Multicriteria Assessment of Renewable Energy Sources in Serbia

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The development of today's economies is inconceivable without energy. However, fossil fuel reserves are declining, climate change is accelerating and some changes in the energy sector are needed. Renewable energy sources are a potential solution for many scientists and practitioners. However, the planning and implementation of renewable energy projects requires consideration of a number of criteria, which is why multicriteria decision-making methods are often used to evaluate renewable energy sources/technologies. Goal of this paper is to evaluate four types of renewable energy sources (photovoltaic, hydro, biomass and wind energy) in Serbia. Analytical hierarchical process and seven criteria were applied. Based on the obtained results, hydro sources are ranked the best. Also, a sensitivity analysis was conducted to determine whether changes in the priority of criteria would cause changes in the range of alternatives. It was found that major changes in priorities are needed for changes to occur, so it can be concluded that the results obtained are relevant.

Key words: *RES, AHP, PV, wind, hydro, biomass*

1. INTRODUCTION

The increase in the world's population and the need for economic development also result in a steady increase in world energy consumption. By 2020, there has been an increase in energy consumption. The increase in consumption was also predicted for the period after 2020. However, the Covid-19 pandemic has caused disruption to the energy sector worldwide. According to [1] global energy demand is set to drop by 5% in 2020, energy-related CO_2 emissions by 7%, energy investment by 18%, also it is estimated falls of 8% in oil demand and 7% in coal. This decline in energy consumption is most likely due to reduced economic growth and economic activity around the world. After the end of the pandemic, the economy can be expected to revive and thus increase energy consumption again. It can be said that energy consumption in Serbia is mainly based on coal, which can be seen in Figure 1.

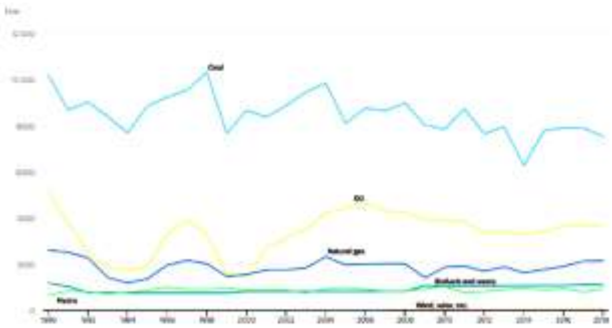

Figure 1 - Total energy supply by source from 1999-2018 (www.iea.org)

However, according to [2] the remaining recognized reserves of fossil fuels on Earth cover 46 years of oil consumption, 58 years of natural gas and nearly 150 years of coal for exploitation. But, what after that? Also, rapid climate change requires a reduction in the use of fossil fuels. Can renewable energy sources (RES) be the solution? According to [3] RES are the fastest growing sources of electricity generation with an average increase of 2.9% annually from 2012. to 2040. and according to [4] the renewable energy sector overall employed (directly and indirectly) around 11 million people worldwide in 2018 [5]. RES can be a long-term, sustainable and reliable support for implementation of energy policies and can provide a

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numerous benefits to economy and society. Authors in [6] believe that RES can contribute to risk reduction because decentralized RES capacities are less exposed to risk such as sabotage compared to centralized ones. RES are also safer in terms of accidents (except for large hydropower plants). Also, RES contribute to greater security through the diversification of both technology and different energy sources [7]. In addition, RES plants do not require fuel to produce electricity. RES can also contribute to significant savings. According to [8] G7 countries can save $ 275-315 billion a year by increasing their share of RES. Also, the price of RES technologies as well as the price of electricity produced from RES is becoming lower and more competitive with the price of energy produced in a conventional way. On the other hand, an increase in the price of fossil fuels is expected, which will also contribute to further strengthening the competitiveness of RES [9, 10].

However, planning, managing and assessing of RES projects is a complex endeavor that has to include a number of criteria (potentials, constraints, legislation, etc.) as well as many stakeholders who often have opposed interests that can lead to conflict situations [11]. Therefore, multi-criteria decision-making methods (MCDM) need to be applied to evaluate RES projects/technologies. Numerous MCDM methods are used in the literature and practice: Preference ranking organization method for enrichment evaluation (PROMETHEE), Analytical hierarchy process (AHP), Analytical network process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The analysis of the literature shows that AHP is a successful and frequently used MCDM method for the evaluation of RES projects / technologies. Also, the advantages of AHP can be mentioned, such as: the ability to decompose a complex problem on the hierarchy and thus gain a clearer insight into the decision problem, the ability to combine with other methods to improve performance, ease of use, the existence of numerous software tools based on AHP which facilitates and accelerates the use of this method, etc. Due to all the above, AHP was selected and applied in this paper to assess four types of renewable energy sources in Serbia. AHP has been used to solve various problems in a number of areas: tourism [12], mining [13, 14]. It was also used to evaluate RES: in [15] authors used analytic hierarchy process (AHP) to evaluate different renewable energy options for the Algerian electricity system; in [16] authors employed hybrid SWOT-AHP to evaluate RES alternatives in Serbia from perspective of investment company. AHP is used and to evaluate eight potential RES projects for municipality of Štrpce in [17].

