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APPLICATION OF THE MULTI-CRITERIA ANALYSIS METHOD MAIRCA, SPOTIS, COMET FOR THE OPTIMISATION OF SUSTAINABLE ELECTRICITY TECHNOLOGY DEVELOPMENT

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Abstract

The development of sustainable electricity technology is of utmost importance in addressing the increasing energy demand while mitigating greenhouse gas emissions. Fossil fuel-based electricity generation is the primary contributor to air pollution and climate change, necessitating a shift towards renewable energy sources. The efficient production, distribution, and utilization of energy resources, along with ensuring affordable energy access and environmental sustainability, are key policy objectives for any country's energy sector. However, assessing sustainable electricity technologies is a complex task due to the diverse range of evaluation criteria and impacts associated with the practical implementation of these solutions. To overcome this challenge, this study proposes a multi-criteria decision-making (MCDM) approach to select the optimal solution for the development of sustainable electricity technology. The study employs several reliable methods, including MAIRCA, SPOTIS, COMET, and the CRITIC weighting method, to perform ranking evaluations. Based on this, an evaluation Table of criteria using linguistic variables is constructed. Furthermore, a ranking of methods for developing sustainable electricity technology is established by combining MCDM optimization methods. The results indicate that future energy policies should prioritize sustainable energy technologies, particularly water and solar thermal solutions. These findings have significant implications for development policymakers as the transition towards a sustainable energy system becomes increasingly crucial. In the future, the findings of this research can be further developed on a regional level, enabling the identification of the most appropriate energy technologies for specific regions based on their unique characteristics and requirements.

Keywords: sustainable energy, MCDM methods, electricity production, weighting method, energy policies.

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1. Introduction

Sustainable technology development is all about creating and implementing environmentally friendly solutions. One particular focus is on sustainable electric energy generation, which many countries are striving for. This involves harnessing sources like solar, wind, hydroelectric, and geothermal energy to produce electricity. The goal is to reduce carbon emissions and decrease reliance on non-renewable energy, leading to a more sustainable and eco-friendly energy system. When developing sustainable electricity technology, it's essential to consider the economic, social, and environmental impacts, aiming to find solutions that benefit all aspects [1, 2]. However, choosing the right electric energy development technology can be a bit complicated with conflicting objectives. That's why decision-making for sustainable electric energy policies are necessary. Many authors have explored this area and introduced various methods, such as the multi-criteria decision-making (MCDM) approach [3–7].

In [8], the authors utilized the MAIRCA method to aid in decision-making for powder-mixed electrical discharge machining (PMEDM). This is the first time that the combination of MARCOS, TOPSIS, and MAIRCA has been used in this field to determine the best solution. Another study [9] also employed the MAIRCA method to evaluate flood susceptibility in Iran's Golestan Province and compared it with MLP neural network-based models. The results showed that MAIRCA is advantageous in making a suitable choice for this research problem. In [10], the MAIRCA method and various weighting techniques were applied to rank solutions in the hole turning process. This study stands out for using multiple methods to make the best choice. Additionally, the MAIRCA method has been instrumental in sustainable material selection [11], with one study introducing an integrated approach to assess the sustainability of biomass resources for biofuel production [12]. Furthermore, the MAIRCA method was used to evaluate the environmental performance of suppliers in the context of green supply chain management in [13]. These examples demonstrate the effectiveness of the MAIRCA method in evaluating options with multiple criteria. Another notable MCDM method is SPOTIS, which avoids rank reversal and uses distance metrics to establish preference ordering [14]. In one study, researchers introduced a new method called Temporal SWARA-SPOTIS to evaluate the temporal performance of alternatives by combining the SWARA method for determining significance values of periods with the SPOTIS method for multi-criteria assessment [15]. In [16], the authors extended the SPOTIS method to fuzzy environments to avoid rank reversal in multi-criteria problems, and the results showed its effectiveness in objectively evaluating criteria. The combination of SPOTIS with other methods has also proven to be effective, as seen in its application in decision-making for the powder-mixed electrical discharge machining process [17]. COMET is another widely used MCDM method that allows for the identification of the entire domain model, providing objectives and reliable recommendations based on gathered data [18]. Building upon COMET, a new MCDM method using the concept of NIVTFNs was developed in [19]. Additionally, COMET has been utilized in solving problems for Multi-Criteria Group Decision-Making (MCGDM) in a hesitant fuzzy environment [20], making it another effective method for MCDM problems. CRITIC is a popular method for determining criteria weights in MCDM problems [21], and in one study, it was used to rank and outline suitable public blockchain platforms [22]. Furthermore, CRITIC has also been applied to optimize materials for energy savings [23].

