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University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Republic of Serbia

HAS PARTICIPATED WITH AN INVITED PAPER ENTITLED

***Prioritization of Measures for Achieving Energy and Climate Goals in Serbia***

AT THE 10TH VIRTUAL INTERNATIONAL CONFERENCE ON SCIENCE, TECHNOLOGY AND MANAGEMENT IN ENERGY, NOVEMBER 25-26, 2024, ORGANIZED BY MATHEMATICAL INSTITUTE

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# Prioritization of Measures for Achieving Energy and Climate Goals in Serbia

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*Abstract*—**The article proposes a hybrid Multiple-Criteria Decision-Making (MCDM) approach for assessing and prioritizing measures for achieving energy and climate goals in Serbia. The analysis was performed using the Simple weighted sum product (WISP), Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS), and Axial-Distance-Based Aggregate Measurement (ADAM) methods. The results emphasized *Research, innovation, and competitiveness* as measure that should be prioritized in current conditions.**

**Keywords** - WISP, MARCOS, ADAM, energy, climate

## I. INTRODUCTION

The growing global focus on sustainable energy transition and the need to mitigate climate change challenges have prompted countries to adopt more effective measures for achieving their energy and climate goals. In 2015, the multilateral climate change process was started with the primary goal of mitigating dangerous climate change by keeping global warming below 2°C and making an effort to reach 1.5°C. The Paris Climate Conference (COP21) resulted in the Paris Agreement, the first universal legally obligated agreement to cope with climate change. The Republic of Serbia ratified the Paris Agreement in 2016, and at the Berlin Process Western Balkans Summit 2022, signed a joint Declaration on Energy Security and Green Transition in the Western Balkans.

However, over the past two decades, Serbia has faced numerous challenges in achieving its energy and climate goals. The energy sector is one of the most important economic branches in Serbia [1], but there are numerous inefficiencies and inherited problems from socialistic regime. Serbia's energy sector faces challenges due to its reliance on fossil fuels and an ongoing energy deficit [2]. The country heavily depends on low-calorie lignite for electricity production, which provides energy independence and stable costs but is highly inefficient [3-4]. On the other hand, the current utilization of renewable energy sources in Serbia's energy mix remains insufficient to achieve the target of raising the share of renewable energy sources (RES) in gross final energy consumption [5]. In addition to an unfavorable energy mix, Serbia faces the significant issue of high energy intensity, driven by energy-intensive industries, a large share of household energy consumption, and unrealistic energy pricing [6]. Furthermore, the rate of temperature increase in Serbia is exceeding the global average, leading to projections of significantly higher average annual temperatures in the future [7].

The intensive use of lignite and high energy intensity in Serbia significantly contribute to growing GHG emissions, worsening the environmental impact of the electricity sector [3]. Consequently, this sector is a major polluter of air, water, and soil, threatening both the environment and public health [1], making

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Serbia the largest $CO_2$ emitter in the Western Balkans from 2010 to 2020 [8]. The negative trends in Serbia's energy sector largely stem from an inefficient institutional environment and a lack of capacity to implement necessary reforms. Despite significant efforts to reform the energy sector since the 1980s, liberalization has progressed slowly and only in select segments [9].

Besides negative trends in energy sector, the underdeveloped circular economy significantly hampers the achievement of climate goals. The concept's utilization remains limited to a few successful examples, primarily due to a lack of awareness, insufficient funding, and consumer culture. Waste management is problematic, characterized by outdated policies and unresolved issues, while the market for secondary raw materials is poorly developed [10]. Most Serbian businesses lack awareness of environmental preservation, resulting in minimal use of waste as a production input. The country lags in waste management and recycling, largely due to inadequate infrastructure for waste collection, sorting, and treatment [11].

To effectively address all challenges, Serbia must advance its science and technology through substantial investment in research and development (R&D). Staying aligned with future trends is essential for maintaining competitiveness. However, Serbia invests less in R&D compared to EU peers adhering to the Lisbon Convention, largely due to low private investment [11].

