Proceedings of the Federated Conference on Computer Science and Information Systems pp. 1235–1239
DOI: 10.15439/2016F489
ACSIS, Vol. 8. ISSN 2300-5963

MCDA-based Decision Support System for Sustainable Management – RES Case Study

Jarosław Wątróbski
West Pomeranian University of Technology in Szczecin,
Żołnierska 49, 71-210 Szczecin, Poland
Email: jwatrobski@wi.zut.edu.pl

Paweł Ziemba
The Jacob of Paradyż University of Applied Sciences in Gorzów Wielkopolski,
Chopina 52, 66-400 Gorzów Wielkopolski, Poland
Email: pziemba@pwsz.pl

Waldemar Wolski
University of Szczecin,
Mickiewicza 64, 71-101 Szczecin, Poland
Email: wwolski@wneiz.pl

***Abstract*—The MCDA methods are used in order to solve complex decision-making problems which require considering many interrelated criteria. They are also the basis of DSS. Nevertheless, these dependencies between criteria can have an influence on the obtained solution. A class of decision-making problems, in which there are intercriteria dependencies, are decisions in the sustainability area, e.g. selection of a location and a design of an RES-based power station. The article presents a complex model, taking into consideration dependencies between criteria.**

I. Introduction

ONE of the greatest challenges of energy-saving in Poland and other countries of the world is its adaptation to the demands of low carbon economy characterized mostly by the use of renewable energy sources (RES) [1].

The Polish Energy Law Act, which is a source of renewable energy, defines the following: wind energy, solar energy, geothermal energy, sea wave and tidal energy, river fall energy, biomass energy, energy from landfilled biogas and biogas produced in the process of sewage disposal and treatment or decomposition of plants and animal remains [4]. Among the above-mentioned RES, the greatest potential for energy production, which can be found in Poland and the EU have wind farms [2], [3].

The selection of a location [5] and of a project design [6] will lead to the successful implementation of a wind farm project. These choices determine the efficiency of wind power plants and also have an effect on the environment, benefits and costs [7]. The problems of location selection and project design selection, as well as other decision factors related to RES management, are multi-criteria decision-making problems which require the examination of many contradictory and mutually correlated criteria which encompass technological, economic, environmental and social issues [5], [6], [8], [9]. Decision-making methods which consist of a sole criterion are unable to cope efficiently with such decision problems [10]. While solving such problems, multi-criteria decision analysis (MCDA) methods can be applied, as they can handle complex decision processes, multiple and conflicting evaluation criteria, different scenarios, preferences of decision-makers, several sources of uncertainty and specific time frames [11] [12]. Many Decision Support Systems (DSS) are based on MCDA methods and algorithms and used for solving environmental problems and those relating to the power industry [13]. DSS provide knowledge indispensable for making decisions and maximize the results of processes of decisions, by lifting cognitive, special and economic restrictions of the decision-maker [14].

The aim of this article is to establish a multi-criteria decision model, based on MCDA methods, which solve a decision problem comprising of the selection of a location and a project design of an onshore wind farm. The model should not bypass the complexity of the decision problem, but should take into account mutual dependencies between criteria and the influence of some criteria on other ones. This model could become a DSS engine for RES management, while paying particular attention to wind farms.

Section II displays the analysis of the explanations on decision support related to the design and construction of wind farms. The pre-selection of evaluation criteria of wind farm location and design was made according to the implementation of the analysis. The evaluation criteria were incorporated into a decision model, which was presented in Section III. Section IV contains a summary of research results, and further research directions are also pointed out.

II. Literature review

Publications regarding the decision for support in wind energy mostly include the construction of decision models as well as that of DSS and GIS (Geographical Information System) systems.

An example of constructing a decision model for the selection of a wind farm location is [15]. In this paper, evaluation criteria and their importance were presented in a decision model for the sake of selecting a wind farm location. On the other hand, in [16] a decision model was devised in order to compare different RES technologies (wind energy received the highest rank), and it subsequently modified in order to select a location of an onshore wind farm. The issue of devising a decision model for the selection of an onshore wind farm location is also dealt with in [17], and an offshore one received a similar treatment in [5]. GIS decision systems were suggested, amongst other things in [18], [19], [20], [21]. These systems evaluate the potential of onshore areas regarding the situation of wind farms nearby. Similarly, in [22] a GIS was presented; itallowed the evaluation of a location of hybrid power stations based on wind and solar energies. In [23], a GIS-based DSS system analyzing the potential of onshore wind farm locations was discussed. The problem of the construction of a DSS for selecting an offshore wind location was attempted in [24], [7]. As far as decision problems relating to the project design of a wind farms are concerned, these were discussed in [6], [25]. The technical aspects of wind turbines are also related to farm designs[8] as well as wind farm development evaluation, in the bigger picture [26].