In this study, our objective is to select the most suitable sustainable electricity technology by employing various MCDM methods that possess distinct characteristics. By incorporating these reviews, let's enhance the credibility of our study. Furthermore, let's introduce the CRITIC weighting method to ensure impartiality in prioritizing criteria. It is worth noting that this study is the first to combine MCDM methods with the CRITIC weighting method.

2. Materials and methods

2. 1. MAIRCA method

The ranking of criteria is conducted according to the MAIRCA method, according to the following steps [24]:

Step 1. Building the decision matrix:

$$X=\left[x_{ij}\right]_{n\times m}=\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ x_{21} & \cdots & x_{2n} \\ \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, \tag{1}$$

where x_{ij} denote the element of the decision matrix corresponding to the i^{th} alternative and j^{th} attribute. Here, m refers to the total number of choices, while n represents the number of criteria being considered.

Step 2. Defining preferences for the choice of alternatives P_{Aj}:

$$P_{Aj}=\frac{1}{m};\ j=1,\ldots,n. \tag{2}$$

Step 3. Determine the elements t_{pij} of the theoretical rating matrix:

$$t_{p_{ij}}=P_{A_j}w_j;\ i=1,\ldots,m;\ j=1,\ldots,n. \tag{3}$$

Here, w_j represents the weight of the j^{th} criterion.

Step 4. Calculating the elements t_{ij} of the real rating matrix.

If the criterion j is such that a larger value is considered better:

$$t_{ij} = t_{p_{ij}} \cdot \left(\frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \right). \tag{4}$$

If the criterion j is such that a smaller value is considered better:

$$t_{ij} = t_{p_{ij}} \cdot \left(\frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \right). \tag{5}$$

Step 5. The total gap matrix e_{ij} is calculated by utilizing the following equation:

$$e_{ij} = t_{p_{ij}} - t_{rij} . \tag{6}$$

Step 6. The calculation of the final values of criteria functions Q_i by alternatives:

$$Q_i = \sum_{i=1}^{m} g_{ij}. \tag{7}$$

2. 2. SPOTIS method

In order to implement the SPOTIS method, the following steps need to be performed [14]:

Step 1. Similar to the first step of the MAIRCA method.

Step 2. Establish the boundaries of the problem:

$$\left[P_n^{min}, P_n^{max} \right] = \left[x_1, x_2 \right], \tag{8}$$

where n is the criterion number, x_1 is the min bound, x_2 is the max bound.

Step 3. Specify the ideal solution point. For profit-type criteria, the maximum value should be considered, while for cost-type criteria, the minimum value should be considered:

$$P^* = \left(P_1^*, P_2^*, P_3^* \right). \tag{9}$$

Step 4. Calculate the normalized distance matrix – for each alternative A_i ($i = 1, 2,\ldots,m$), compute its normalized distance with respect to the ideal solution for each criterion C_j ($j = 1,2,\ldots,n$):

$$d_{ij}(A_i, P_j^*) = \frac{\left| A_i - P_j^* \right|}{\left| P_j^{max} - P_j^{min} \right|}. \tag{10}$$

Step 5. Calculate the normalized average distance with the multi-criteria solution for each option A_i ($i = 1,2,\ldots,m$) using the following formula:

$$\hat{p}_j = \sum_{j=1}^{n} w_j \, d_{ij}(A_i, P_j^*). \tag{11}$$

Rank criteria by preference – values should be ranked in ascending order.

2. 3. COMET method

The implementation of the COMET method follows the calculation steps outlined in the following steps [25]:

Step 1. Establish the problem space – the expert determines the dimensionality of the problem by selecting the number r of criteria, C_1, C_2, ..., C_r. Subsequently, the set of fuzzy numbers is selected for each criterion C_i:

$$C_r = \left\{ \tilde{C}_{r1}, \tilde{C}_{r2}, \ldots, \tilde{C}_{rC_r} \right\}, \tag{12}$$

where C_1, C_2, ..., C_r are numbers of the fuzzy numbers for all criteria.

