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Analyzing Growing Wood Pellet Markets in Face of Renewable Energy Demand: Making Informed Trading Decisions with Multi-Criteria Decision-Making Model

Analiza rastućih tržišta drvnih peleta u uvjetima potražnje obnovljive energije: donošenje informiranih odluka o trgovanju utemeljenih na višekriterijskome modelu odlučivanja

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ABSTRACT • *As a sustainable and cost-effective biofuel source for power generation and heating systems, wood pellets play a critical role in the renewable energy landscape. This leads to the discussion on their international trade on the edge of major global challenges such as climate change and energy security. In this paper, we focus on the wood pellets trade and analyze its growing markets by decision-making models. A hybrid multi-criteria decision-making model (MCDM) is proposed, supported by critical criteria of international trade, to trading countries' executives to make informed decisions on target markets. The model includes both criteria (value imported, trade balance, unit value, annual growth in value, CO_2 emission, logistic performance index, concentration of supplying countries) and alternatives (17 prior importing countries). It determines the weights of criteria by Criteria Importance Through Intercriteria Correlation (CRITIC) method and ranks alternatives by Additive Ratio Assessment (ARAS) technique. Based on CRITIC analysis, "concentration of supplying countries" is found as the most significant criterion. According to the results, within informed trading decisions, the top three markets for exporting countries are determined as the United Kingdom, Japan, and the Netherlands in terms of growing demand for wood pellets.*

KEYWORDS: *wood pellet; international market; biofuel trade; CRITIC; ARAS*

SAŽETAK • *Drvni peleti imaju ključnu ulogu u proizvodnji obnovljive energije kao održiv i troškovno učinkovit izvor biogoriva za proizvodnju električne energije i za grijanje. To nas dovodi do bitne rasprave o međunarodnoj trgovini u kontekstu velikih globalnih izazova kao što su klimatske promjene i energetska sigurnost. U ovom radu fokus je na trgovini drvnim peletima i analizi rastućeg tržišta primjenom posebnog modela odlučivanja. Predlaže*

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se hibridni višekriterijski model odlučivanja (MCDM) podržan kritičkim kriterijima međunarodne trgovine kako bi operativci trgovinskih zemalja donosili informirane odluke o ciljanim tržištima. Model uključuje kriterije međunarodne trgovine (vrijednost uvoza, trgovinsku bilancu, jediničnu vrijednost, godišnji rast vrijednosti, emisiju CO_2, indeks logističke učinkovitosti, koncentraciju zemalja izvoznica) i alternative (17 prethodnih zemalja uvoznica). Usto, modelom se određuju ponderi kriterija metodom njihove važnosti putem međukriterijske korelacije (CRITIC) te se alternative rangiraju tehnikom procjene omjera aditiva (ARAS). Na temelju CRITIC analize utvrđeno je da je najvažniji kriterij koncentracija zemalja izvoznica. Prema rezultatima, unutar informiranih trgovačkih odluka kao tri najveća tržišta za zemlje izvoznice u smislu rastuće potražnje drvnih peleta prepoznate su Velika Britanija, Japan i Nizozemska.

KLJUČNE RIJEČI: *drvni pelet; međunarodno tržište; trgovina biogorivom, CRITIC; ARAS*

1 INTRODUCTION
1. UVOD

The rapid growth in the world population, urbanization, and industrialization in emerging regions led to a considerable increase in the demand for energy generation and consumption. However, while fossil fuels meet 80 per cent of the current global primary energy demand used in heating, electricity, transportation and industry, they are also the cause of approximately two-thirds of greenhouse gas (GHG) emissions (UN, 2015). The relevant institutions strongly emphasize that the use of renewable energy should be increased and that the share of fossil fuels in energy consumption should be significantly reduced to combat global climate change. Therefore, renewable energy has increasingly become more important to meet the global energy demand. Gielen *et al*. (2019) demonstrated in their study that the proportion of renewable energy in the total primary energy supply can increase from 15 % in 2015 to 63 % in 2050.

Wood pellets are one of the significant renewable biofuel energies derived from woody biomass and are considered to be a promising carbon-neutral alternative to fossil fuels. According to Bioenergy Europe, wood pellets are mentioned to be a reliable and affordable solution for all sectors in the context of achieving carbon neutrality by 2050 and will contribute significantly to the decarbonization of the heating sector, which is responsible for almost half of the energy consumption (Bioenergy Europe Statistical Report, 2021). They are highly efficient, effective and cheaper energy sources with a lower moisture content and relatively high heating value compared to other types of biomass fuels; they also stand out among all renewable energy sources with ease of production technology (Proskurina *et al*., 2016). Moreover, due to their smaller volume, their storage and shipping is also more efficient (Uslu *et al*., 2008) and they are suitable for use in both local, urban, and large public areas due to their characteristics (Giacomo and Taglieri, 2019). Therefore, wood pellets have recently become an important energy carrier trad-