The AHP (Analytic Hierarchy Process) [27] method is used in selecting a location or a design of a wind farm, both in its crisp and fuzzy [28] [29] versions. It is primarily employed to determine the importance of criteria. A generalization of AHP, namely ANP (Analytic Network Process) [30], and different variants of the ELECTRE method are rarely used. Other MCDA methods, such as DEMATEL, OWA, SAW, PROMETHEE, NAIADE, TOPSIS, VIKOR, Lexicographic method and the conjunctive method, etc are also incidentally used. [31]. It should be noted that, in order to solve decision-making problems related to wind energy, decision models are used, and these are characterized by various complexities. The amount of criteria considered while selecting a location or a design of a wind firm ranges from 6 [19] to 35 [6]. These criteria are often interrelated and interdependent. For example, in this publication [6], the following criteria were used: generating cost, generating profit, and payback period. It can be easily seen that the payback period results from, among other things, a calculation of costs and profits.

III. THE PROPOSED DECISION MODEL FOR DSS

The construction of the decision model was done in the following manner:

1) The preparation of a set of criteria and sub-criteria for the evaluation of locations and designs of onshore wind farms,
2) The analysis of sub-criteria and indication of relationships and dependencies which occur place between them,
3) The presentation of sub-criteria dependencies in a networking decision model.

On the basis of the literature analysis presented in Section II, a set of criteria for the evaluations of locations and designs of onshore wind farms was prepared and displayed in Table I. The sub-criteria section was shown as well.

Next, the sub-criteria were analyzed and their interdependencies were explained.

C1.1The wind conditions influence the output power which is obtained from a wind turbine, at a specific wind speed and consequently, the desired amount of energy is generated. Generally, a stronger wind generates more energy; however, the wind should not be too strong, as most wind turbines switch off when the wind reaches the speed of about 25-30 m/s [8]. The wind speed is essential, depending on the height at ground level. Most towers which have turbines mounted onto them are 50-100m high [32], therefore the wind speed at the height of ca. 100m is crucial.

TABLE I.
CRITERIA AND SUB-CRITERIA FOR EVALUATING LOCATIONS AND DESIGNS OF ONSHORE WIND FARMS

Criteria		Sub-criteria		References
C1	Technical	C1.1	Average wind speed at the height of 100m	[5], [6], [15], [17], [19]-[21], [23], [24], [26]
		C1.2	Output power of wind turbine	[8]
		C1.3	Power grid voltage on the site of connection	[26]
C2	Economic	C2.1	Yearly amount of energy generated	[6], [7], [25]
		C2.2	Investment cost	[5]-[7], [16], [25]
		C2.3	Operational costs per year	[5], [6], [16], [25]
		C2.4	Incomes from generated energy per year	[26]
		C2.5	Profits from generated energy per year	[5], [6], [24]
		C2.6	Payback period	[5]-[7]
C3	Social	C3.1	Number of generated workplaces	[5], [6], [15]
		C3.2	Social acceptance	[16], [25]
C4	Spatial and environmental	C4.1	Distance from power grid connection	[20]-[24]
		C4.2	Distance from the road network	[15], [18]-[23]
		C4.3	Location in Natura 2000 protected area	[7], [19], [22], [23]

C1.2 The maximum output power of a turbine is achieved at a specific wind speed, which is critical. If the wind speed is lower, then the output power is equally lower.

C1.3 Voltages of the national power grid, which are used in Poland, amount to 110kV, 220kV, 400kV and 750kV [33]. The voltage of a power grid is an essential sub-criterion, since changes in the wind speed cause frequency, voltage and power fluctuations in the grid connected to a wind turbine [34]. Such fluctuations may, in turn, cause damage to transmission lines of the grid or transformers. Such a hazard is more likely in the case of high-voltage wind farms (from several dozens of MW) to a low-voltage grid (110kV) [35].