Step 2. Generate characteristic objects (*CO*) by utilizing the Cartesian product of the core of fuzzy numbers for all criteria:

$$CO = C(C_1)\times C(C_2)\times\ldots\times C(C_r). \tag{13}$$

Step 3. Assess typical objects and establish the expert evaluation matrix:

$$M = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1t} \\ \alpha_{22} & \alpha_{22} & \cdots & \alpha_{2t} \\ \cdots & \cdots & \cdots & \cdots \\ \alpha_{t1} & \alpha_{t2} & \cdots & \alpha_{tt} \end{pmatrix}, \tag{14}$$

where α_{ij} represents the comparison result between CO_i and CO_j. The function f_{exp} embodies the expert's cognitive judgment, which is influenced by their knowledge and expertise:

$$\alpha_{ij} = \begin{cases} 0.0, f_{exp}(CO_i) < f_{exp}(CO_j) \\ 0.5, f_{exp}(CO_i) = f_{exp}(CO_j). \\ 1.0, f_{exp}(CO_i) > f_{exp}(CO_j) \end{cases} \tag{15}$$

The vertical vector of the Summed Judgments (SJ) is obtained in the following manner:

$$SJ_i = \sum_{j=i}^{t} \alpha_{ij}. \tag{16}$$

Step 4. Priority values are assigned to each feature, resulting in the vertical vector P, where the ith row represents the approximate priority value for CO_i. Each feature object and its corresponding priority value are then transformed into fuzzy rules using the following procedure:

$$IF\, C(\tilde{C}_{1i}) \quad AND \quad C(\tilde{C}_{2i}) \ AND\ldots THEN\, P_i. \tag{17}$$

Step 5. The Mamdani fuzzy inference method is employed to calculate the preference of the ith alternative.

2. 4. CRITIC method

The weights of the criteria were determined in this study using the CRITIC method, which involved the following steps [26, 27]:

Step 1. Similar to step 1 of the MAIRCA method.

Step 2. Normalize the matrix separately for positive criteria and negative criteria:

$$x_{ij} = \frac{r_{ij} - rN_i}{rP_i - rN_i};\ i = 1,\ldots,m;\ j = 1,\ldots,n, \tag{18}$$

$$x_{ij} = \frac{r_{ij} - rP_i}{rN_i - rP_i};\ i = 1,\ldots,m;\ j = 1,\ldots,n, \tag{19}$$

where x_{ij} denote the normalized value of the decision matrix for the ith alternative at the jth criterion. Additionally, let rP_i represent the maximum value among r_1, r_2, ..., r_m, and rN_i represent the minimum value among r_1, r_2, ..., r_m.

Step 3. Calculate the correlation coefficient between the jth and kth criteria:

$$p_{jk} = \sum_{i=1}^{m}(x_{ij} - xC_j) \Bigg/ \sqrt{\sum_{i=1}^{m}(x_{ij} - xC_{ij})^2 \sum_{i=1}^{m}(x_{ik} - xC_k)^2}, \tag{20}$$

where xC_{ij} and xC_k representing the j^{th} and k^{th} criteria, respectively, xC_j is calculated using the formula (21). Similarly, xC_k is obtained using a similar approach:

$$xC_j = \frac{1}{n}\sum_{j=1}^{n} x_{ij}; i = 1,\ldots,m. \tag{21}$$

Step 4. Compute the standard deviation for each criterion:

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_{ij} - \bar{x}_{ij})^2}\,;\ i = 1,\ldots,m, \tag{22}$$

$$F_j = \sigma_j \sum_{k=1}^{n}\left(1 - p_{jk}\right);\ j = 1,\ldots,n. \tag{23}$$

Step 5. Calculate the weights according to the following formula:

$$w_j = \frac{F_j}{\sum_{j=1}^{n} F_j};\ j = 1,\ldots,n. \tag{24}$$

3. Results and discussion

A survey was conducted to review the criteria and indicators used for evaluating energy technologies [29–34]. **Table 1** presents these criteria, which are focused on economic, environmental, and societal aspects in order to assess the long-term sustainability of developed technologies. The Table describes the seven most popular criteria selected to address the energy and environmental policy priorities of the European Union.

