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Ranking of factors affecting the prediction of RES share in total energy consumption in Serbia

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***Abstract**: The "Green Agenda" as a new global political and economic framework includes the gradual phase-out of coal by 2050 and a shift toward environmentally clean energy sources. This process, known as the energy transition, is driven by three key pillars: tackling climate change, protecting the environment, implementing energy efficiency measures, and integrating renewable energy sources (RES). Since Serbia has adopted a new National Energy Strategy and Energy and Climate Plan for 2040, this strategic framework has been incorporated into technical studies based on the country's existing renewable energy potential. Every country must preserve the stability of its electricity system and energy security, while also maintaining economic and financial sustainability. This study presents a methodology for predicting the share of RES in total energy consumption using a multi-criteria mathematical model for ranking the most influential factors. A prediction model for the year 2030 is proposed, and the ranking of influencing factors reveals the limitations of individual variables and their interactions. Ranking factors affecting the prediction of the RES share involves a sequence of mathematical steps that describe the behavior of input variables such as meteorological conditions, types of days, electricity consumption, energy prices, and other characteristics. The model output is a ranked set of alternatives showing the expected RES share for the forecast period, based on projected consumption, climate variability, energy prices, technology development level, and global investment trends. The multi-criteria ELECTRE method demonstrated that the selected mathematical approach incorporates all variables, corrective*

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coefficients, and weighting factors required to improve prediction reliability and accuracy. Such models have become mandatory components of energy development strategies worldwide for the period up to 2050.

***Keywords**: energy transition, ranking of factors, prediction of RES share in total energy consumption, model ELECTE, energy development strategies.*

Rangiranje faktora uticaja na predikciju ucešća obnovljivih izvora energije u ukupnoj potrošnji energije Srbije

***Apstrakt**: „Zelena agenda" kao nova politička i ekonomska paradigma u svetu sadrži smanjenje upotrebe uglja sa tendencijom obustave eksploatacije do 2050. godine i prelazak na ekološki „čiste" izvore energije. Ovaj proces se naziva energetska tranzicija i ključni elementi takve tranzicije su: suočavanje sa klimatskim promenama i zaštita životne sredine, implementacija mera energetske efikasnosti i korišćenje obnovljivih izvora. Od kada je Srbija kreirala novu Nacionalnu energetsku strategiju i plan do 2040. godine, ovo je implementirano u mnogim tehničkim studiama, zasnovane na postojećim obnovljivim izvorima energije. Svaka zemlja mora da očuva svoj elektroenergetski sistem i energetsku bezbednost, kao i ekonomsku i finansijsku održivost. Ova studija predstavlja elemente predviđanja udela OIE u ukupnoj potrošnji energije koristeći više kriterijuma kao matematičke modele za rangiranje faktora koji utiču. Model predviđanja može se kreirati za 2030. godinu i kao rezultat ove studije, rangiranje faktora pokazuje ograničenu funkciju. Rangiranje faktora koji utiču na predviđanje udela OIE podrazumeva skup matematičkih koraka koji opisuju različita ponašanja ulaznih podataka (meteorološke varijable, vrste dana, potrošnja električne energije, cene energije itd.). Izlazni podaci iz modela su rangirani alternativni niz podataka koji prikazuju očekivani udeo OIE u ukupnoj potrošnji električne energije za period prognoziranja potrošnje, klimatskih promena, potrošnje i cene energenata, nivoa razvoja opreme i investicija na svetskom tržištu. Ovaj višekriterijumski model ELECTE je pokazao da su ove odabrane matematičke metode uključile sve promenljive, korektivne i ponderske faktore, kako bi se povećala verovatnoća predviđanja i tačnost, ali su postale obavezni delovi strategija razvoja energetike mnogih zemalja za period do 2050.*

Ključne reči: *energetska tranzicija, rangiranje faktora, predikcija učešća OIE u ukupnoj potrošnji energije, model ELECTE, strategije razvoja energetike.*

1. Introduction

The energy transition represents the strategic pathway toward achieving a sustainable energy system (Crawley, & Lawrie, 2001). Its key components include the implementation of energy efficiency measures, the integration of renewable energy sources (RES), environmental protection, and the reduction of climate-related impacts.

Challenges within the transition process require defining new targets for energy efficiency, RES deployment, and greenhouse gas emission reduction for 2030, with a long-term vision extending to 2050 (Tomić, 2021). Establishing an optimal energy mix—balancing efficiency, renewable energy, security of supply, and energy poverty—determines the pace of decarbonization.