Considering the complex nature of the necessary reforms, the Republic of Serbia developed the Integrated National Energy and Climate Plan (INECP) covering 2021 to 2030 [12] to achieve the perceived targets regarding decreasing GHG emissions and increasing energy efficiency and share of RES. Aligning with international sustainability standards and fulfilling national commitments requires a strategic approach to decision-making that takes into account diverse and often conflicting priorities. In this context, multiple-criteria decision-making (MCDM) methods can provide a comprehensive framework for evaluating and prioritizing the multiple aspects involved in formulation and implementation of energy and climate policy. In the recent literature in this research area, MCDM methods have been already used in analysis of energy transition [5], optimizing energy mix [13], energy security assessment [14], and similar topics. This paper introduces a hybrid MCDM approach to support the prioritization of measures prescribed by INECP. The novelty of this research lies in the use of multiple MCDM methods (WISP, MARCOS, and ADAM), synthesized by usage of the Borda rule, to ensure a more objective prioritization of the proposed measures. Such approach supports policymakers in making more informed, evidence-based decisions, which are particularly crucial for energy and climate policymaking.

## II. Methodology and Data

### A. The Entropy Method

The Entropy method was introduced by Shannon [15], and Shannon and Weaver [16]. This method enables the calculation of the criteria's objective weighting coefficients, excluding the decision-makers influence. The Entropy method is based on the hypothesis that higher weight indication data is rather helpful than the opposite one [17]. Because of its relatively comprehensive computation procedure, the Entropy method has been used to facilitate various decision-making problems [18-22].

Defining the criteria weighting coefficients using the Entropy method is based on (1) as follows:

$$w_j = \frac{1-e_j}{\sum_{j=1}^{n}\left(1-e_j\right)} , \quad (1)$$

where $j =,...,n$.

The $e_j$ value that represents the output entropy of the $j_{th}$ factor is determined as follows:

$$e_j = -\frac{1}{\ln\left(m\right)}\sum_{j=1}^{n} r_{ij} \ln\left(r_{ij}\right) , \quad (2)$$

where $j =,...,n$ and $\sum_{j=1}^{n} w_j = 1$.

### B. The WISP Method

The WISP method [23] was proposed to create an approach that would be understandable and convenient for application even for users unfamiliar with MCDM methods. This method integrates four relationships between a set of benefit and cost criteria, defining the alternatives' total utility measure. Until now, the WISP method has been used to facilitate different kinds of business and real-world problems [24-28].

The computation procedure for the WISP method involves the following steps:

**Step 1.** Define the initial decision-making matrix.

**Step 2.** Create the normalized decision-making matrix:

$$r_{ij} = \frac{x_{ij}}{\max_i x_{ij}} \ , \quad (3)$$

where $r_{ij}$ represents a dimensionless number that designates a normalized rating of the $i-th$ alternative regarding the $j-th$ criterion.

**Step 3.** Compute the values of four utility measures as it is presented:

$$u_i^{wsd} = \sum_{j\in\Omega_{max}} r_{ij}w_j - \sum_{j\in\Omega_{min}} r_{ij}w_j \ , \quad (4)$$

$$u_i^{wpd} = \prod_{j\Omega_{max}} r_{ij}w_j - \prod_{j\in\Omega_{min}} r_{ij}w_j \ , \quad (5)$$

$$u_i^{wsr} = \frac{\sum_{j\in\Omega_{max}} r_{ij}w_j}{\sum_{j\in\Omega_{min}} r_{ij}w_j} \ , \quad (6)$$

$$u_i^{wpr} = \frac{\prod_{j\in\Omega_{max}} r_{ij}w_j}{\prod_{j\in\Omega_{min}} r_{ij}w_j} \ , \quad (7)$$

where $u_i^{wsd}$ and $u_i^{wpd}$ designate differences between the weighted sum and weighted product of normalized ratings of alternative *i*, respectively, additionally, $u_i^{wsr}$ and $u_i^{wpr}$ represent ratios between weighted sum and weighted product of normalized ratings of alternative $i$, respectively.