Table 1

Criteria for evaluating the sustainability of electricity production technology

Indicator	Acronym	Units of measurement
Human health impact	HHI	EURcnt/kWh
GHG emissions	GHG	kg/kWh
Private costs	PC	EURcnt/kWh
Environmental external costs	EEC	EURcnt/kWh
Radionuclide external costs	REC	EURcnt/kWh
Fatal accidents	FC	Fatalities/kWh
Average availability (load) factor	AAF	%

Human health impact (HHI) criterion: this criterion measures the health damage caused by emissions into the environment, such as air, land, and water. It is expressed in EURcnt/kWh and takes into account particles, gases, and metals.

GHG emissions (GHG) criterion: this criterion quantifies the amount of greenhouse gas emissions in kg/kWh. Given the significance of climate change as a global environmental concern, this criterion reflects the potential negative impact of greenhouse gas emissions from producing 1 kWh of electricity.

Private costs (investments and operation costs) (PC) criterion: this criterion evaluates the generation costs in EURcnt/kWh, considering the net power supplied to the station busbar, which feeds electricity to the grid.

External Environmental Costs Criterion (EEC): this criterion estimates the external environmental cost in EURcnt/kWh, accounting for damage to the ecosystem caused by emissions of particles, gases, and metals into the air, soil, and water.

Radionuclide external costs (REC) criterion: this criterion estimates the cost in EURcnt/kWh of health damage caused by nuclear radioactive emissions, including the indirect use of nuclear power in production and export.

Fatal accidents (FA) criterion: this criterion considers the frequency of serious accidents and associated fatalities in tasks related to the development of electrical technologies. It is expressed as Fatalities/kWh.

Average availability (load) factor (AAF) criterion: this criterion is based on the typical load factor of power plants and assesses the average availability of electricity generation.

These criteria have been widely used in energy technology assessment studies [29–34] and are aligned with the energy and environmental policy priorities of the European Union.

The evaluated electricity production technologies include: electricity production and Electricity and heating production.

The power generation technologies listed in **Table 2** are evaluated by compiling data according to the decision matrix outlined in **Table 3** [28].

Furthermore, in order to examine the sensitivity of the assessment results, the study utilizes the decision matrix presented in **Table 3** to evaluate the sustainability of electricity technologies.

This evaluation is then used to construct a criteria weight Table using the CRITIC method, as shown in **Table 4**.

Table 2
Electricity production technologies

Technologies and types of power plants				Acronyms
Electricity production	Nuclear	Nuclear		NUC
		Oil	Heavy oil condensing PP	OIL CL
		Coal	Condensing PP	COA CL
	Hydropower	Run of river	<10 MW	HYD S
			<100 MW	HYD M
	Wind	On shore		WIND ON
		Off shore		WIND OFF
	Solar PV	Roof		PV ROOF
		Open space		PV OPEN
Electricity and heating production	Coal	Coal	PP	CHP COAL

Table 3
The decision matrix evaluates the sustainability of electric technologies

Technology	HHI	GHG	PC	EEC	REC	FC	AAF
NUC	0.19	0.013	2.653	0.015	0.1452	0.001	0.9
OIL CL	2.39	0.208	7.194	0.213	0.0017	0.132	0.85
COA CL	1.548	0.751	3.203	0.186	0.0012	0.157	0.85
HYD S	0.198	0.013	7.229	0.016	0.0001	0.001	0.8
HYD M	0.142	0.009	4.519	0.011	0.0001	0.001	0.8
WIND ON	0.142	0.01	6.019	0.007	0.0004	0.001	0.29
WIND OFF	0.173	0.007	6.143	0.006	0.0022	0.001	0.5
PV ROOF	0.479	0.056	25.14	0.032	0.0028	0.001	0.15
PV OPEN	1.082	0.108	20.829	0.064	0.0002	0.001	0.15
CHP COAL	1.406	0.674	0.945	0.167	0.001	0.157	0.85

Table 4
Weighting of criteria according to CRITIC method

HHI	GHG	PC	EEC	REC	FC	AAF
0.1	0.117	0.215	0.107	0.172	0.126	0.163

The results of ranking the options are presented in **Table 5**.