The current structure of Serbia's energy sector requires significant adjustments and investments to align with European policies. Accordingly, a key task in preparing the Integrated National Energy and Climate Plan is developing scenarios that define updated energy targets.

Renewable energy sources offer sustainability and low environmental impact, supported by rapidly advancing technologies. RES includes solar, hydropower, wind, marine energy, geothermal resources, hydrogen, and biomass Some authors also consider nuclear energy within low-carbon alternatives. Accurate forecasting of future electricity consumption and the share of RES has therefore become essential, and many researchers are developing mathematical models to predict RES shares for 2030, 2040, and 2050. Such predictions have become indispensable components of national energy development strategies.

The choice of prediction model depends on several factors, including ease of application, availability of input data, and required accuracy. Developing and validating a prediction model includes collecting historical RES data (primarily from EUROSTAT), statistical processing, identifying correlations, and evaluating the accuracy of predictive models using multi-criteria analysis such as the ELECTRE method.

2. Multicriteria Analysis (ELECTE method)

In the multi-criteria analysis of prediction models for RES share, three evaluation criteria were used (Ishizaka & Nemery, 2013):

1. Prediction accuracy – how closely model outputs match actual RES share values. Models with lower prediction errors are rated higher.
2. Model robustness – the model's stability under varying conditions and time periods.
3. Transparency and interpretability – how clearly model processes and outputs can be understood.

The analyzed constraints considered as quantitative variables include:

- Climate change (mean annual temperature, °C)
- Total electricity consumption (GWh)
- Electricity price ($/kWh)
- Level of mechanization/automation (year)
- Investment volume (million EUR)

The ELECTRE method is an outranking technique based on pairwise comparison of alternatives. The steps in solving this method start from a decision matrix and criterion weights. The method proceeds through nine steps: normalization, weighting, defining concordance and discordance sets, calculating concordance and discordance matrices, determining dominance matrices, aggregating dominance, and eliminating fewer desirable alternatives.

Input data were obtained from the Statistical Office of Serbia (Energy Balance Bulletins) and EUROSTAT (EUROSTAT Energy statistics database,2023).

Table of parametars od impact on RES consider data from Statistical Official Bilten of Serbia Energy balance and EUROSTAT present official data:

*Table 1: Parameters of impact on RES listed in key years (*Statistical Office of the Republic of Serbia. 2013., 2017., 2023.).

Parameters of Impact C1, C2, C3, C4, C5	*2012 A5*	*2014 A4*	*2016 A3*	*2020 A2*	*2022 A1*
Ti Temperatures (°C) (average for the year)	*12.4*	*12.7*	*12.2*	*12.1*	*12.6*
D Consumption balance (GWh)	*28,366*	*26,256*	*26,782*	*28,328*	*27,937*
COE Electricity price ($/KWh)	*40*	*50*	*60*	*80*	*100*
Pj Possibility of mechanization and automation (year)	*2-8*	*3-7*	*5-10*	*8-15*	*10-20*
Si Investment degree (mil. EUR)	*33*	*42*	*50*	*60*	*80*

Source: authors calculation

Table 1 presents the data parameters of impact on RES of Serbia collect historical data on RES from EUROSTAT, from 2012 until 2022, as well as on electricity consumption trends D(GWh), meteorological parameters such as average air temperature Ti (°C), electricity prices COE ($/KWh), the degree of mechanization use Pj (year) , and the extent of investment deree Si (mil. EUR).

In this study, the ELECTRE method was applied, which is a multi-criteria decision-making method based on comparing alternatives in pairs. ELECTRE starts from the decision matrix and the weights of the criteria and in nine steps comes to a solution to the problem, that is, the choice of the best alternative. The steps in solving according to this method are:

- step 1: consideration of the normalized decision matrix;
- step 2: determination of the weighted normalized decision matrix;
- step 3: determination of the sets of agreement and disagreement;
- step 4: determination of the agreement matrix;
- step 5: calculation of the disagreement matrix;
- step 6: calculation of the dominance matrix by agreement;
- step 7: calculation of the dominance matrix by disagreement;
- step 8: determination of the aggregate dominance matrix;
- step 9: elimination of less desirable alternatives.

2.1. Defining alternatives and criteria

The criteria have qualitative structure, which cannot be precisely determined or changed and it is necessery to form a qualitative scale with five level (Table 2; Roy 1991; 49-73). In this case, by defining alternatives and criteria, an evaluation matrix is formed.