**Step 4.** Recalculate the four utility measure values in the following way:

$$\bar{u}_i^{wsd} = \frac{1+u_i^{wsd}}{\left(1+u_{max_i}^{wsd}\right)} \ , \quad (8)$$

$$\bar{u}_i^{wpd} = \frac{1+u_i^{wpd}}{\left(1+u_{max_i}^{wpd}\right)} \ , \quad (9)$$

$$\bar{u}_i^{wsr} = \frac{1+u_i^{wsr}}{\left(1+u_{max_i}^{wsr}\right)} \ , \quad (10)$$

$$\bar{u}_i^{wpr} = \frac{1+u_i^{wpr}}{\left(1+u_{max_i}^{wpr}\right)} \ , \quad (11)$$

where: $\bar{u}_i^{wsd}$ , $\bar{u}_i^{wpd}$ , $\bar{u}_i^{wsr}$ and $\bar{u}_i^{wpr}$ outline recalculated values of $u_i^{sd}$ , $u_i^{pd}$ , $u_i^{sr}$ and $u_i^{pr}$ .

**Step 5.** Determine the overall utility $u_i$ of each alternative as follows:

$$u_i = \frac{1}{4}\left(\bar{u}_i^{wsd} + \bar{u}_i^{wpd} + \bar{u}_i^{wsr} + \bar{u}_i^{wpr}\right) \ , \quad (12)$$

**Step 6.** Rank the alternatives in descending order, choosing the one with the highest $u_i$ value as optimal.

## *C. The MARCOS Method*

The essence of the MARCOS method [29] relies on finding the relations between ideal and anti-ideal alternatives and determining the compromise rankings according to ideal and anti-ideal solutions. Decisions are made regarding the utility functions representing the distance between an alternative and the ideal and anti-ideal solution. The alternative closest to the ideal solution and the most distant from the anti-ideal solution represents the optimal choice. The applicability of the MARCOS method has been proven in many research studies [30-33].

The MARCOS method calculation procedure is based on the following series of steps.

**Step 1.** As in the WISP method, define the initial decision matrix.

**Step 2.** Create the extended decision matrix that involves the ideal and anti-ideal solutions. The ideal solution is the alternative with the best performance regarding the particular criterion, while the alternative with the worst performance is designated as the anti-ideal solution. Ideal and anti-ideal solutions are defined in the following way:

$$AAI = \min_j x_{ij} \ \ if \ \ j \in B \ and \ \max_j x_{ij} \ \ if \ \ j \in C \ , \quad (13)$$

$$AI = \max_j x_{ij} \ \ if \ \ j \in B \ and \ \min_j x_{ij} \ \ if \ \ j \in C \ , \quad (14)$$

**Step 3.** Normalize the extended initial decision matrix in the following manner:

$$r_{ij} = \frac{x_{ai}}{x_{ij}} if \ j \in C \ , \quad (15)$$

$$r_{ij} = \frac{x_{ij}}{x_{ai}} if\ j \in B \ , \quad (16)$$

where $x_{ij}$ and $x_{ai}$ represent elements of the decision matrix.

**Step 4.** Define the weighted decision matrix as follows:

$$v_{ij} = r_{ij} \cdot w_j \ , \quad (17)$$

**Step 5.** Compute the utility degree of the alternatives $K_i$ in the following way:

$$K_i^- = \frac{S_i}{S_{aai}} \ , \quad (18)$$

$$K_i^+ = \frac{S_{aai}}{S_i} \ , \quad (19)$$

where $S_i\,(i=1,2,\ldots,m)$ is the sum of the elements of a difficult matrix:

$$S_i = \sum_{i=1}^{n} v_{ij} \ , \quad (20)$$

**Step 6.** Using (21) create the utility function of the alternatives $f\,(K_i)$:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1-f\left(K_i^-\right)}{f\left(K_i^-\right)}} \ , \quad (21)$$

where $f\left(K_i^-\right)$ is the utility function versus the anti-ideal solution and $f\left(K_i^+\right)$ is the utility function versus the ideal solution. Mentioned functions are defined in the presented way:

$$f\left(K_i^-\right) = K_i^+ / \left(K_i^+ + K_i^-\right) \ , \quad (22)$$

$$f\left(K_i^+\right) = K_i^- / \left(K_i^+ + K_i^-\right) \ . \quad (23)$$

**Step 7.** Rank the alternatives in descending order, with the best option designated by the highest value of the utility function.