C2.1 We have mentioned above that the amount of energy generated is directly affected by the output power of wind turbines installed in the wind farm. The yearly amount of energy generated by a wind farm is presented, in its simplest form, in the formula (1):

$$E = \sum_i W_{out}(t_i) * 8760 \qquad (1)$$

where: E – yearly amount of energy generated [MWh], $W_{out}(t_i)$ – output power of an i-th turbine [AMW], 8760 – the number of hours in a year [Ah].

C2.2 The overall investment costs consist mostly of the costs of purchasing and installing turbines, towers and their foundations, the costs of preparing a wind farm design, as well as the costs of connecting a wind farm to the power grid [36]. The amount of capital investment for an onshore wind farm in Poland, depending on the technology applied, varies from 4.5 million to 7.5 million PLN/MW [37].
C2.3 The operational costs also include the operation, repairs and servicing of the devices, leasing costs of the land, management, insurance, taxes and charges, the energy consumption of the wind farm, as well as balance costs. It is estimated that the operation costs of a wind farm in Poland in 2011, in total, amounted to 83 PLN per one MWh of the energy generated by the wind farm [36].
C2.4 The income from the energy production is a product of generated (and sold) amount of energy and its price. An average sales price of the electric energy on the competitive market in Poland in the third quarter of 2015 amounted to ca. 173 PLN/MWh [38]. However, a new law defining RES auctions has been recently introduced. RES-based power stations can participate in such auctions. When an auction is won, the power station has the certainty that the Polish state will purchase from them the energy at a set price for a period of 15 years [39]. The reference price of the onshore wind energy for an RES auction, which is generated in a wind farm of combined power greater than 1MW in 2016, amounts to 385PLN/MWh [40].
C2.5 In simple terms, a yearly profit from selling the energy can be determined as being the difference between incomes from the energy sales and operational costs incurred to generate the energy sold.
C2.6 The payback period determines a period of time after which capital expenditure incurred through the construction of a wind farm will pay for itself. The payback period is, in fact, a ratio of investment costs to a yearly profit generated by the wind farm.
C3.1 The construction of new wind farms and maintenance of existing ones generate workplaces related to the preparation of the investment, its operation, maintenance, repairs and equipment servicing. Estimates for Poland suggest that the installation of 10MW in a given year generates 39 direct and 75 indirect workplaces. The maintenance of 10MW, in turn, is connected with the employment of 5 workers in subsequent years [41].
C3.2 Social acceptance refers to benefits, threats and inconveniences for a local community. Research results highlight that the high level of acceptance for the wind energy is declared by about 12% of Polish citizens, low – 3%, whereas 85% of Polish citizens accept the wind energy to a certain degree. [42]. It is unlikely that potential workplaces can positively influence the social acceptance of constructing a wind farm.
C4.1 The distance from a power grid connection is related with the facility of connecting the wind farm to the power grid. Such a connection should be as close as possible, since it reduces the possibility of potential problems on a transfer line related to the quality and stability of power supply [43].
C4.2 The distance from the road is important during the construction period. A short distance from main roads enables the comfortable delivery of construction elements, such as masts or rotors, to the site. One needs to understand that, as far as Poland is concerned, the road infrastructure is usually poorly developed in the areas with good wind conditions, [44].
C4.3 The Natura 2000 protected areas are breeding and resting sites for rare and endangered fauna and flora, as well as some rare natural habitats which are crucial to the European Community [45]. Locations which form part of the Natura 2000 protected areas are more likely to encounter difficulties with investment, since some potentially negative acts towards the sites are prohibited. It is possible to obtain permits to carry out actions which negatively impact the sites [45]; however, these are connected with incurring financial outlays and downtimes in the construction of a wind farm. It should be noted that, according to Polish law, wind farms and other buildings cannot be situated within national and landscape parks or nature reserves [45].

On the basis of the individual analysis of sub-criteria one can easily determine their dependencies and relationships. These dependencies of one criterion onto another are illustrated by a graphic outline of the decision model presented in Figure 1.

IV. Conclusions

The complex decision model, prepared by the authors of this article was prepared, in order to deal with the problem of selection of the location and design of a wind farm. Therefore, it takes into consideration complex dependencies between decision-making criteria (sub-criteria) and consequently, it can be more precise than decision models which assume independence between criteria.

The precision of a decision model is particularly important in Decision Support Systems; the latter recommend pareto optimal solutions to decision-makers. In the case of a less accurate decision model which does not take into consideration interdependencies of criteria, recommendations obtained in DSS can be inexact. Therefore, the designed decision model can be used as a DSS decision engine.