Table 2: Qualitative scale

Qualitative value	*very weak*	*weak*	*medium*	*high*	*very high*
Numerical value	*1*	*2*	*3*	*4*	*5*

Source: authors calculation

Table 3: Quantification decision matrix

Alter./criteria	*C1*	*C2*	*C3*	*C4*	*C5*
A1	*5*	*5*	*4*	*4*	*5*
A2	*4*	*4*	*4*	*4*	*4*
A3	*3*	*2*	*3*	*2*	*4*
A4	*3*	*3*	*3*	*4*	*2*
A5	*1*	*2*	*2*	*3*	*2*

The quantified matrix is the basis for the application of the ELECTRE method, using the ELECTRE program. The program consists of nine steps.

3. Research Methodology – Multicriteria approach for selecting optimal alternatives

Decision-making represents the process of selecting an optimal solution based on clearly defined objectives, information, and expert assessment (Roy, 1991). In this research (Ishizaka, A., & Nemery, P. 2013)., alternatives correspond to selected years (2012–2022), while the criteria reflect factors influencing RES share.”....The most common and proper methods that were used for determination of the influence of different groups of factors on electricity consumption.” (Krstić, Reljić, & Filipović, 2019).

The ELECTRE method was applied in nine steps, starting from the normalized decision matrix, through weighted matrices, concordance and discordance sets, to dominance relationships and elimination of inferior alternatives. The qualitative criteria were quantified using a five-level scale.
Those are:

1. Zero situation analysis.

2. Description of the problem or opportunity.
3. Defining goals.
4. Identification of alternatives.
5. Information gathering.
6. Assessing alternatives.
7. Choosing one alternative.
8. Application of the decision.
9. Analysis of the results of the applied decision/solution.

The AHP method is used to evaluate the evaluation criteria, while the ELECTRE and COPRAS methods are used to rank the alternatives (Stojanović, 2016). In this consideration, the ELECTRE method was applied, which is a method of multi-criteria decision-making based on comparing alternatives in pairs. ELECTRE starts from the decision matrix and the weight of the criteria, and in nine steps the problem is solved, that is, the best alternative is chosen.

Step 1: Calculating the normalized decision matrix

Table 4. Normalized Decision Matrix

Alternatives criteria	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*
A1	*0.64550*	*0.65653*	*0.54433*	*0.51215*	*0.62017*	*0.49614*
A2	*0.51640*	*0.52523*	*0.54433*	*0.51215*	*0.49614*	*0.62017*
A3	*0.38730*	*0.26261*	*0.40825*	*0.25607*	*0.49614*	*0.49614*
A4	*0.38730*	*0.39392*	*0.40825*	*0.51215*	*0.24807*	*0.24807*
A5	*0.12910*	*0.26261*	*0.27217*	*0.38411*	*0.24807*	*0.24807*

Source: authors calculation

Step 2: Calculating the weighted normalized decision matrix

Table 5. Weighted Normalized Decision Matrix

Alternatives criteria	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*
A1	*0.12910*	*0.16413*	*0.10887*	*0.07682*	*0.06202*	*0.04961*
A2	*0.10328*	*0.13131*	*0.10887*	*0.07682*	*0.04961*	*0.06202*
A3	*0.07746*	*0.06565*	*0.08165*	*0.03841*	*0.04961*	*0.04961*
A4	*0.07746*	*0.09848*	*0.08165*	*0.07682*	*0.02481*	*0.02481*
A5	*0.02582*	*0.06565*	*0.05443*	*0.05762*	*0.02481*	*0.02481*

Source: authors calculation

Step 3: Determining the sets of agreement (S) and disagreement (NS)

In this step, pairs of actions are compared. The actions to be compared are denoted by p and r (p,r = 1,2…m and p≠r). First, a consensus set (Spr) is formed *for the actions ar and ar, consisting of all criteria (J=j and j=1,2…n). If there is a minimum-type criterion, the inequality sign is opposite (≤). Then, a complementary disagreement set is formed. If there is a minimum-type criterion, the inequality sign is opposite (>).*

Step 4: Determining the Consistency Matrix

Table 6. Consistency Matrix

A1	0	0.90000	0.85000	1.00000	0.85000
A2	0.45000	0	0.85000	1.00000	0.85000
A3	0.25000	0.25000	0	0.75000	1.00000
A4	0.15000	0.15000	0.65000	0	0.85000
A5	0.15000	0.15000	0.25000	0.35000	0

Source: authors calculation

The value of Sp ranges from 0 to 1. The closer the value of this index is to unity, the more desirable the action ar is than the action ar (according to the agreement criterion).