*D. The ADAM Method*

The ADAM method [34] represents a pioneer as the first geometric MCDM method. The ranking process of the alternatives is performed by determining the volumes (aggregated measurement) of complex polyhedral defined by points in a three-dimensional coordinate system. Although relatively new, this method has been recognized by scientists and used in various cases [35-38].

The following steps could illustrate the computation procedure of the ADAM method.

**Step 1.** As in previous cases, create the decision matrix.

**Step 2.** From the sorted decision matrix *S*:

$$S = \left[ s_{ij} \right]_{mxn} \ , \quad (24)$$

where $s_{ij}$ denotes the sorted evaluations $e_{ij}$ in descending order according to the criteria weightings.

**Step 3.** Normalize sorted decision matrix *S*:

$$n_{ij} = \begin{Bmatrix} \dfrac{s_{ij}}{\max_i s_{ij}} & for \quad j \in B \\ \dfrac{\min_i s_{ij}}{s_{ij}} & for \quad j \in C \end{Bmatrix} \ , \quad (25)$$

where $n_{ij}$ is the normalized evaluations, *B* is the benefit set, and *C* is the cost set of the criteria.

**Step 4.** Determine the $x, y$ and $z$ coordinates of the $R_{ij}$ reference and $P_{ij}$ weighted reference points that define the complex polyhedron as follows:

$$x_{ij} = n_{ij} \times \sin \alpha_j, \ \forall j = 1,\ldots,n; \ \forall_i = 1,\ldots m \ , \quad (26)$$

$$y_{ij} = n_{ij} \times \cos \alpha_j, \ \forall j = 1,\ldots,n; \ \forall_i = 1,\ldots n \ , \quad (27)$$

$$z_{ij} = \begin{cases} 0, for\ R_{ij} \\ w_j, for\ P_{ij} \end{cases} \ , \ \forall j = 1,\ldots,m; \ \forall_i = 1,\ldots n \ , \quad (28)$$

where $\alpha_j$ is the angle that defines the orientation of the vector that outlines the alternatives′ value, designated as follows:

$$\alpha_j = (j-1)\frac{90^\circ}{m-1}, \forall j = 1,\ldots,n \ , \quad (29)$$

**Step 5.** Compute the complex polyhedral $V_i^C$ volumes as the sum of the volumes of the composing pyramids as shown:

$$V_i^C = \sum_{k=1}^{n-1} V_k, \ \forall i = 1,\ldots,n \ , \quad (30)$$

where $V_k$ represents the volume of the pyramid defined as follows:

$$V_k = \frac{1}{3} B_k \times h_k, \forall k = 1, \ldots, n-1 \quad , \qquad (31)$$

where $B_k$ designates the surface of the base of the pyramid determined by the reference and weighted reference points of two successive criteria computed in the following way:

$$B_k = c_k \times a_k + \frac{a_k \times (b_k - c_k)}{2} \quad , \qquad (32)$$

where $\alpha_k$ denotes the Euclidean distance between the reference points of two successive criteria, determined in the following way:

$$a_k = \sqrt{(x_{j+1} - x_j)^2 + (y_{j+1} - y_j)^2} \quad , \qquad (33)$$

$b_k$ and $c_k$ represent the magnitudes of the vectors corresponding to the weights of two successive criteria:

$$b_k = z_j \quad , \qquad (34)$$

$$c_k = z_{j+1} \quad , \qquad (35)$$

$h$ is the height of the pyramid from the defined base to the top of discovered in the coordinate origin $(O)$, which is calculated in the following way:

$$h_k = \frac{2\sqrt{s_k (s_k - a_k)(s_k - d_k)(s_k - e_k)}}{a_k} \quad , \qquad (36)$$

where $s_k$ is the semicircumference of the triangle defined by the *x* and *y* coordinates of two successive criteria and the coordinate origin, computed using the following Eqs.:

$$d_k \sqrt{x_j^2 + y_j^2} \quad , \qquad (37)$$

$$e_k = \sqrt{x_{j+1}^2 + y_{j+1}^2} \quad , \qquad (38)$$

**Step 6.** Rank the alternatives in descending order where the best-ranked alternative has the highest volume of complex polyhedral $V_i^C \left(i = 1, \ldots, m\right)$.