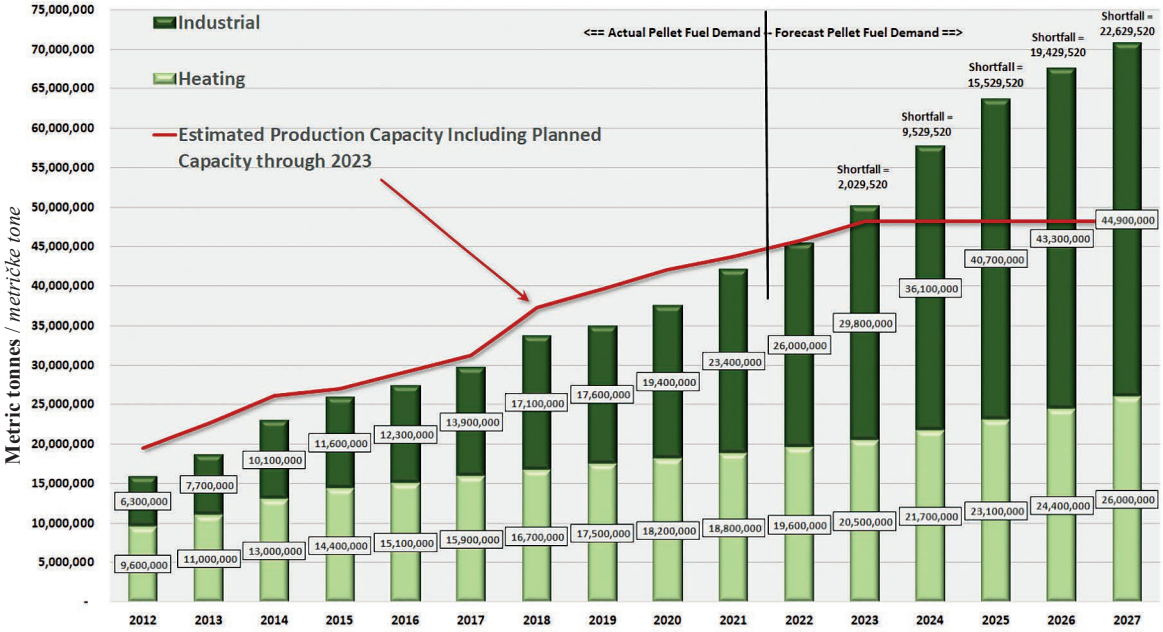

Figure 1 Global heating and industrial pellet demand with the forecast up to 2027 (Strauss (2022), Canadian BioMass, https://www.canadianbiomassmagazine.ca/2022-wood-pellet-markets-outlook/)
Slika 1. Globalna potreba za grijanjem i potražnja industrijskih peleta s predviđanjem do 2027. godine (Strauss, 2022., Canadian BioMass; https://www.canadianbiomassmagazine.ca/2022-wood-pellet-markets-outlook/)

ed on a large scale and over long distances, due to their high energy density and stable characteristics (Scarlat *et al*., 2019).

Figure 1 shows the global heating and industrial wood pellets demand with the forecast up to 2027. According to a forecast analysis by Future Market Insights (FMI), the total global demand for wood pellets, for both industrial and heating purposes, is projected to expand at a compound annual growth rate (CAGR) of 44 % during the forecast period between 2021 and 2027. However, this growth projection assumes that the production capacity will increase in parallel with the demand growth.

To meet the growing demand for wood pellets, global production totaled 1.7 million metric tons in the year 2000 (Statista, 2021), and it had surpassed 44.3 million tonnes by 2021. Europe produced roughly 25.4 million tonnes of wood pellets, accounting for the largest share of wood pellet production that year, and America followed Europe with 13.2 million tonnes of production in 2021 (Food and Agriculture Organization – FAO, 2023). The total global exports amounted to over 31.1 million tonnes, with a total value of US$ 4.7 billion. Meanwhile, the total import was 27.7 million tonnes, with a total value of US$ 50.0 billion in 2021 (FAO, 2023). Therefore, the wood pellets market appears to be developing dynamically in response to the increasing global demand for renewable energy in the face of climate change. In this sense, it is crucial to focus on wood pellets markets to create insight for both researchers and trading bodies for the future of the industry in the face of renewable energy demand.

2 LITERATURE REVIEW AND STUDY AIM
2. PREGLED LITERATURE I CILJ ISTRAŽIVANJA

Although there is an increasing interest in wood pellets markets due to the demand for renewable energy, few studies have focused on an overview of the current market, price policies and future economic expectations for several pioneer countries.