The verification of the prepared decision model should be carried out while taking into account the decision problem in the field of wind energy. Unfortunately, most MCDA methods, which form the foundation of DSS, assume that the independency between criteria is to simplify the decision-making process. These methods cannot be easily applied to more challenging decision-making problems [46] because, if redundant criteria are used in the model, one can reach an incorrect solution [47]. Therefore, an essential factor is a proper selection of an MCDA method [48], [31] which would make it possible to build a complex decision-making

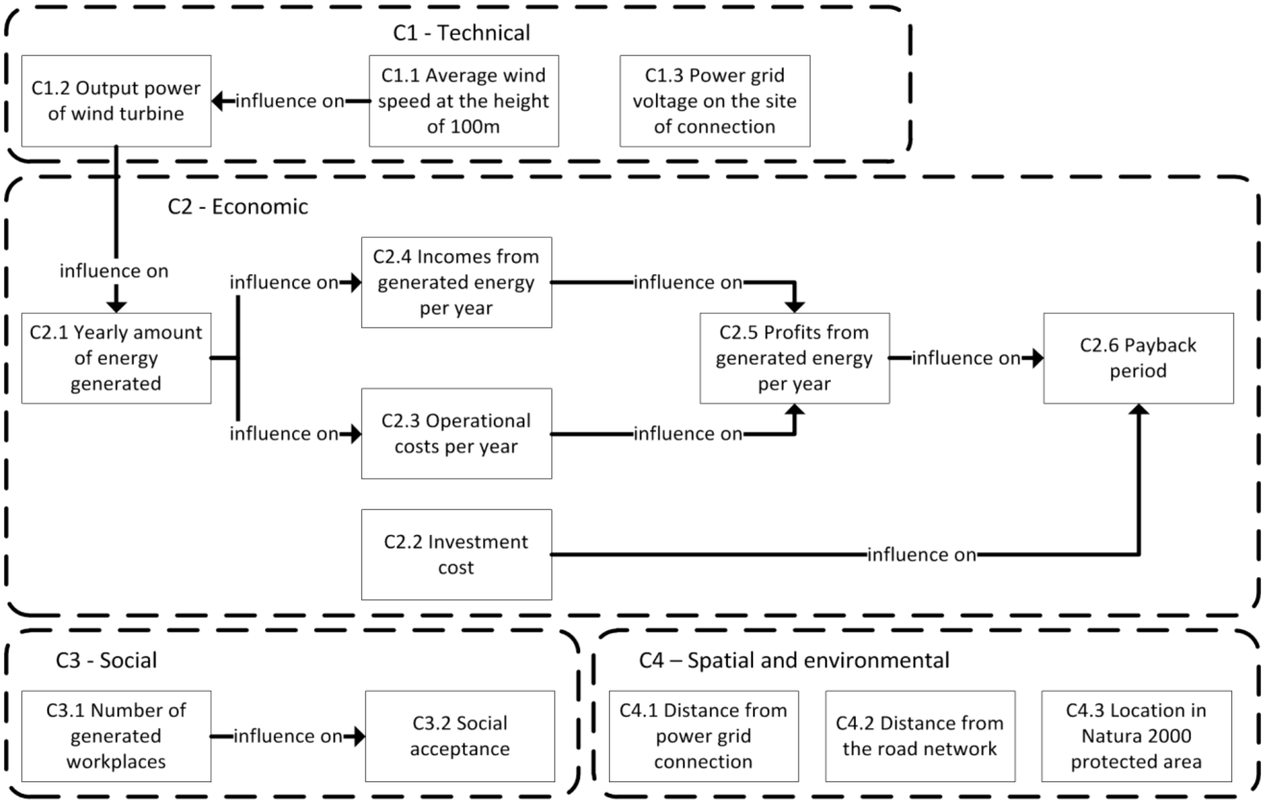

Fig. 1 Dependencies between criteria considered in the decision model

model for DSS, while taking into consideration mutual dependencies between criteria. The methods which allow the observation of the influence of individual criteria on other ones in the model are ANP [49], [30] and DEMATEL [50], [24].

The decision model which has been designed should evidently be used on a continuous basis. The best course of action would be to add criteria and sub-criteria of evaluations of wind farms, as well as other RES factors to the model. It would also be interesting to present the decision model in the form of an ontology [51], which would enable the deduction of new information from the model [52], [53]. The performance of the model would also move in a smoother manner towards the application of DSS in other situations.

