develop the policy for the solution. In decision-making type of Delphi technique, a large group of decision makers considers for survey instead of a small number of person [3-4].

## 1.5. Objective

To identify most significant factor for selection of a suitable location for Wind energy power plant with the help of literature and expert based Delphi analysis.

## II. METHODOLOGY

Here is the methodology in which the several steps has been adopted to obtain the required result.so firstly with the help of literature survey, seven factor has been identified which include wind power potential, Wind power density, Capacity factor, Altitude, Annual and seasonal average wind speed, Wind turbine height, Ambient temperatures. Then among that factor, which factor hold the most significant position identified by the survey of four type of literature .first one is decision-making paper(multi-criteria decision making), simulation paper, optimization method paper, general paper.

To find the most significant factor the literature survey has been done in which four type of literature paper has taken into account the first one is simulation paper second one is decision-making paper third one is optimization paper and the fourth one is general paper.
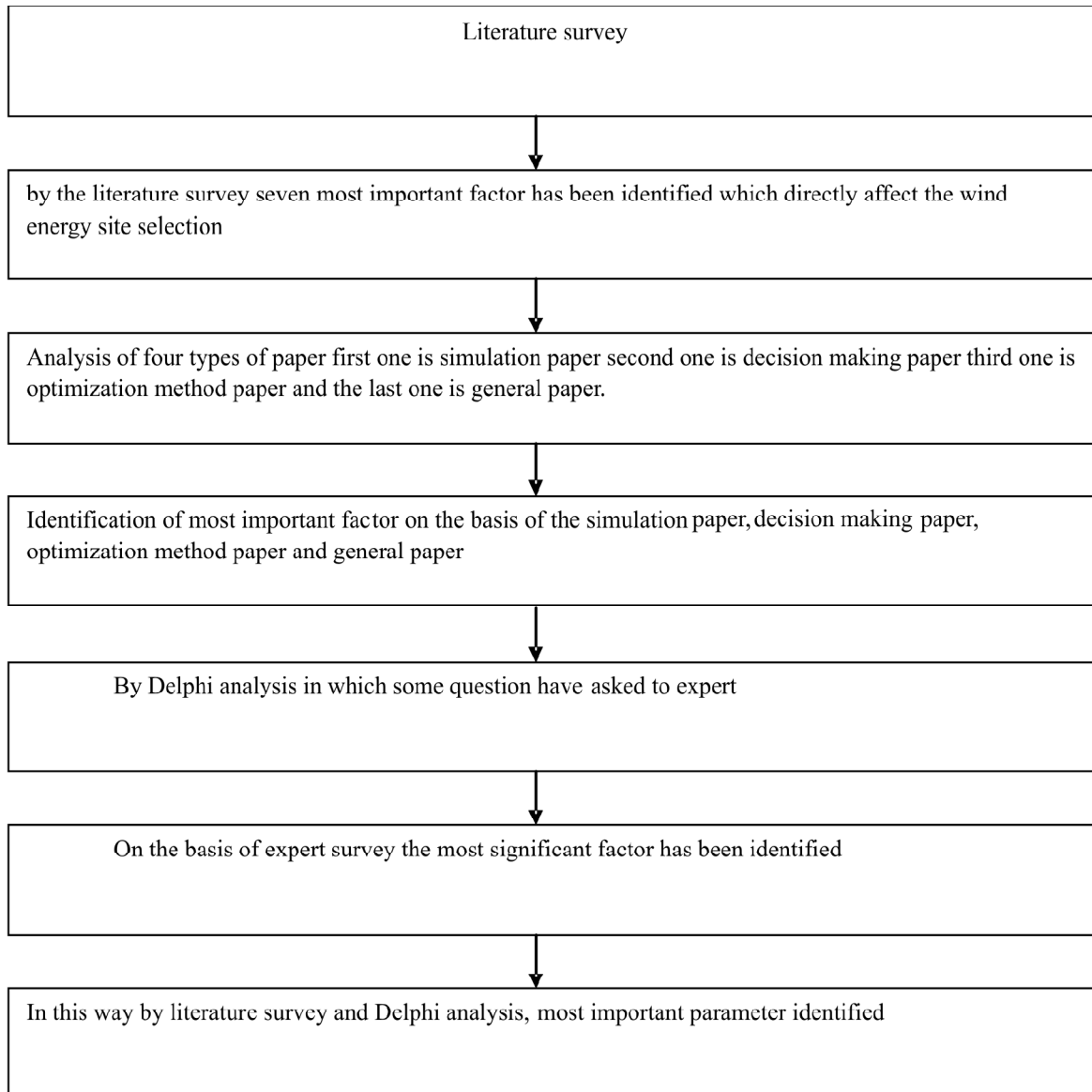
On the basis of literature survey seven factors has been identified which is given below [5]-