Peng *et al*. (2010) examined the current and future wood pellet market for Canada. Sikkema *et al*. (2011) provided a comprehensive overview of the current wood pellet market in Europe, including demand, supplies, market types, prices, and outlook, considering raw material supply. Goh *et al*. (2013) overviewed the wood pellet markets in various countries, including market factors and relevant policies under the discussion on global production and consumption in 2010, with a focus on the EU as the primary market. Roni *et al*. (2017) investigated the industrial-grade wood pellet market assuming potential buyers and suppliers optimize their decision independently. Jonsson and Rinaldi (2017) used economic modeling to assess the impact of gradually increasing wood pellets on global wood-based product markets. Their findings indicated that an increase in EU demand for wood pellets would result in a significant rise in imports, in addition to increasing EU production. Thran (2018) examined the global wood pellets market dynamics and traced sectoral developments in production, consumption, export/import and price patterns under the effect of policies between 2008 and 2016. Schipfer *et al*. (2020) aimed to understand the efficiency of the wood pellet market using modern trade theory. The writers analyzed the recent European market data for wood pellets used in small-scale heating systems, specifically focusing on trade flows and price developments between Italy, Austria, Germany, and France. They also examined market integration, identified potential inefficiencies, and made policy recommendations to ensure access and affordability of this renewable heating commodity in the long run based on the findings. Krivokochenko (2021) considered the current state and prospects for the wood pellet market and characterized the major trends in production, consumption and international wood pellet trade. Franco (2022) conducted a review of the literature published from 2010 to March 2020 that helped to understand the dynamics of the forest biomass supply for wood pellets production. However, these papers did not fully address the trade potential of wood pellets globally. Many studies have just focused on local or country-based production or trade potential and furthermore, no studies focused on modeling the growing wood pellet exporting markets by any decision-making models in the face of growing renewable energy demand.

Consequently, identifying target countries and focusing on growing markets is a critical issue for wood pellet trading countries to gain a competitive advantage and a significant market share in the future. This leads to the multi-criteria decision-making (MCDM) problem, which should be addressed by considering various criteria and solved using relevant MCDM methods. With this perspective in mind, the aims of this study have been determined as follows:

1. Create a multi-criteria decision-making system for wood pellets trading countries, by determining important criteria and their weights for target market selection,

2. Provide export forecasting to trading countries' executives about the priority target markets within the most rapidly growing 17 alternatives.

To achieve these aims, the methods were discussed in detail and applied for both determining the criteria and ranking the countries for export within the MCDM methods in the methodology part supported by the literature review.

3 EMPIRICAL METHODS AND DATA
3. EMPIRIJSKE METODE I PODATCI

Target market selection is seen as one of the most complex and time-consuming activities of both countries and companies, due to conflicting objectives, abundance of alternatives and diversity of criteria. For this reason, target market selection can be defined as a Multi-Criteria Decision Making problem (Aghdaie and Alimardani, 2015).

Various MCDM methods have been employed in multiple studies in recent years to assess the selection of target markets for both organizations and industries. Albadvi *et al*. (2007) applied the PROMETHEE method to select the best target market for TV in Iran. Aghdaie *et al*. (2011) utilized Fuzzy AHP and Fuzzy TOPSIS to evaluate and choose market segments. Mobin *et al*. (2014), employed Entropy, SAW, TOPSIS and VIKOR to identify markets for Iranian pistachios. Aghdaie and Alimardani (2015) used AHP and TOPSIS to elicit a suitable target market. Söyler and Yaraş (2016) applied AHP and TOPSIS methods to select the target markets for the travertine market. Ortiz-Barrios and Lopez-Meza (2016) proposed an integrated AHP-VIKOR approach for selecting the most suitable markets for prospective companies.

Tosun (2017) utilized Fuzzy VIKOR to determine the target market for fresh fruit and vegetables. Oey *et al*. (2018) evaluated the international market selection of a metal company in Indonesia using AHP and Goal Programming. Sukoroto *et al*. (2020) implemented the AHP method for target market selection of a rolling stock manufacturer in Indonesia. Zakeri *et al*. (2020) used Grey COPRAS and Grey TOPSIS to select the target market for the Iranian dairy market. Aghajani (2021) prioritized target markets using a combined method of AHP/Monte Carlo simulation and Fuzzy AHP. Yıldız and Özbek (2021) employed TOPSIS, Grey Relational Analysis and ANP to evaluate alternative sock export markets. Espinoza-Lastra *et al*. (2022) applied AHP to select the target market for the Indonesian rolling stock market. Celik and Akmermer (2022) evaluated export markets for major aquaculture products of Turkey using Fuzzy AHP and TOPSIS methods.

In this paper, a hybrid MCDM model was proposed combining CRITIC and ARAS methods to create a multi-criteria decision-making system. Since it is an objective decision-making method, the CRITIC method is used to determine the weights. The ARAS method is preferred for this study because it is easy to understand, has a short calculation time and requires few mathematical operations, but is still a reliable method. It is assumed that using the CRITIC and ARAS methods together would contribute to the literature. The analysis was conducted in three stages, including constructing the decision model, analysis, and scenario analysis as presented in the framework of the application shown in Figure 2.

The first stage of the application is to create the decision matrix, as in all MCDM problems. Evaluation criteria and alternative countries for creating a decision matrix were defined using data obtained from the international trade database. In the second stage, the CRITIC method is used for weighting the criteria objectively, and the ARAS method is applied for evaluating the top priority markets. These methods are detailed below.