Table 5
Ranking of options according to MCDM methods

No.	Technology	MAIRCA	SPOTIS	COMET
1	NUC	5(0.019)	5(0.194)	4(0.082)
2	OIL CL	7(0.041)	7(0.412)	8(0.733)
3	COA CL	10(0.043)	10(0.431)	7(0.75)
4	HYD S	2(0.009)	2(0.086)	2(0.929)
5	HYD M	1(0.006)	1(0.056)	1(0.956)
6	WIND ON	4(0.018)	4(0.179)	5(0.865)
7	WIND OFF	3(0.014)	3(0.138)	3(0.893)
8	PV ROOF	8 (0.042)	8(0.417)	10 (0.486)
9	PV OPEN	9(0.043)	9(0.427)	9(0.519)
10	CHP COAL	6(0.038)	6(0.382)	6(0.815)

Based on the results, it is evident that: The ranking is determined objectively by evaluating various criteria using the CRITIC method. The findings indicate that all three MCDM methods yield the same highest ranking for HYD M technology, highlighting hydropower as the most sustainable electricity development option (HYD M ranked 1st and HYD S ranked 2nd). The consistency among the three methods is notable in the top three rankings. Conversely, COA CL ranks the worst when using MAIRCA and SPOTIS, whereas COMET identifies PV ROOF as the least sustainable solution. This suggests that these solutions are more environmentally polluting and pose greater risks to life compared to the other options. The plan to utilize wind power also receives high sustainability ratings, ranking from 3rd to 5th. Energy technologies reliant on traditional fuels such as oil, gas, coal, and nuclear rank poorly, indicating a low level of sustainability. The findings of this study have significant implications for proposing solutions and can serve as a valuable reference for countries' sustainable electricity technology or sustainable energy development strategies.

This study only considers seven input criteria, such as human health impact, GHG emissions, private costs, environmental external costs, radionuclides external costs, fatal accident, and average availability (load) factor. However, this is a limitation, and in the future, it would be beneficial to include additional criteria and conduct a more comprehensive evaluation of options. Additionally, incorporating fuzzy logic methods can help address uncertainties associated with measuring values according to the criteria of different options.

4. Conclusions

1. To ensure robust results, three evaluation methods (MAIRCA, SPOTIS, COMET) are employed simultaneously. These methods, based on different criteria, demonstrate a high degree of consistency in their results.

2. The multi-criteria analysis reveals that renewable energy-based electricity generation is crucial for sustainable development. Specifically, hydropower and wind power systems are identified as the most sustainable options, while nuclear technology, coal, and solar PV are found to be the least sustainable.

3. Traditional fuel-based electricity generation technologies receive low rankings in terms of sustainability. This underscores the importance of reducing reliance on traditional fuels in energy policy.

4. The results highlight the comprehensive assessment capabilities of the MCDM method across multiple criteria. As a result, future energy policy should integrate MCDM into management, policy planning processes, and development strategies to promote more sustainable energy development.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

[1] Pérez-Gladish, B., Ferreira, F. A. F., Zopounidis, C. (2020). MCDM/A studies for economic development, social cohesion and environmental sustainability: introduction. International Journal of Sustainable Development & World Ecology, 28 (1), 1–3. https://doi.org/10.1080/13504509.2020.1821257

[2] Nasrollahi, S., Kazemi, A., Jahangir, M.-H., Aryaee, S. (2023). Selecting suitable wave energy technology for sustainable development, an MCDM approach. Renewable Energy, 202, 756–772. https://doi.org/10.1016/j.renene.2022.11.005

[3] Dua, T. V. (2023). Combination of design of experiments and simple additive weighting methods: a new method for rapid multi-criteria decision making. EUREKA: Physics and Engineering, 1, 120–133. https://doi.org/10.21303/2461-4262.2023.002733