REFERENCES

[1] K. Halicka, "Designing routes of development of renewable energy technologies," *Procedia – Social and Behavioral Sciences*, vol. 156, pp. 58-62, 2014.

[2] J. Paska and T. Surma, "Electricity generation from renewable energy sources in Poland," *Renewable Energy*, vol. 71, pp. 286-294, 2014.

[3] N. Scarlat, J.F. Dallemand, F. Monforti-Ferrario, M. Banja, and V. Motola, "Renewable energy policy framework and bioenergy contribution in the European Union – An overview from National Renewable Energy Action Plans and Progress Reports," *Renewable and Sustainable Energy Reviews*, vol. 51, pp. 969-985, 2015.

[4] J. Paska, M. Sałek, and T. Surma, "Current status and perspectives of renewable energy sources in Poland," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 142-154, 2009.

[5] Y. Wu, J. Zhang, J. Yuan, S. Geng, and H. Zhang, "Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: A case of China," *Energy Conversion and Management*, vol. 113, pp. 66-81, 2016.

[6] Y. Wu, S. Geng, H. Xu, and H. Zhang, "Study of decision framework of wind farm project plan selection under intuitionistic fuzzy set and fuzzy measure environment," *Energy Conversion and Management*, vol. 87, pp. 274-284, 2014.

[7] J. Wątróbski, P. Ziemba, and W. Wolski, "Methodological Aspects of Decision Support System for the Location of Renewable Energy Sources," *Annals of Computer Science and Information Systems*, vol. 5, pp. 1451-1459, 2015. http://dx.doi.org/ 10.15439/2015F294

[8] A.H.I. Lee, M.C. Hung, H.Y. Kang, and W.L. Pearn, "A wind turbine evaluation model under a multi-criteria decision making environment," *Energy Conversion and Management*, vol. 64, pp. 289-300, 2012.

[9] R.A. Taha and T. Daim, "Multi-Criteria Applications in Renewable Energy Analysis, a Literature Review," in *Research and Technology Management in the Electricity Industry*, T. Daim, T. Oliver, and J. Kim, Ed. London: Springer, 2013, pp. 17-30.

[10] J.R. San Cristobal, "Multi-criteria decision making in the selection of a renewable energy project in spain: The Vikor method," *Renewable Energy*, vol. 36, pp. 498-502, 2011.

[11] C. Henggeler Antunes and C. Oliveira Henriques, "Multi-Objective Optimization and Multi-Criteria Analysis Models and Methods for Problems in the Energy Sector," in *Multiple Criteria Decision Analysis. State of the Art Surveys*, 2nd ed., S. Greco, M. Ehrgott, and J.R. Figueira, Ed. New York: Springer, 2016, pp. 1067-1165.

[12] J. Jankowski, J. Wątróbski, P. Ziemba, "Modelling the impact of visual components on verbal comunication in online advertising," in *Computational Collective Intelligence. ICCCI 2015, Part II. LNAI,* vol. 9330, Heidelberg: Springer, 2015, pp. 44-53.

[13] F. Cavallaro, "Multi-criteria decision aid to assess concentrated solar thermal technologies," *Renewable Energy*, vol. 34, pp. 1678-1685, 2009.

[14] C.W. Holsapple, "DSS Architecture and Types," in *Handbook on Decision Support Systems*, vol. 1, F. Burstein and C.W. Holsapple, Ed. Heidelberg: Springer, 2008, pp. 163-189.

[15] T.M. Yeh and Y.L. Huang, “Factors in determining wind farm location: Integrating GQM, fuzzy DEMATEL and ANP,” *Renewable Energy*, vol. 66, pp. 159-169, 2014.

[16] T. Kaya and C. Kahraman, “Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul,” *Energy*, vol. 35, pp. 2517-2527, 2010.

[17] A.H.I. Lee, H.H. Chen, and H.Y. Kang, “Multi-criteria decision making on strategic selection of wind farms,” *Renewable Energy*, vol. 34, pp. 120-126, 2009.

[18] S. Al-Yahyai, Y. Charabi, A. Gastli, and A. Al-Badi, “Wind farm land suitability indexing using multi-criteria analysis,” *Renewable Energy*, vol. 44, pp. 80-87, 2012.