3.1 CRITIC Method
3.1. CRITIC metoda

The CRITIC method has been proposed to objectively determine the importance weights of the criteria of MCDM problems. The CRITIC method was introduced to the literature in 1995 by Diakoulaki *et al*. This method is a weighting method performed by using the standard deviations of the criteria and the correlation between the criteria. The steps of the CRITIC method are as follows (Diakoulaki *et al*., 2015; Aytaç Adalı and Tus Işık, 2017);

Step 1: Creation of the Decision Matrix

In the decision matrix expressed by Eq. (1), the index i represents the alternatives and the index j repre-

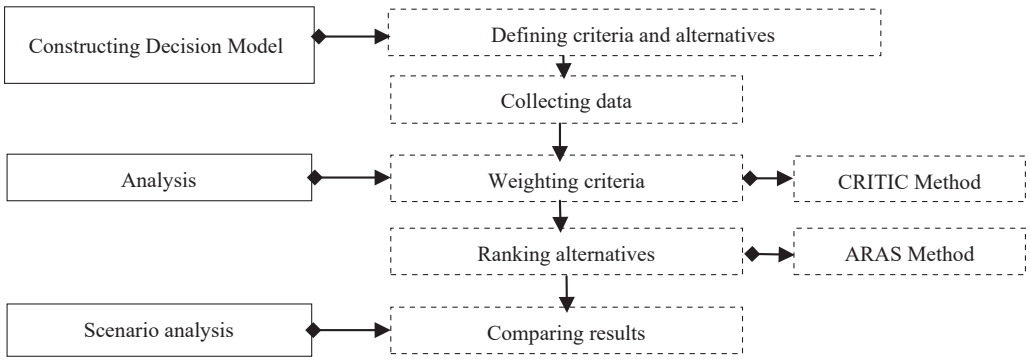

Figure 2 Application framework
Slika 2. Okvir aplikacije

sents the criteria. x_{ij}, represents the performance value of i*th* alternative in terms of j*th* criteria.

$$X = [X_{ij}]_{mxn} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

i= 1,2,…m and j = 1,2,…,n) (1)

Step 2: Decision matrix is normalized by Eq. (2).

$$x_i j^* = \frac{x_{ij} - \min x_{ij}}{\max(x_{ij}) - \min(x_{ij})}$$

(i= 1,2,…m and j = 1,2,…,n) (2)

Step 3: In this step, the standard deviation of the criterion and its correlation with other criteria are included. Then the weight is calculated by Eq. (3).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (3)$$

C_j shows the quantity of information comprised in j*th* criterion settled as:

$$C_j = \sigma_j \sum_{j=1}^{n} (1 - r_{ij}) \quad (4)$$

Where σ_j represents the standard deviation of the j*th* criterion and r_{ij} is the correlation coefficient between the two criteria. This method tends to assign greater importance to criteria exhibiting a high standard deviation and weak correlation with other criteria. To be specific, a higher value of C_j means that a greater amount of information is obtained from the given criterion, so the criterion has higher relative importance for the decision problem.

3.2 ARAS Method
3.2. ARAS metoda

Zavadskas and Turskis (2010) introduced the ARAS (Additive Ratio Assessment) method as an MCDM (Multi-Criteria Decision Making) approach. This method, as outlined in their works (Zavadskas and Turskis, 2010; Zavadskas *et al*., 2010), comprises the following sequential steps.

Step 1: Formation of decision matrix: x_{ij} values are created for *m* alternatives and *n* criteria.

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix};$$

$i = 0, 1,\ldots,m$ $\quad$ j = 0,1,…,*n* (5)

Let x_{ij} denote the performance value and x_{0j} denote the optimal value for criterion *j*. In cases where the optimal value x_{0j} j is not known, it is assigned as follows:

$x_{0j} = \max_i x_{ij}$, if maximization is preferable, (6)

$x_{0j} = \min_i x_{ij}$, if minimization is preferable.

Step 2: Creating a normalized decision matrix $(\bar{X})$w

The criteria values, which are desired to be maximized, are normalized as follows:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (7)$$

The criteria values, which are preferred to be minimized, undergo normalization using the method illustrated below:

$$x_{ij}^* = \frac{1}{x_{ij}} \quad (8)$$

$$\bar{x}_{ij} = \frac{x_{ij}^*}{\sum_{i=0}^{m} x_{ij}^*} \quad (9)$$

Step 3: Defining weighted normalized decision matrix $(\hat{X})$

$$\sum_{j=1}^{n} w_j = 1 \quad (10)$$

$$\hat{x}_{ij} = \bar{x}_{ij} \cdot w_{ij}$$

Where the weights are denoted by w_j and $0 < w_j < 1$.

Step 4: The determination of optimality function values is performed through the calculation process.

$$S_{i=} \sum_{j=1}^{n} \hat{x}_{ij}, \quad i = 0,1,\ldots,m \quad (11)$$

Where the optimality function value of alternative *i* is represented by S_i.

Step 5: The degree of utility (K_i) for alternatives is obtained through the process of assessment.

$$K_i = \frac{S_i}{S_0}, \; i = 0,1,\ldots,m \quad (12)$$

Where the optimal value of the alternative is denoted as S_0. The K_i values, which range between 0 and 1, are sorted in ascending order, with the highest degree indicating the most favorable outcome.

3.3 Scenario analysis
3.3. Analiza scenarija

In the last stage, scenario analysis was applied to assess the impact of changes in criteria weights on the rankings and evaluate the reliability of the proposed methodology.