1. Wind power potential (WPP): It indicates the source of the energy so availability of it is a key factor for site selection.

2. Capacity factor (CF): The capacity factor also known as load factor is defined as the amount of power which wind turbine can generate at its wind speed. Capacity factor depends on the wind speed or variability of the wind in that location [6].

3. Annual and seasonal average wind speed (WS): Wind speed is the most important factor for site selection. At the start of the site selection process, the long-term mean wind speed of that site should be known. Here the most important factor of wind farm site is wind speed [7].

4. Height at which wind turbine is situated (H): Tower height is the important factor in the selection of suitable site: the wind blows depend on the height of the wind turbine. The wind blows faster at high

altitude because of the drag of the surface and the viscosity and pressure of air. As a result of high altitude the wind speed is higher and the turbine will produce more power [8].

5.  Ambient temperature (AT): Thermal factor potentially important for wind power site selection. Change in temperature water and land can cause local atmospheric circulation which directly affects wind speed. The Wind is usually strong in winter and goes slowdown in summer. Wind speed varies season to season. The temperature gradient can cause a difference in air pressure which directly affects the wind speed [9-10].

6.  Swept area (SA): The power output of the wind turbine is directly related to the swept area of the blades. The larger the diameter of the blades the more power it is capable of extracting from the wind. Swept area is defined as the area through which the blades of wind turbine spin [11].

7.  Blade angle (BA): Blade angle directly affect the power output so it is important [12].

**Methodology flow chart**

| Literature survey |
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| by the literature survey seven most important factor has been identified which directly affect the wind energy site selection |
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| Analysis of four types of paper first one is simulation paper second one is decision making paper third one is optimization method paper and the last one is general paper. |
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| Identification of most important factor on the basis of the simulation paper, decision making paper, optimization method paper and general paper |
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| By Delphi analysis in which some question have asked to expert |
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| On the basis of expert survey the most significant factor has been identified |
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| In this way by literature survey and Delphi analysis, most important parameter identified |
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## III. RESULTS AND DISCUSSIONS