[19] D. Latinopoulos and K. Kechagia, “A GIS-based multi-criteria evaluation for wind farm site selection. A regional scale application in Greece,” *Renewable Energy*, vol. 78, pp. 550-560, 2015.

[20] J.M. Sanchez-Lozano, M.S. Garcia-Cascales, and M.T. Lamata, “Identification and selection of potential sites for onshore wind farms development in Region of Murcia, Spain,” *Energy*, vol. 73, pp. 311-324, 2014.

[21] J.M. Sanchez-Lozano, M.S. Garcia-Cascales, and M.T. Lamata, “GIS-based onshore wind farm site selection using Fuzzy Multi-Criteria Decision Making methods. Evaluating the case of Southeastern Spain,” *Applied Energy*, vol. 171, pp. 86-102, 2016.

[22] N.Y. Aydin, E. Kentel, H.S. Duzgun, “GIS-based site selection methodology for hybrid renewable energy systems: A case study from western Turkey,” *Energy Conversion and Management*, vol. 70, pp. 90-106, 2013.

[23] Y. Noorollahi, H. Yousefi, and M. Mohammadi, “Multi-criteria decision support system for wind farm site selection using GIS,” *Sustainable Energy Technologies and Assessments*, vol. 13, pp. 38-50, 2016.

[24] A. Fetanat and E. Khorasaninejad, “A novel hybrid MCDM approach for offshore wind farm site selection: A case study of Iran,” *Ocean & Coastal Management*, vol. 109, pp. 17-28, 2015.

[25] F. Cavallaro and L. Ciraolo, “A multicriteria approach to evaluate wind energy plants on an Italian island,” *Energy Policy*, vol. 33, pp. 235-244, 2005.

[26] W. Tian, J. Bai, H. Sun, and Y. Zhao, “Application of the analytic hierarchy process to a sustainability assessment of coastal beach axploitation: A case study of the wind power projects on the coastal beaches of Yancheng, China,” *Journal of Environmental Management*, vol. 115, pp. 251-256, 2013.

[27] P. Ziemba, J. Wątróbski, J. Jankowski, and M. Piwowarski, “Research on the Properties of the AHP in the Environment of Inaccurate Expert Evaluations,” in *Selected Issues in Experimental Economics*, K. Nermend and M. Łatuszyńska, Ed. Switzerland: Springer, 2016, pp. 227-243.

[28] J. Jankowski, J. Watrobski, and M. Piwowarski, “Fuzzy Modeling of Digital Products Pricing in the Virtual Marketplace,” in *Proceedings of 6th International Conference on Hybrid Artificial Intelligent Systems*, LNCS, vol. 6678. Heidelberg: Springer, 2011, pp. 338-346.

[29] J. Jankowski, K. Kolomvatsos, P. Kazienko, J. Wątróbski, "Fuzzy Modeling of User Behaviors and Virtual Goods Purchases in Social Networking Platforms," *Journal of Universal Computer Science*, vol. 22, no. 3, pp. 416-437, 2016.

[30] P. Ziemba and J. Wątróbski, “Selected Issues of Rank Reversal Problem in ANP Method,” in *Selected Issues in Experimental Economics*, K. Nermend and M. Łatuszyńska, Ed. Switzerland: Springer, 2016, pp. 203-225.

[31] J. Wątróbski, J. Jankowski, “Guideline for MCDA Method Selection in Production Management Area,” in *New Frontiers in Information and Production Systems Modelling and Analysis. Intelligent Systems Reference Library*, vol. 98, Heidelberg: Springer, 2016, pp. 119-138.

[32] Y. Kumar, J. Ringenberg, S.S. Depuru, V.K. Devabhaktuni, J.W. Lee, E. Nikolaidis, B. Andersen, and A. Afjeh, “Wind energy: Trends and enabling technologies,” *Renewable and Sustainable Energy Reviews*, vol. 53, pp. 209-224, 2016.

[33] *Plan sieci elektroenergetycznej najwyższych napięć*, PSE, http://www.pse.pl/index.php?dzid=80&did=23

[34] H. Sadeghi, “A novel method for adaptative distance protection of transmission line connected to wind farms,” *Electrical Power and Energy Systems*, vol. 43, pp. 1376-1382, 2012.

[35] J. Paska and M. Kłos, “Elektrownie wiatrowe w systemie elektroenergetycznym – przyłączanie, wpływ na system i ekonomika,” *Rynek energii*, no. 1/2010, pp. 3-10, 2010.