The application of scenario analysis serves multiple purposes: (1) validating the results derived from MCDM problems, (2) identifying the primary factors responsible for alterations in alternative rankings, and (3) ranking alternatives based on variations in criteria weights, as described by Butler *et al*. (1997). In the final phase of implementation, a scenario analysis is conducted, encompassing seven distinct scenarios. This analysis explores changes in rankings resulting from modifications in criteria weights and assesses the robustness of the proposed methodology. The outcomes obtained from the analysis are subsequently compared for evaluation.

4 EMPIRICAL RESULTS AND DISCUSSIONS
4. EMPIRIJSKI REZULTATI I RASPRAVA

4.1 Constructing decision model
4.1. Konstruiranje modela odlučivanja

In the first stage of the application, the decision matrix was created by defining evaluation criteria and alternative countries for the analysis, using data obtained from the international trade database.

In the determination of the criteria, we examined the target market analysis reports to identify the main criteria for trading decisions. In many research studies, various criteria have been used from different perspectives (Aghdaie and Alimardani, 2015; Akmermer and Celik, 2021; Özekenci, 2024). To determine the primary criteria, a survey was conducted with the export experts, who have experience in Forest industry. We also referred to the studies in the literature and checked data availability in the database. Consequently, we determined seven criteria, listed in Table 1, to evaluate potential markets.

The datasets of 6 criteria (VI, TB, UV, AG, CO_2, and COS) were obtained from TradeMap, UNdata and FAOSTAT. The criterion LPI was obtained from WorldBank. We used the Harmonized Commodity Description and Coding Systems for products to search for the data in the database. The 6-digit HS tariff Classification Number for wood pellets is 440131. All these data pertaining to the criteria were utilized in the analysis phases for the construction of the multi-criteria decision-making model.

In the second step, we determined the potential target countries. We identified the wood pellet importing countries and then evaluated them based on their con-

Table 1 Evaluation criteria
Tablica 1. Kriteriji ocjenjivanja

Criteria / *Kriterij*	**Explanation** / *Objašnjenje*
Value imported in 2022 (USD thousand) (VI) *vrijednost peleta uvezenih 2022. (tisuće USD) (VI)*	Total monetary value of pellets that a country has brought in from other countries during 2022 *Ukupna novčana vrijednost peleta koje je neka zemlja uvezla iz drugih zemalja tijekom 2022.*
Trade balance in 2022 (USD thousand) (TB) *trgovinska bilanca u 2022. (tisuće USD) (TB)*	The trade balance is equal to the difference between the value of the exports and imports. (Negative Trade Balance values are important for supplying countries. According to CRITIC and ARAS methods we take the Trade Balance data in absolute value.) *Trgovinska bilanca jednaka je razlici između vrijednosti izvoza i vrijednosti uvoza. (Vrijednosti negativne trgovinske bilance važne su za zemlje izvoznice. Prema metodama CRITIC i ARAS, uzimamo podatke o trgovinskoj bilanci u apsolutnoj vrijednosti.)*
Unit value (USD/unit) (UV) *jedinična vrijednost (USD/jedinica) (UV)*	The unit value is the quotient of the value and the quantity. It shows the average value per unit of quantity of the commercial transactions. It is not in any case a selling price of the pellets. *Jedinična vrijednost je kvocijent vrijednosti i količine. Prikazuje prosječnu vrijednost po jedinici količine komercijalnih transakcija. To nikada nije prodajna cijena peleta.*
Annual growth in value between 2018-2022 (%) (AG) *godišnji rast vrijednosti između 2018. i 2022. (%) (AG)*	The computation formula of the growth rate over five years is the following: *Formula za izračun stope rasta tijekom pet godina glasi:* $\left(\exp\left(\frac{\sum_{i=1}^{5} i\cdot \mathrm{Ln}(v_i) - 3\cdot\sum_{i=1}^{5}\mathrm{Ln}(v_i)}{10}\right)-1\right)\cdot 100$ Where v_i is the value of the i-th year in current US dollar. *Pritom je v_i vrijednost i-te godine izražena američkim dolarima.*
CO_2 emission (tons) (CO_2) *emisija CO_2 (tona) (CO_2)*	The amount of carbon dioxide (CO_2) released into the atmosphere by a particular source or activity, measured in metric tons. *Količina ugljikova dioksida (CO_2) ispuštena u atmosferu iz određenog izvora ili od neke aktivnosti mjerena metričkim tonama.*
Logistic Performance Index (LPI) *indeks logističke učinkovitosti (LPI)*	A measure used to assess a country's logistics performance based on six key dimensions, including customs performance, infrastructure, and timeliness of shipments. *Mjera koja se upotrebljava za procjenu logističke učinkovitosti zemlje na temelju šest ključnih dimenzija, uključujući carinsku učinkovitost, infrastrukturu i pravodobnost pošiljaka.*
Concentration of supplying countries (COS) *koncentracija zemalja izvoznica (COS)*	The concentration is based on the Herfindahl index (H). It is calculated by squaring the share of each country in the selected market and by summing the resulting numbers. Koncentracija se temelji na Herfindahlovu indeksu (H). Izračunava se kvadriranjem udjela svake zemlje na odabranom tržištu i zbrajanjem dobivenih brojeva. $H = \sum_{i=1}^{N} s_i^2$ Where s_i is the share of the country i in the market, and N is the number of countries. *Pritom je s_i udio zemlje i na tržištu, a N broj zemalja.*