[4] Danh, T. H., Huy, T. Q., Lam, P. D., Cuong, N. M., Tu, H. X., Pi, V. N. (2022). A study on multi-criteria decision-making in powder mixed electric discharge machining cylindrical shaped parts. EUREKA: Physics and Engineering, 5, 123–129. https://doi.org/10.21303/2461-4262.2022.002367

[5] Trung, D. D., Tien, D. H., Son, N. H. (2022). Decısıon makıng for car selectıon ın Vıetnam. EUREKA: Physics and Engineering, 6, 139–150. https://doi.org/10.21303/2461-4262.2022.002505

[6] Thinh, H. X., Trung, D. D. (2022). A research on application of the measurement of alternatives and ranking according to compromise solution method for multi-criteria decision making in the grinding process. EUREKA: Physics and Engineering, 2, 101–110. https://doi.org/10.21303/2461-4262.2022.002120

[7] Dua, T. V. (2023). Combination of symmetry point of criterion, compromise ranking of alternatives from distance to ideal solution and collaborative unbiased rank list integration methods for woodworking machinery selection for small business in Vietnam. EUREKA: Physics and Engineering, 2, 83–96. https://doi.org/10.21303/2461-4262.2023.002763

[8] Nguyen, H.-Q., Nguyen, V.-T., Phan, D.-P., Tran, Q.-H., Vu, N.-P. (2022). Multi-Criteria Decision Making in the PMEDM Process by Using MARCOS, TOPSIS, and MAIRCA Methods. Applied Sciences, 12 (8), 3720. https://doi.org/10.3390/app12083720

[9] Hadian, S., Shahiri Tabarestani, E., Pham, Q. B. (2022). Multi attributive ideal-real comparative analysis (MAIRCA) method for evaluating flood susceptibility in a temperate Mediterranean climate. Hydrological Sciences Journal, 67 (3), 401–418. https://doi.org/10.1080/02626667.2022.2027949

[10] Do, D. T., Nguyen, N.-T. (2022). Applying Cocoso, Mabac, Mairca, Eamr, Topsis and Weight Determination Methods for Multi-Criteria Decision Making in Hole Turning Process. Strojnícky Časopis – Journal of Mechanical Engineering, 72 (2), 15–40. https://doi.org/10.2478/scjme-2022-0014

[11] Ul Haq, R. S., Saeed, M., Mateen, N., Siddiqui, F., Ahmed, S. (2023). An interval-valued neutrosophic based MAIRCA method for sustainable material selection. Engineering Applications of Artificial Intelligence, 123, 106177. https://doi.org/10.1016/j.engappai.2023.106177

[12] Hezam, I. M., Vedala, N. R. D., Kumar, B. R., Mishra, A. R., Cavallaro, F. (2023). Assessment of Biofuel Industry Sustainability Factors Based on the Intuitionistic Fuzzy Symmetry Point of Criterion and Rank-Sum-Based MAIRCA Method. Sustainability, 15 (8), 6749. https://doi.org/10.3390/su15086749

[13] Chatterjee, K., Pamucar, D., Zavadskas, E. K. (2018). Evaluating the performance of suppliers based on using the R'AMATEL-MAIRCA method for green supply chain implementation in electronics industry. Journal of Cleaner Production, 184, 101–129. https://doi.org/10.1016/j.jclepro.2018.02.186

[14] Dezert, J., Tchamova, A., Han, D., Tacnet, J.-M. (2020). The SPOTIS Rank Reversal Free Method for Multi-Criteria Decision-Making Support. 2020 IEEE 23rd International Conference on Information Fusion (FUSION). https://doi.org/10.23919/fusion45008.2020.9190347

[15] Bączkiewicz, A. (2023). Temporal SWARA-SPOTIS for Multi-Criteria Assessment of European Countries Regarding Sustainable RES Exploitation. Lecture Notes in Business Information Processing, 171–191. https://doi.org/10.1007/978-3-031-29570-6_9

[16] Shekhovtsov, A., Paradowski, B., Wieckowski, J., Kizielewicz, B., Salabun, W. (2022). Extension of the SPOTIS method for the rank reversal free decision-making under fuzzy environment. 2022 IEEE 61st Conference on Decision and Control (CDC). https://doi.org/10.1109/cdc51059.2022.9992833