## *E. Data*

The INECP [12] addresses five main dimensions that will enable reaching the national energy and climate goals. These dimensions include: 1. **Decarbonization** - increasing the RES share and GHG emissions reduction; 2. **Energy efficiency** - increasing energy efficiency across all sectors; 3. **Energy security** - diversification of the energy sources and establishing the cooperation between EU and Energy Community (EnC) countries to secure the energy supply; 4. **Internal energy market** - direction to establishing an integrated and functional market; 5. **Research innovation and competitiveness** - supporting cutting-edge low-carbon and clean energy technologies. Each of the presented dimensions, which could be considered as measure, is elaborated on a certain number of targets.

The presented measures contribute to energy and climate goals. To perform prioritization of these measures they are assessed by usage of following criteria: 1. implementation costs (billion €); 2. own funds over total implementation cost (%); 3. CAPEX WEM (billion €) - scenario with the existing measures; 4. CAPEX WAM (billion €) - scenario with the additional measures. Table I contains the initial data regarding the given question.

TABLE I. INITIAL DATA.

| **Alternatives** | **Criteria** | | | |
|---|---|---|---|---|
| | ***Implementation costs*** | ***Own funds over total implementation cost*** | ***CAPEX WEM*** | ***CAPEX WAM*** |
| | ***billion €*** | ***%*** | ***billion €*** | ***billion €*** |
| | ***min*** | ***min*** | ***min*** | ***min*** |
| Decarbonization | 5.19 | 77 | 1.16 | 4.03 |
| Energy efficiency | 20.94 | 61.2 | 12.31 | 8.62 |
| Energy security | 3.13 | 57.6 | 1.99 | 1.14 |
| Internal energy market | 1.19 | 85.0 | 1.19 | 0.00 |
| Research innovation and competitiveness | 0.11 | 45.7 | 0.11 | 0.00 |

## III. RESULTS AND DISCUSSION

### A. *Results*

The weighting coefficients were calculated using the Entropy method based on the data presented in Table I. The obtained results are presented in Table II.

The weighting coefficients revealed that the most influential criterion is **CAPEX WAM** (0.3462), while the least significant criterion is **Own funds over total implementation cost** (0.0107). The weighting coefficients necessary for the next procedure were obtained, so we continued with the procedure and applied the WISP, MARCOS, and ADAM method to define the ranking order of the considered measures.

Table III shows that **Research, innovation, and competitiveness** are the priority measure for all three methods. At the same time, **Energy efficiency** is the measure with the lowest priority for implementation. This result is confirmed by the performed sensitivity analysis, which involved varying the weighting coefficients, but the analysis results are not presented here due to the length of the article. The final results obtained using the Borda rule verified the first-ranked measure. The reason could be that energy efficiency is somewhat outdated as a measure of preserving climate change and improving the state of the energy sector. Modern conditions require innovative and modern approaches, which the first-ranked measure certainly offers. So, the emphasis has to be toward innovative strategies, as reflected in the best-ranked measure, which aligns with the need for modern, cutting-edge solutions to support decarbonization energy security, and competitiveness in the energy sector.

TABLE II. CRITERIA WEIGHTS.

| Criteria | Weights |
|---|---|
| Implementation costs | 0.3089 |
| Own funds over total implementation cost | 0.0107 |
| CAPEX WEM | 0.3342 |
| CAPEX WAM | 0.3462 |

### B. *Discussion and Policy Recommendations*

The results highlight several important points for policy recommendations. The restructuring of lignite mining and the diversification of mining regions should be prioritized in the energy transition. This is in line with [1], who emphasize that competition and setting electricity prices at an economically viable level are prerequisites for the energy transition in a liberalized market. In addition, circular economy principles should be introduced to reduce GHG emissions through sustainable production practices, the promotion of secondary raw materials usage and the development of an efficient waste management system [8]. To achieve this, a multi-layered and cross-sectoral integration of national policies is needed to promote favorable conditions for investment and consensus on the sustainable use of resources in line with circular economy objectives [10].