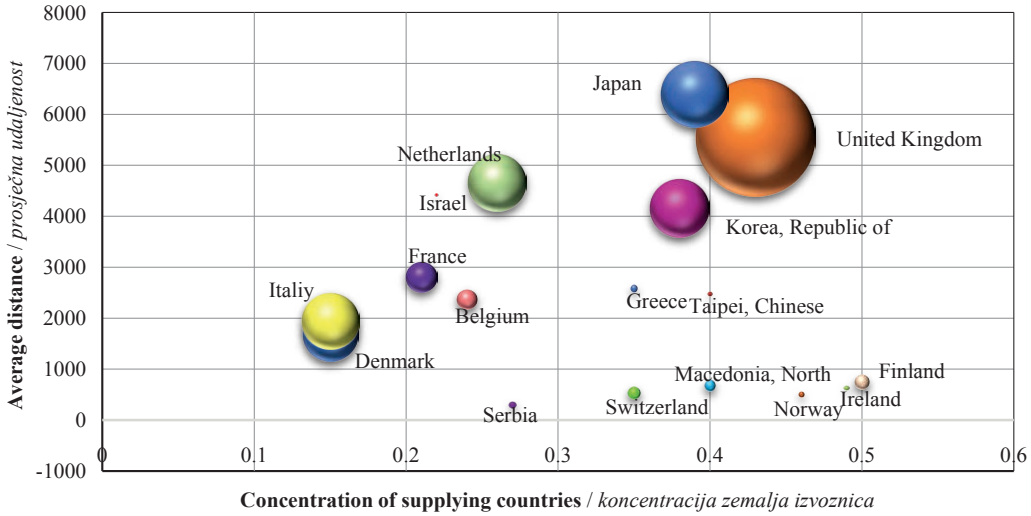

Figure 3 Importer countries
Slika 3. Zemlje uvoznice

centration of importing, the average distance from their supplying countries and their trade balance of more than one million USD Dollars in absolute value. The data was obtained from Trademap Database. The bubble map in Figure 3 shows the results of this evaluation, prompting us to determine 17 alternative countries for analysis. These countries were all included in the analysis stages for creating the multi-criteria decision-making model.

4.2 Analysis
4.2. Analiza

This stage consists of weighting the criteria and ranking the potential target markets for wood pellets. The steps of the CRITIC method are applied to weight the criteria objectively. Then the rankings of alternative countries are calculated by the ARAS method. To that end, the decision matrix of the problem is created as shown in Table 2.

Applying the Equations (1-4) to the CRITIC method, the weights of the criteria are calculated as in Table 3. In this context, the most important criterion is found as "concentration of supplying countries (COS)", whereas the least important criterion is found as "logistic performance index (LPI)".

In the subsequent phase of analysis, the ranking of countries is determined using Eqs. (5-12) based on the ARAS method. Table 4 shows the scores of the ARAS method. Considering the ranking column, the

Table 2 Decision matrix
Tablica 2. Matrica odlučivanja

Importers / *Uvoznici*	**VI**	**TB**	**UV**	**AG**	**CO_2**	**LPI**	**COS**
United Kingdom	1794802	1794207	217	9	364.995	3.987	0.43
Japan	562691	562547	204	54	1164.931	4.026	0.39
Denmark	525270	374074	222	0	32.078	3.992	0.15
Netherlands	499624	420581	186	91	160.938	4.019	0.26
Korea, Republic of	439379	439379	183	4	659.578	3.612	0.38
Italy	414321	410980	218	3	333.722	3.739	0.15
Belgium	159103	48568	168	-1	96.965	4.039	0.24
France	150615	120198	343	25	318.349	3.844	0.21
Finland	27297	25433	208	23	45.392	3.969	0.5
Switzerland	19176	19165	410	-3	38.950	3.901	0.35
Serbia	15482	5175	235	16	83.153	2.841	0.27
Macedonia, North	15367	15261	198	9	7.885	2.705	0.4
Norway	11222	3874	186	8	43.610	3.697	0.46
Ireland	8629	2867	349	16	37.338	3.510	0.49
Greece	7254	6136	303	-4	67.671	3.205	0.35
Taipei, Chinese	1938	1930	197	-6	286.023	3.600	0.4
Israel	1076	1076	211	34	68.269	3.308	0.22

Table 3 Weights of criteria
Tablica 3. Ponderi kriterija

VI	**TB**	**UV**	**AG**	**CO_2**	**LPI**	**COS**
0.143	0.128	0.152	0.131	0.158	0.124	0.164

Table 4 Scores of ARAS method
Tablica 4. Rezultati ARAS metode

Importers *Uvoznici*	**Score (K_i)** *Rezultati (K_i)*	**Ranking** *Rangiranje*
United Kingdom	0.659	1
Japan	0.567	2
Netherlands	0.420	3
Korea, Republic of	0.341	4
Italy	0.254	5
France	0.252	6
Denmark	0.207	7
Finland	0.187	8
Ireland	0.184	9
Israel	0.167	10
Taipei, Chinese	0.149	11
Switzerland	0.146	12
Serbia	0.143	13
Norway	0.142	14
Belgium	0.131	15
Macedonia, North	0.126	16
Greece	0.123	17

United Kingdom can be seen as the top priority market for wood pellets. Other prior target markets for wood pellets trading are Japan and the Netherlands.