In simulation type of paper, twenty manuscripts are considered and the analysis of papers is given in figure 1. This shows that how many times a particular factor is considered in all twenty papers like factor four is considered in fifteen manuscripts out of twenty papers it means factor four is the most significant factor with respect to simulation paper. In the same way, the analysis of decision-making paper is shown in figure 2 in which factor four are considered in fifteen papers out of fifteen papers then the factor four which indicate the most significant factor with respect to decision-making paper. In optimization type paper factor six are the most important factor in which factor six is considered in ten out of ten papers instead of factor four. In general, type paper factor four is considered in five out of five paper which indicates the most suitable factor with respect to the general paper.
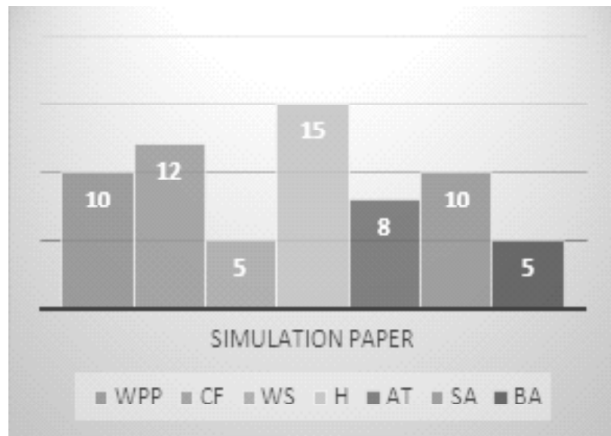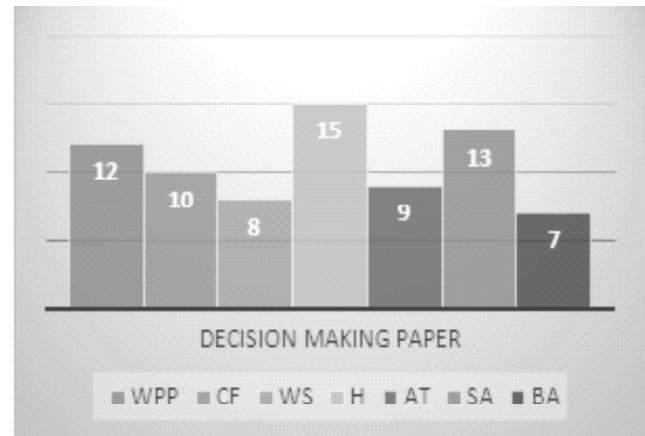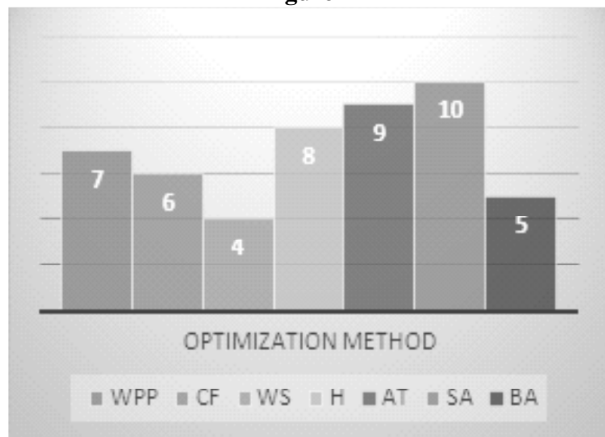

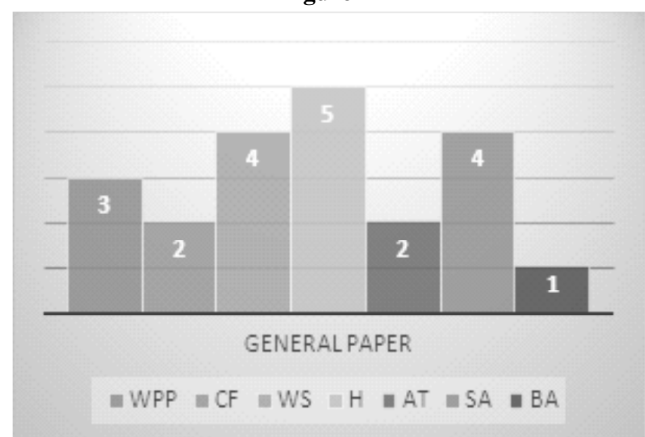
**Figure 1**



**Figure 2**



**Figure 3**



**Figure 4**

The Results are shown in figure 5, 6, 7 indicate the importance pf each parameter with respect to cost, efficiency, and socio-economic and this importance is obtained by the expert survey .expert survey is based on the following question.