2. METHODOLOGY

Based on the review of the literature and the needs of this paper, a decision model shown in Figure 2 is proposed. AHP method is used for RES alternative assessment/ranking. AHP methodology is described in more detail in the text that follows.

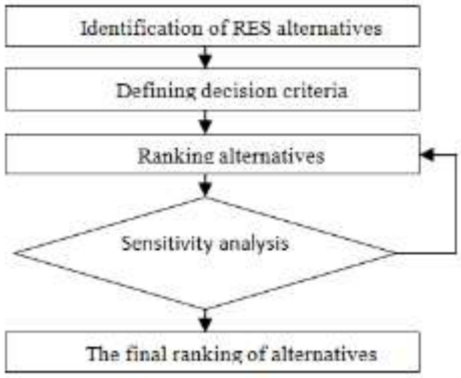

Figure 2 - Proposed decision making model

The AHP is a method to select one alternative from a given set of alternatives, where there are multiple decision criteria involved, and to rank available alternatives in a desirability order based on a rational framework of quantitative comparisons [18]. The AHP was developed by Thomas Saaty, 1980 [19]. The AHP methodology can be explained step by step approach as following [20]:

- In the first step, the problem is formulated in a hierarchical manner. In this step, the aim, main criteria, sub criteria and alternatives should be identified clearly.
- Paired comparisons are performed and the relative importances are determined.
- The consistency of pair wise comparison matrices is determined. If the consistency ratio (CR) is equal or smaller than 0.1 value, the comparisons are consistent.
- In the final step, priorities of alternatives are found by combining the weights of criteria and the ratings of the alternatives.

In AHP method criteria weight is determined by pair wise comparisons using scale (Table 1).

Table 1. Saaty's scale

Intensity of importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

The general form of pairwise comparison matrix is shown as

$$A=\begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{pmatrix} \quad (1)$$

Where a_{ij} is the relative importance of element *i* on element *j*,

$$A = (a_{ij}) \qquad a_{ij} > 0 \quad (2)$$

$$a_{ji} = 1/a_{ij} \quad a_{ij} \neq 0 \quad (3)$$

$$a_{ii} = 1 \quad (4)$$

$$i, j = 1,2,....,n. \quad (5)$$

3. RESULTS AND DISCUSION

Decision making model proposed in Figure 2 is applied and shown in this chapter on case of Serbia. Step by step description follows.

Step 1. Identification of RES alternatives - In this step, the relevant national documents in the field of energy (Laws, Strategies, etc.) are considered. In addition to fossil fuels, Serbia also has significant RES potential. The total technically available potential of renewable energy sources in the Republic of Serbia is estimated at 5.65 million tons per year. Of this potential, 1.054 million tons of biomass (mostly as firewood) and 909 thousand tons of hydropower are already used [21]. RES potentials are presented in the Table 2.

Based on the above review, a list of RES was determined, which will be the subject of further evaluation, namely: solar, hydro, wind and biomass. Since the potential of geothermal energy is significantly lower than other sources and available only in certain areas, this type of energy is excluded from further consideration. Also, the goal is defined here: evaluation and selection of an appropriate RES alternative.

Table 2. RES potential in Serbia [21]

	Available technical potential used (million ten / year)	Unused available technical potential (million ten / year)	Total available technical potential (million ten / year)
Biomass	1,054	2,394	3,448
Hydro energy	0.909	0.770	1.679
Solar energy	≈0	0.240	0.240
Geothermal energy	≈0	0.1	0.180
Wind energy	≈0	0.103	0.103

Step 2. Defining decision-making criteria - a large number of criteria are used in the literature to evaluate RES technologies and projects. For the purposes of this paper, a total of 7 criteria were selected (Table 3).

Unused available technical potential (million ten / year) – although it has significant potentials, Serbia has not used RES enough. This criterion can show potential investors the limits of available technical potentials for different RES. This can be very important from the aspect of potential investors but also state bodies.

Cost/instaled kW - Investment cost is one of the mostly used economic criterion to evaluate energy alternatives. In the Table 3 investment costs (EUR/kW) for different RES technologies are shown.

Job creation - The contribution of RES projects in terms of creating new jobs is of great importance for local economies where RES are implemented. Also, it have contribution to the economy development at state level too, through numerous taxes.