In the concluding part of the application, we applied the scenario analysis to assess the impact of changes in criteria weights on the rankings and evaluate the reliability of the proposed methodology. Scenario analysis is utilized to evaluate the reliability of outcomes in the face of uncertainties arising from Multiple Criteria Decision Making (MCDM) problems, as indicated by Karande *et al.* (2016). In MCDM problems, decision makers often assign weights to criteria based on subjective evaluations, employing methods like AHP, ANP, and others. Consequently, conducting sensitivity analysis becomes crucial in the decision-making process to ensure accurate interpretation of the collected data.

In all scenarios, the United Kingdom, Japan, and the Netherlands consistently emerge as the foremost priority markets for wood pellets, in six out of the seven scenarios. Furthermore, Figure 4 presents a visual representation of the data.

5 CONCLUSION AND POLICY IMPLICATIONS
5. ZAKLJUČAK I UTJECAJ NA POLITIKU

Wood pellets have gained considerable attention among renewable energy sources due to their several advantages in mitigating global warming and promoting energy security. Thus, the wood pellet industry and its trading potential are growing globally. Therefore, focusing on growing markets for wood pellets has become a crucial strategic discussion for producing countries to maintain their competitive edge in renewable energy markets. In this study, we proposed a MCDM model for executives in producing countries to forecast the growing wood pellets markets in international markets. We selected seven criteria that are commonly used in international trade decisions, such as imported value, trade balance, unit value, annual growth in value, CO_2 emission, logistic performance index, and the concentration of supplying countries, and applied the CRITIC method to weigh these criteria. Then, we chose 17 alternative target countries, which are among