1. Which are the parameter do you think to increase the cost of wind power installation?

2. Which parameter can increase the efficiency of wind power system?

3. What is the role of wind power potential in wind power plant?

4. How the Wind speed and tower height affect the plant performance?

5. What is the significance of design variables like Blade angle Swept area of the turbine and Ambient temperature?

These questions are asked to expert and according to their responses, it is found that the capacity factor is the most relevant and important factor and blade angle is found to be a least important factor with respect to cost.

After analyzing the responses of experts it is found that they give priorities for each factor like two experts put the wind power potential into first priorities one expert said that it should be in second priorities and two experts indicate that the position of it should be third and the rest of five have put it into the fourth priorities with respect to cost. So for Wind Power Potential 2, 1, 2 and 5 are the PRIORITIES VALUES and it is multiply by the weightage then the summation of it gives actual index value for wind power potential which is 20. Similarly, priority value and the actual index value for all the factor are given in table 1, 2, 3 with respect to cost, efficiency, socio-economic.

**Index Value = Σ (Priority Value × Weightage)**

**Table 1**
**(I.V. for all Factors with respect to Cost)**

| weightage | 4 | 3 | 2 | 1 | *Σ(P.V. × W)* | *I.V.* |
|---|---|---|---|---|---|---|
| **Parameter/rank** | 1 | 2 | 3 | 4 | | |
| WPP | 2 | 1 | 2 | 5 | (4×2)+(3×1)+(2×2)+(1×5) | 20 |
| CF | 7 | 3 | 0 | 0 | (4×7)+(3×3)+(2×0)+(1×0) | 37 |
| WS | 0 | 3 | 3 | 4 | (4×0)+(3×3)+(2×3)+(1×4) | 19 |
| H | 0 | 2 | 4 | 4 | (4×0)+(3×2)+(2×4)+(1×4) | 18 |
| AT | 0 | 1 | 3 | 7 | (4×0)+(3×1)+(2×3)+(1×7) | 16 |
| SA | 0 | 0 | 3 | 7 | (4×0)+(3×0)+(2×3)+(1×7) | 13 |
| BA | 0 | 0 | 3 | 7 | (4×0)+(3×0)+(2×3)+(1×7) | 13 |

**Table 2**
**(I.V. for all Factors with respect to Efficiency)**

| weightage | 4 | 3 | 2 | 1 | *Σ(P.V. × W)* | *I.V.* |
|---|---|---|---|---|---|---|
| **Parameter/rank** | 1 | 2 | 3 | 4 | | |
| WPP | 7 | 2 | 1 | 0 | (4×7)+(3×2)+(2×1)+(1×0) | 36 |
| CF | 8 | 2 | 0 | 0 | (4×8)+(3×2)+(2×0)+(1×0) | 38 |
| WS | 0 | 2 | 4 | 4 | (4×0)+(3×2)+(2×4)+(1×4) | 18 |
| H | 6 | 3 | 1 | 0 | (4×6)+(3×3)+(2×1)+(1×0) | 35 |
| AT | 0 | 2 | 3 | 5 | (4×0)+(3×2)+(2×3)+(1×5) | 17 |
| SA | 0 | 3 | 4 | 3 | (4×0)+(3×3)+(2×4)+(1×3) | 20 |
| BA | 5 | 2 | 3 | 0 | (4×5)+(3×2)+(2×3)+(1×0) | 32 |

**Table 3**
**(I.V. for all Factors with respect to Socio-Economic)**

| weightage | 4 | 3 | 2 | 1 | *Σ(P.V. × W)* | *I.V.* |
|---|---|---|---|---|---|---|
| **Parameter/rank** | 1 | 2 | 3 | 4 | | |
| WPP | 4 | 3 | 2 | 1 | (4×4)+(3×3)+(2×2)+(1×1) | 30 |
| CF | 6 | 3 | 1 | 0 | (4×6)+(3×3)+(2×1)+(1×0) | 35 |
| WS | 0 | 2 | 3 | 5 | (4×0)+(3×2)+(2×3)+(1×5) | 17 |
| H | 4 | 5 | 1 | 0 | (4×4)+(3×5)+(2×1)+(1×0) | 33 |
| AT | 4 | 5 | 1 | 0 | (4×4)+(3×5)+(2×1)+(1×0) | 33 |
| SA | 0 | 1 | 3 | 6 | (4×0)+(3×1)+(2×3)+(1×6) | 15 |
| BA | 0 | 3 | 2 | 5 | (4×0)+(3×2)+(2×4)+(1×4) | 18 |