Step 5: Determining the MNS disagreement matrix

The disagreement index ranges from 0 to 1 and shows that the alternative ar is less desirable than ar. The higher the disagreement index, i.e. closer to unity, the less desirable the disagreement criterion ar is.
Disagreement indices are calculated based on the weighted normalized decision matrix (TN) and the set of disagreements for the observed alternatives Tables 7,8,9,10 defined by steps 5,6,7,8 in the methodology show the process.

Table 7. Disagreement Matrix

A1	0	0.37812	0.39003	0.00000	0.18590
A2	1.00000	0	0.58498	0.00000	0.24787
A3	1.00000	1.00000	0	0.85473	0.00000
A4	1.00000	1.00000	1.00000	0	0.37180
A5	1.00000	1.00000	1.00000	1.00000	0

Source: authors calculation

Step 6: Determining the Consonant Dominance Matrix (CDM)

Table 8. Consonant Dominance Matrix

A1	0	1	1	1	1
A2	0	0	1	1	1
A3	0	0	0	1	1
A4	0	0	1	0	1
A5	0	0	0	0	0

Source: authors calculation

Step 7: Determining the dominance discrepancy matrix

Table 9. Dominance Discrepancy Matrix

A1	*0*	*1*	*1*	*1*	*1*
A2	*0*	*0*	*1*	*1*	*1*
A3	*0*	*0*	*0*	*0*	*1*
A4	*0*	*0*	*0*	*0*	*1*
A5	*0*	*0*	*0*	*0*	*0*

Source: authors calculation

Step 8: Determining the aggregate dominance matrix MAD

Table 10. Aggregate Dominance Matrix

A1	*a1*	*1*	*1*	*1*	*1*
A2	*0*	*a2*	*1*	*1*	*1*
A3	*0*	*0*	*a3*	*0*	*1*
A4	*0*	*0*	*0*	*a4*	*1*
A5	*0*	*0*	*0*	*0*	*a5*

Source: authors calculation

Step 9. Elimination of less desirable actions

If the value of MADpr=1, (Mean Absolute Deviation of prediction residuals) then action ar dominates over action ar, according to both criteria (agreement and disagreement). Here another condition should be satisfied:
MADpr=1 for at least one r=1,2…m and p≠r
MADpr=0 for all i, u=1,2…m and p≠r and u≠r

4. Results

The results show that the best alternative is A1 (2022), followed by alternatives A2 (2020), A3 (2016), A4 (2014) and in last place alternative A5 (2012).
The analysis shows the following dominance structure (Mapoka, Masebu, & Zuva, 2023):

- A1 (2022) dominates all other alternatives.
- A2 (2020) dominates A3, A4, and A5.
- A3 (2016) dominates A5.
- A4 (2014) dominates A5.
- A5 (2012) does not dominate any alternative.

The best-ranked alternative is A1 (2022), characterized by the highest RES share, favorable climatic conditions, increased electricity consumption, and the strongest investment cycle, alongside advanced technological development and higher automation levels. The dominance hierarchy reveals the evolution of Serbia's RES sector and reflects the impact of climate conditions, investment intensity, electricity prices, and system modernization.

5. Conclusion

The results indicate that 2022 (A1) represents the most favorable year for RES application, due to the highest share of renewables and improved conditions for production capacity development. The year 2016 (A3) shows moderate performance, constrained by temperature patterns, electricity prices, and mechanization levels.

The least favorable year, 2012 (A5), corresponds to the early phase of RES integration in Serbia, characterized by low investment and technological development. From 2016 onward, Serbia began fully implementing EU directives on RES and energy efficiency.

Multi-criteria analysis using ELECTRE confirms that climatic, economic, and technological factors significantly influence RES penetration. The applied model provides a transparent and structured approach to ranking alternatives and can guide policymakers in prioritizing investments and strategic measures to strengthen sustainable energy development (Tomić, A., 2022).. Multi-criteria prediction models are increasingly becoming mandatory components of national energy development strategies up to 2050.

The share of RES in total electricity consumption is directly influenced by these predictable factors. order to increase the probability of forecasting and the accuracy of RES participation, these mathematical methods have become mandatory parts of the energy development strategies of many countries for the period up to 2050.

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