[36] *Wpływ energetyki wiatrowej na wzrost gospodarczy w Polsce*, Report, Ernst & Young, March 2013.

[37] *Wind energy in Poland*, Report, TPA Horwath, November 2013.

[38] *Informacja Prezesa Urzędu Regulacji Energetyki nr 46/2015 w sprawie średniej ceny sprzedaży energii elektrycznej na rynku konkurencyjnym w III kwartale 2015 roku*, Energy Regulatory Office, 21 December 2015, http://www.ure.gov.pl/pl/stanowiska/ 6361, Informacja-nr-462015.html

[39] *Ustawa o odnawialnych źródłach energii*, Dziennik Ustaw RP, 20 February 2015, http://isap.sejm.gov.pl/ DetailsServlet?id=WDU20150000478

[40] *Rozporządzenie Ministra Gospodarki w sprawie ceny referencyjnej energii elektrycznej z odnawialnych źródeł energii w 2016 roku*, Dziennik Ustaw RP, 13 November 2015, http://dziennikustaw.gov.pl/du/2015/2063/1

[41] M. Bukowski and A. Śniegocki, *Wpływ energetyki wiatrowej na polski rynek pracy*. Warszawa: Warszawski Instytut Studiów Ekonomicznych, 2015.

[42] B. Mroczek, *Akceptacja dorosłych Polaków dla energii wiatrowej i innych odnawialnych źródeł energii (streszczenie raportu)*. Szczecin: Polskie Stowarzyszenie Energetyki Wiatrowej, 21 March 2011.

[43] F. Santier, “Influence of Transmission Lines on Grid Connection,” in *Proc. Deutsche Windenergie-Konferenz DEWEK 2006*, Bremen, 22-23 November 2006.

[44] P. Michalak and J. Zimny, “Wind energy development in the world, Europe and Poland from 1995 to 2009; current status and future perspectives,” *Renewable and Sustainable Energy Reviews*, vol. 15, pp. 2330-2341, 2011.

[45] *Ustawa o ochronie przyrody*, Dziennik Ustaw RP, 18 April 2016, http://isap.sejm.gov.pl/DetailsServlet?id=WDU20040920880

[46] A. de Montis, P. De Toro, B. Droste-Franke, I. Omann, and S. Stagl, “Assessing the quality of different MCDA methods,” in *Alternatives for Environmental Valuation*, M. Getzner, C.L. Spash, and S. Stagl, Ed. New York: Taylor & Francis, 2005, pp. 99-133.

[47] P. Thokala and A. Duenas, “Multiple Criteria Decision Analysis for Health Technology Assessment,” *Value in Health*, vol. 15, no. 8, pp. 1172-1181, 2012.

[48] J. Wątróbski, J. Jankowski, “Knowledge Management in MCDA Domain,” in *Proceedings of the Federated Conference on Computer Science and Information Systems. Annals of Computer Science and Information Systems*, vol. 5, pp. 1445–1450, 2015.

[49] T. L. Saaty and L.G. Vargas, *Decision Making with the Analytic Network Process. Second Edition*. New York: Springer, 2013.

[50] H. S. Lee, G.H. Tzeng, W. Yeih, Y.J. Wang, and S.C. Yang, “Revised DEMATEL: Resolving the Infeasibility of DEMATEL,” *Applied Mathematical Modelling*, vol. 37, no. 10-11, 2013, pp. 6746-6757.

[51] P. Ziemba, J. Jankowski, J. Wątróbski, J. Becker, „Knowledge Management in Website Quality Evaluation Domain,” *Lecture Notes in Artificial Intelligence*, vol. 9330, pp. 75-85, 2015.

[52] P. Ziemba, J. Jankowski, J. Wątróbski, W. Wolski, and J. Becker, “Integration of Domain Ontologies in the Repository of Website Evaluation Methods,” *Annals of Computer Science and Information Systems*, vol. 5, pp. 1585-1595, 2015. http://dx.doi.org/ 10.15439/2015F297

[53] P. Ziemba, J. Wątróbski, J. Jankowski, and W. Wolski, “Construction and Restructuring of the Knowledge Repository of Website Evaluation Methods,” *Lecture Notes in Business Information Processing*, vol. 243, pp. 29-52, 2016. http://dx.doi.org/ 10.1007/978-3-319-30528-8_3