**Figure 5**



**Figure 6**



**Figure 7**

## IV. CONCLUSIONS

The present study tried to identify the Most important factor to select a Most important location with the help of LEDA for the installation of Wind Power Plant.According to the results Annual and seasonal average wind speed was found to be a most important parameter with respect to Wind However based on the Cost, Efficiency, socio-economic the parameter capacity factor was found to be Most Important Parameter for the wind. Although the study was successful in the identification of the Most Important Parameter for selection of the location to install the Wind Power Plant. But with respect to an absolute scale and the ranking may change if the relative scale is used. Another limitation of the method is that if another method of ranking is utilized or a number of literature or experts are consulted result may change. That is why a uniform policy may be imposed for the locations under a country or state where the same method, number of sources will be consulted for identification of the most important parameter.

## REFERENCE

[1]    Johansson, Thomas B. *Renewable energy: sources for fuels and electricity*. Island press, 1993.

[2]    Manwell, James F., Jon G. McGowan, and Anthony L. Rogers. *Wind energy explained: theory, design, and application*. John Wiley & Sons, 2010.

[3]    Dalkey, Norman, and Olaf Helmer. "An experimental application of the Delphi method to the use of experts." *Management science* 9, no. 3 (1963): 458-467.

[4]    MacCarthy, Bart L., and Walailak Atthirawong. "Factors affecting location decisions in international operations-a Delphi study." *International Journal of Operations & Production Management* 23, no. 7 (2003): 794-818.

[5]    Ghosh, Soumya, Tilottama Chakraborty, Satyabrata Saha, Mrinmoy Majumder, and Manish Pal. "Development of the location suitability index for wave energy production by ANN and MCDM techniques." *Renewable and Sustainable Energy Reviews* 59 (2016): 1017-1028.

[6]    Wang, Caisheng, and M. Hashem Nehrir. "Analytical approaches for optimal placement of distributed generation sources in power systems." *IEEE Transactions on Power Systems* 19, no. 4 (2004): 2068-2076.

[7]    Ackermann, Thomas, ed. *Wind power in power systems*. Vol. 140. Chichester, UK: John Wiley, 2005.

[8]    Yang, Hongxing, Wei Zhou, Lin Lu, and Zhaohong Fang. "Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm." *Solar energy* 82, no. 4 (2008): 354-367.

[9]    Perez-Collazo, Carlos, D. Greaves, and G. Iglesias. "A review of combined wave and offshore wind energy." *Renewable and Sustainable Energy Reviews* 42 (2015): 141-153.

[10]   Herbert, GM Joselin, Selvaraj Iniyan, E. Sreevalsan, and S. Rajapandian. "A review of wind energy technologies." *Renewable and sustainable energy Reviews* 11, no. 6 (2007): 1117-1145.

[11]   Aras, Haydar, Þenol Erdoðmuþ, and Eylem Koç. "Multi-criteria selection for a wind observation station location using analytic hierarchy process." *Renewable Energy* 29, no. 8 (2004): 1383-1392.

[12]   Lee, Amy HI, Hsing Hung Chen, and He-Yau Kang. "Multi-criteria decision making on strategic selection of wind farms." *Renewable Energy* 34, no. 1 (2009): 120-126.

[13]   Lee, Amy HI, Meng-Chan Hung, He-Yau Kang, and W. L. Pearn. "A wind turbine evaluation model under a multi-criteria decision making environment." *Energy Conversion and Management* 64 (2012): 289-300.