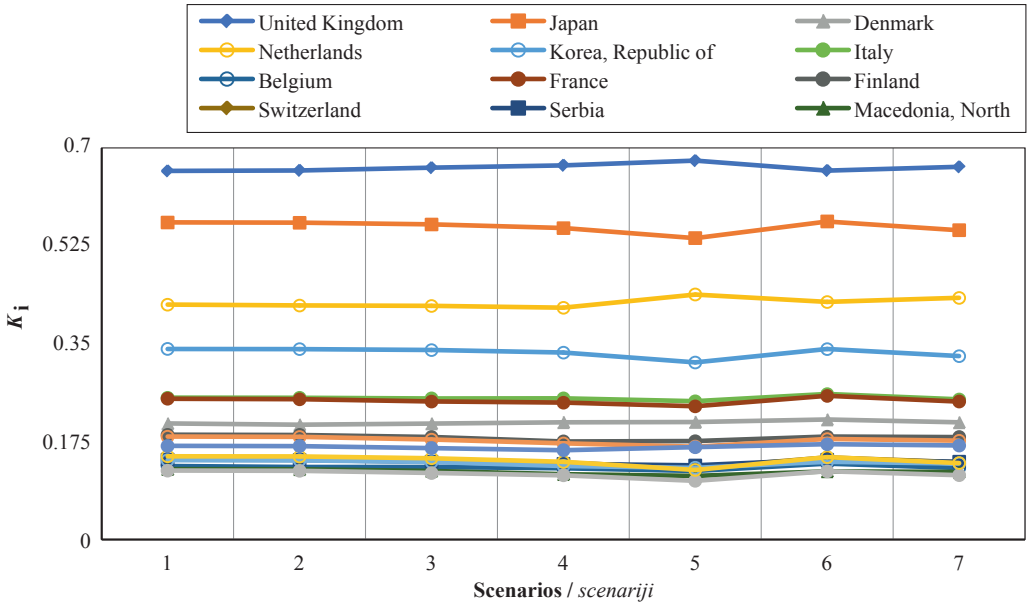

Figure 4 Scenario analysis
Slika 4. Analiza scenarijâ

Table 5 Scenario analysis
Tablica 5. Analiza scenarija

Scenarios *Scenariji*	**1**		**2**		**3**		**4**		**5**		**6**		**7**	
Weights *Ponderi*	w_1	0.143	w_1	0.128	w_1	0.152	w_1	0.164	w_1	0.143	w_1	0.143	w_1	0.143
	w_2	0.128	w_2	0.143	w_2	0.128	w_2	0.128	w_2	0.164	w_2	0.128	w_2	0.143
	w_3	0.152	w_3	0.152	w_3	0.143	w_3	0.152	w_3	0.128	w_3	0.152	w_3	0.143
	w_4	0.131	w_4	0.131	w_4	0.131	w_4	0.131	w_4	0.152	w_4	0.131	w_4	0.143
	w_5	0.158	w5	0.158	w_5	0.158	w_5	0.158	w_5	0.131	w_5	0.158	w_5	0.143
	w_6	0.124	w_6	0.124	w_6	0.124	w_6	0.124	w_6	0.158	w_6	0.164	w_6	0.143
	w_7	0.164	w_7	0.164	w_7	0.164	w_7	0.143	w_7	0.124	w_7	0.124	w_7	0.143
	K_i	**ranking**	**K_i**	**ranking**	**K_i**	**ranking**	**K_i**	**ranking**	**K_i**	**ranking**	**K_i**	**ranking**	**K_i**	**ranking**
United Kingdom	0.659	1	0.660	1	0.665	1	0.669	1	0.677	1	0.660	1	0.666	1
Japan	0.567	2	0.566	2	0.563	2	0.557	2	0.539	2	0.569	2	0.553	2
Netherlands	0.420	3	0.418	3	0.418	3	0.414	3	0.438	3	0.425	3	0.432	3
Republic of Korea	0.341	4	0.340	4	0.339	4	0.334	4	0.317	4	0.341	4	0.328	4
Italy	0.254	5	0.254	5	0.252	5	0.252	5	0.247	5	0.260	5	0.251	5
France	0.252	6	0.251	6	0.247	6	0.245	6	0.238	6	0.257	6	0.247	6
Denmark	0.207	7	0.205	7	0.207	7	0.210	7	0.210	7	0.215	7	0.209	7
Finland	0.187	8	0.187	8	0.183	8	0.175	8	0.176	8	0.184	8	0.183	8
Ireland	0.184	9	0.184	9	0.179	9	0.172	9	0.166	9	0.180	9	0.177	9
Israel	0.167	10	0.167	10	0.163	10	0.160	10	0.165	10	0.170	10	0.168	10
Serbia	0.143	13	0.142	13	0.139	13	0.135	13	0.133	11	0.143	13	0.139	11
Switzerland	0.146	12	0.146	12	0.141	12	0.137	12	0.128	13	0.147	12	0.138	12
Taipei, Chinese	0.149	11	0.148	11	0.145	11	0.139	11	0.124	14	0.147	11	0.137	13
Norway	0.142	14	0.142	14	0.139	14	0.131	14	0.128	12	0.139	14	0.136	14
Belgium	0.131	15	0.130	15	0.130	15	0.127	15	0.123	15	0.136	15	0.128	15
North Macedonia	0.126	16	0.126	16	0.123	16	0.117	16	0.114	16	0.122	17	0.121	16
Greece	0.123	17	0.123	17	0.119	17	0.115	17	0.105	17	0.122	16	0.115	17

the growing importing countries and have a trade balance of one million USD dollars in absolute value. The ARAS method was applied to evaluate and rank the top-priority markets for wood pellet trading countries. In conclusion, a scenario analysis was carried out, encompassing seven distinct scenarios, with the aim of evaluating the influence of variations in criteria weights on rankings and assessing the dependability of the proposed methodology. Therefore, we have successfully analyzed the expanding wood pellet markets in response to the demand for renewable energy, providing executives with scientifically informed trading decisions. This paper makes a significant contribution to literature as it is the first study to combine the CRITIC and ARAS methods. According to the available literature, there is a dearth of research examining the assessment of target markets for wood pellets utilizing the MCDM approach. Furthermore, this paper presents a practical method for evaluating target markets and demonstrates its application. However, this study has certain limitations pertaining to the scope of the research and the methods used. The examination is limited to 17 countries, and there are limitations in terms of the number of alternatives and the availability of data. Besides, the number of selected criteria is also limited due to the unavailability of data for some criteria. Future studies are encouraged to investigate the incorporation of supplementary criteria that could potentially impact performance in practical settings.

According to the results, the export executives of countries who want to make informed trading decisions should focus on the United Kingdom, Japan, and the Netherlands under the criteria of concentration of supplying countries. The criterion of logistics performance index does not demonstrate significance in relation to wood pellets trading. However, due to the environmental interest of wood pellets and their commitment to energy and CO_2 emission saving, the way of transportation of wood pellets should be especially considered by the trading countries. There are some significant but very limited studies in the literature discussing the management of logistics and ways of transportation of wood pellets (European Biomass Industry Association [EUBIA], 2009; Fritsche *et al.*, 2019) and considering the CO_2 emission of wood pellets in different transportation types. Researchers are

advised to prioritize this significant issue in their future investigations, as it will assist executives in making informed transportation decisions amid the challenges posed by global climate change.

On the other hand, all analyses were conducted using data from the past five years, which indicated that Europe is currently the largest market for wood pellet trading. This finding is supported by company-based sectoral reports, which also suggest that Europe will continue to be the largest wood pellet market in the next five years. However, according to the sectoral reports, the Asia-Pacific region is expected to be the fastest-growing market during the forecast period (ReportLinker, 2023; Mondor Intelligence, 2023; Research and Markets, 2023; Fortune Business Insight, 2023). Therefore, in the coming years, future research can reapply a similar methodology using the Asia-Pacific countries as potential alternatives to explore the new target markets for wood pellets.

We believe that this research will not only make a significant contribution to the academic literature but also advance the knowledge of foreign trade executives in exporting countries regarding the growing market for wood pellets, ultimately supporting their capacity building. Additionally, our findings can offer new insights and understanding for enterprises, particularly in sustainably managing the energy industry with a focus on renewable energy sources.

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