[17] Bui, H.-A., Tran, N.-T., Nguyen, D.-L. (2023). Multi-criteria decision making in the powder-mixed electrical discharge machining process based on the cocoso, spotis algorithms and the weighting methods. International Journal of Modern Manufacturing Technologies, 15 (1), 69–79. https://doi.org/10.54684/ijmmt.2023.15.1.69

[18] Wątróbski, J., Bączkiewicz, A., Król, R., Sałabun, W. (2022). Green electricity generation assessment using the CODAS-COMET method. Ecological Indicators, 143, 109391. https://doi.org/10.1016/j.ecolind.2022.109391

[19] Faizi, S., Sałabun, W., Ullah, S., Rashid, T., Więckowski, J. (2020). A New Method to Support Decision-Making in an Uncertain Environment Based on Normalized Interval-Valued Triangular Fuzzy Numbers and COMET Technique. Symmetry, 12 (4), 516. https://doi.org/10.3390/sym12040516

[20] Faizi, S., Sałabun, W., Rashid, T., Wątróbski, J., Zafar, S. (2017). Group Decision-Making for Hesitant Fuzzy Sets Based on Characteristic Objects Method. Symmetry, 9 (8), 136. https://doi.org/10.3390/sym9080136

[21] Mukhametzyanov, I. (2021). Specific character of objective methods for determining weights of criteria in MCDM problems: Entropy, CRITIC and SD. Decision Making: Applications in Management and Engineering, 4 (2), 76–105. https://doi.org/10.31181/dmame210402076i

[22] Zafar, S., Alamgir, Z., Rehman, M. H. (2021). An effective blockchain evaluation system based on entropy-CRITIC weight method and MCDM techniques. Peer-to-Peer Networking and Applications, 14 (5), 3110–3123. https://doi.org/10.1007/s12083-021-01173-8

[23] Ulutaş, A., Balo, F., Sua, L., Karabasevic, D., Stanujkic, D., Popovic, G. (2021). Selection of insulation materials with PSI-CRITIC based CoCoSo method. Revista de La Construcción, 20 (2), 382–392. https://doi.org/10.7764/rdlc.20.2.382

[24] Gigović, L., Pamučar, D., Bajić, Z., Milićević, M. (2016). The Combination of Expert Judgment and GIS-MAIRCA Analysis for the Selection of Sites for Ammunition Depots. Sustainability, 8 (4), 372. https://doi.org/10.3390/su8040372

[25] Salabun, W., Karczmarczyk, A., Watrobski, J., Jankowski, J. (2018). Handling Data Uncertainty in Decision Making with COMET. 2018 IEEE Symposium Series on Computational Intelligence (SSCI). https://doi.org/10.1109/ssci.2018.8628934

[26] Diakoulaki, D., Mavrotas, G., Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The critic method. Computers & Operations Research, 22 (7), 763–770. https://doi.org/10.1016/0305-0548(94)00059-h

[27] Tuş, A., Aytaç Adalı, E. (2019). The new combination with CRITIC and WASPAS methods for the time and attendance software selection problem. OPSEARCH, 56 (2), 528–538. https://doi.org/10.1007/s12597-019-00371-6

[28] Streimikiene, D., Balezentis, T., Krisciukaitienė, I., Balezentis, A. (2012). Prioritizing sustainable electricity production technologies: MCDM approach. Renewable and Sustainable Energy Reviews, 16 (5), 3302–3311. https://doi.org/10.1016/j.rser.2012.02.067

[29] CASES, Cost Assessment of Sustainable Energy System. Development of a set of full cost estimates of the use of different energy sources and its comparative assessment in EU countries (2008).

[30] CASES, Cost Assessment of Sustainable Energy System. Report on policy instruments assessment methods and comparative analyses (2008).

[31] EUSUSTEL, European Sustainable Electricity. Comprehensive analysis of future European demand and generation of European electricity and its security of supply, final technical report (2007).

[32] NEEDS, New Energy Externalities Developments for Sustainability. Survey of criteria and indicators (2005).

[33] NEEDS, New Energy Externalities Developments for Sustainability. Final report on technology foresight method (2006).

[34] NEEDS, New Energy Externalities Developments for Sustainability. Environmental, economic and social criteria and indicators for sustainability assessment of energy technologies (2007).

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