Low-Carbon (LC) technologies need to be integrated into the electricity market instead of relying solely on support mechanisms. However, current electricity prices are not sufficient to incentivize the necessary investments. To achieve the decarbonization targets by 2030, the authorities need to create a favorable environment with long-term incentives and share the investment risks between the state, end-users, and investors [9]. A model that links subsidies to market prices could reduce investment risks and ensure that support decreases when electricity prices rise. Improving consumer awareness of the electricity market and infrastructure enhancements, such as expanding transmission grids and promoting regional cooperation, will also optimize the integration of RES and avoid grid congestion [9].

To attract EU and other international funding for Serbia's green transition, the country needs to identify sectors with exceptional growth potential. Vertical industrial policy measures should ensure coherent integration of science and

TABLE III. FINAL RANKING ORDER.

| Measures | WISP | | MARCOS | | ADAM | | Final rank |
|---|---|---|---|---|---|---|---|
| | ***Score*** | ***Rank*** | ***Score*** | ***Rank*** | ***Score*** | ***Rank*** | |
| Decarbonization | 0.4437 | 4 | 0.0427 | 3 | 0.0004 | 4 | 4 |
| Energy efficiency | 0.2558 | 5 | 0.0125 | 5 | 0.0001 | 5 | 5 |
| Energy security | 0.4832 | 3 | 0.0365 | 4 | 0.0008 | 3 | 3 |
| Internal energy market | 0.5334 | 2 | 0.2915 | 2 | 0.0070 | 2 | 2 |
| Research, innovation, and competitiveness | 1.0000 | 1 | 0.5000 | 1 | 0.1369 | 1 | 1 |

industry, especially in the use of pioneering technologies such as green hydrogen, solar energy, and carbon capture, to create a new technological basis for climate-neutral production [2].

By using energy more productively, Serbia can increase its economic competitiveness while reducing consumer costs and emissions. Key measures include energy-efficient lighting, heating and cooling systems, industrial process automation, and improved energy data management. These efforts should be accompanied by a shift to RES and a reduction in energy losses during distribution. In addition, strengthening administrative capacity, and promoting a new energy culture are essential steps to drive the energy transition [3].

Finally, it is necessary to develop a basic infrastructure and create incentives for the individual players to make waste management profitable and thus contribute to Serbia's circular economy and sustainability goals [11].

## IV. Conclusion

For Serbia to meet international sustainability standards and fulfill its national commitments, a strategic decision-making approach is essential to manage conflicting priorities. MCDM methods provide a robust framework for evaluating different aspects of energy and climate policy formulation and implementation. This paper presents a hybrid MCDM approach that combines several methods (WISP, MARCOS, and ADAM) by usage of Borda rule, allowing for a more objective assessment of measures aimed at achieving Serbia's energy and climate goals as outlined in the INECP. The results show that **Research, innovation, and competitiveness** are the highest priority, while **Energy efficiency** is the lowest priority for implementation.

This study underlines the urgent need for Serbia to adopt comprehensive strategies for its energy transition. Key policy measures include the restructuring of the lignite mining sector to bring it in line with market liberalization and sustainable practices, integration of circular economy principles to reduce GHG emissions. To achieve decarbonization targets, LC technologies need to be integrated into the electricity market, supported by market-based pricing mechanisms and long-term investment incentives to mitigate risks. At the same time, key infrastructure and incentives need to be developed to support a profitable waste management sector and drive the circular economy. Parallel with that, strengthening governance, restructuring national energy companies and promoting a new energy culture is necessary.

This study has limitations, including possible biases due to the use of secondary data and the focus on Serbia, which could limit the generalizability of the results. The prioritization framework used could also oversimplify complex energy policy decisions. Future research should address these issues by incorporating primary data for greater accuracy and examining the long-term impacts of proposed measures. These primary data should include the sub-measures in the evaluation procedure, which will refine the final results. Furthermore, comparing Serbia with developed countries, such as European Union members, will give a more nuanced perspective on the effectiveness of the energy policy applied in Serbia.

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