Table 3. Decision making criteria

	HYDRO	WIND	BIOMASS	PV*	REFERENCE
Unused available technical potential (million ten / year) (C1)	0.770	0.103	2,394	0.240	[21]
Investment (EUR/kW) (C2)	2,500	1,610	4,500*	1,450	[22] *expert
Work and maintenance (jobs/MW (C3)	2.4	0.2	1.5	0.3	[23]
Efficiency (%) (C4)	80-90%	24-54%	28%	4-22%	[24] [25]
LAND requirements km2/1000 MW (C5)	750	100	5,000	35	[26]
GHG emissions gCO2eq/kWh (C6)	26	26	45	85	[27]
The price of energy/USD (C7)	0.047	0.056	0.062	0.085	[28]

*Photovoltaic

Technology efficiency - Different RES technologies have different degrees of efficiency as presented in Table 3. Hydropower plants have the highest efficiency of all RES technologies considered while PV technology has the lowest efficiency and due to the many different solar cells available on the market.

Significant land requirement - Implementation of RES projects may require significant land areas. Depending on the place of implementation, this can be a very important criterion.

GHG emissions – Emissions are measured in equivalent emissions of CO_2 per energy unit produced (g CO2eq/kWh). In a life-cycle assessment (LCA) of emissions, all the stages of the energy production system, from raw material extraction, refining, processing, transportation, construction, to operation and maintenance, and dismantling, were considered [27].

The price of energy – In many parts of the world, renewables are the lowest-cost source of new power generation. Cost of electricity for different RES for 2018 is showed in Table 3.

Step 3. Ranking the RES alternative. The AHP method was used to rank the RES alternative. First, the decision-making criteria were ranked in relation to the goal (Table 4). In doing so, all criteria have equal priority.

Table 4. Comparison of criteria in relation to the goal

	C1	C2	C3	C4	C5	C6	C7
C1	1	1	1	1	1	1	1
C2		1	1	1	1	1	1
C3			1	1	1	1	1
C4				1	1	1	1
C5					1	1	1
C6						1	1
C7							1
Inconsistency 0							

The ranking of alternatives that are the subject of decision in relation to the criteria is presented in tables from 5 to 11.

Table 5. Comparison of the alternative in relation to criterion C1

	A1	A2	A3	A4
A1	1	4	1/5	4
A2		1	1/7	1/2
A3			1	7
A4				1
Inconsistency 0.08				

When it comes to Unused available technical potential (C1), the best ranked is A3 (Table), which is understandable because as much as 2.394 million ten / year is unused. This means that there is great biomass potential to be exploited.

Although there has been a noticeable decline in the required investment in the RES sector in recent years, the amount of investment is one of the most important criteria for investors. In that sense, the lowest costs refer to PV, which is also confirmed in the Table 6 because according to this criterion, PV is convincingly ranked first.

Table 6. Comparison of the alternative in relation to criterion C2

	A1	A2	A3	A4
A1	1	1/4	3	1/5
A2		1	6	1/3
A3			1	1/7
A4				1
Inconsistency 0.06				

Among other things, RES can significantly contribute to the development of the local economy. Starting new jobs is one of the most important in any economy today. In that sense, A1 is the best ranked (Table 7) alternative according to criterion C3 because it is considered that it can bring the most new jobs. Also, in terms of RES efficiency, A1 technology is the best ranked alternative (Table 8).

Table 7. Comparison of the alternative in relation to criterion C3

	A1	A2	A3	A4
A1	1	6	3	6
A2		1	1/4	3
A3			1	5
A4				1
Inconsistency 0.08				

Table 8. Comparison of alternatives against criterion C4

	A1	A2	A3	A4
A1	1	5	4	8
A2		1	1/3	3
A3			1	3
A4				1
Inconsistency 0.06				

Based on the data from the Table 3, the least land is needed for PV projects. That is why the result according to which A4 is the best ranked alternative (Table 9) is not surprising. On the other hand, the largest areas of land are needed for biomass, which is ranked last according to this criterion.

Table 9. Comparison of alternatives against criterion C5

	A1	A2	A3	A4
A1	1	1/5	4	1/8
A2		1	8	1/3
A3			1	1/9
A4				1
Inconsistency 0.09				

When it comes to GHG emissions, hydro and wind share the first place (Table 10), while PV is in the last ranked.

Table 10. Comparison of alternatives against criterion C6

	A1	A2	A3	A4
A1	1	1	4	7
A2		1	4	7
A3			1	3
A4				1
Inconsistency 0.01				

The price of electricity is also very important for end consumers, but also for the economy of each country. In this research, the ranking of RES alternative by price criterion was performed on the basis of data defined by [28]. Based on them, the best ranked is A1 whose energy price is 0.047 eurocents and is lower than all other RES alternatives considered (Table 11).

Table 11. Comparison of alternatives against criterion C7

	A1	A2	A3	A4
A1	1	3	3	4
A2		1	2	3
A3			1	3
A4				1
Inconsistency 0.05				

Step 4. Sensitivity analysis was also conducted in this paper. The aim is to determine how changes in the weighting factors of the criteria affect changes in the range of alternatives. In the Table 12 only minimal (increase or decrease) changes in weight factors that lead to a change in the rank of the first-ranked alternative A1 are given. Increasing the weighting factor of the criteria C1, C2, C5, C6 leads to a change in rank. However, all changes leading to a change in rank are greater than 20%. This is a significant percentage, so it can be said that the obtained rank of the alternative is not sensitive to changes in the weighting factors of the criteria. Maximum increases or decreases in weighting factor C3, C4, and C7 do not result in a change in the rank of the first-ranked alternative. By maximizing the weight factor C6 (by + 27.1%), alternative A2 (41.4) shares first place with alternative A1 (41.4) with the same priority. Based on the sensitivity analysis, it can be concluded that the results obtained are stable and that a reassessment of the alternative is not necessary.

Table 12. Sensitivity analysis

Criteria	Reference value (%)	Minimal change (%)	New rank alternative (%)
C1	14.3	+ 23.2	A3 (32.4) A1 (32.3) A2 (11.3) A4 (17)
C2	14.3	+ 22.6	A4 (29.6) A1 (29.5) A2 (24.6) A3 (16.4)
C3	14.3	/	No change
C4	14.3	/	No change
C5	14.3	+21	A4 (29.7) A1 (29.5) A2 (24.4) A3 (16.4)
C6	14.3	+27.1	A1 and A2 (41.4) A3 (12.0) A4 (5.2)
C7	14.3	/	No change

Step 5. Final RES ranking list. After all, previous grades were synthesized and a final ranking was obtained. By sensitivity analysis it was found that only significant changes in the weights of certain criteria affect changes in the rank of the first-ranked alternative A1 (0.362). Therefore, it can be said that the obtained results are relevant. The final ranking of the alternative is presented in Figure 3.

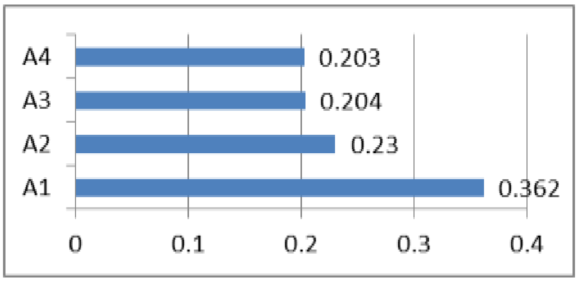

Figure 3 - The final rank of the alternative (inconsistency 0.03)

3. CONCLUSION

Four types of RES by using of 7 criteria were evaluated in this paper by analytical hierarchical process. According to the results of this research, alternative A1 (hydro sources) is ranked first. However, in practice, the implementation of small hydropower projects in Serbia has often met with resistance from stakeholders. Therefore, it is necessary to further investigate the attitudes of stakeholders regarding the assessment of RES. Also, the possibility of stakeholder participation in the decision-making process should be considered.

The proposed model is of a universal character. The criteria used in this model can be replaced by other criteria that are relevant to future decision makers. The proposed model can be helpful to decision makers who create public policies in the RES field, potential investors but also other interested stakeholders in the ranking and selection of RES technologies / projects.

Future studies need to include a greater number of criteria. Also, it is necessary to consider the introduction of a larger number of decision makers from different fields (experts, stakeholders, business sector, NGO sector, public sector, etc.). Future research should be based on the application of fuzzy environments to avoid inaccuracies.

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REZIME

VIŠEKRITERIJUMSKA OCENA OBNOVLJIVIH IZVORA ENERGIJE U SRBIJI

Razvoj današnjih ekonomija nezamisliv je bez energije. Međutim, rezerve fosilnih goriva se smanjuju, klimatske promene se ubrzavaju i potrebne su određene promene u energetskom sektoru. Obnovljivi izvori energije su potencijalno rešenje za mnoge naučnike i praktičare. Međutim, planiranje i realizacija projekata obnovljivih izvora energije zahteva razmatranje brojnih kriterijuma, zbog čega se višekriterijumske metode odlučivanja često koriste za procenu obnovljivih izvora energije/tehnologija. Cilj ovog rada je procena četiri vrste obnovljivih izvora energije (fotonaponska, hidro, biomasa i energija vetra) u Srbiji. Primenjen je analitički hijerarhijski proces i sedam kriterijuma. Na osnovu dobijenih rezultata, hidro izvori su najbolje rangirani. Takođe je sprovedena analiza osetljivosti da bi se utvrdilo da li bi promene prioriteta kriterijuma prouzrokovale promene u rangu alternativa. Utvrđeno je da su potrebne značajne promene u prioritetima da bi došlo do promena ranga, pa se može zaključiti da su dobijeni rezultati relevantni.

Ključne reči: *OIE, AHP, PV, vetar, hidro, biomasa*