Konya Mühendislik Bilimleri Dergisi, c. 12, s. 2, 326-343, 2024
Konya Journal of Engineering Sciences, v. 12, n. 2, 326-343, 2024
ISSN: 2667-8055 (Electronic)
DOI: 10.36306/konjes.1328033

# RANKING OF THE MEMBER COUNTRIES IN THE BLACK SEA ECONOMIC COOPERATION ORGANIZATION USING MULTI-CRITERIA DECISION-MAKING METHODS

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## *Highlights*

- A ranking of member countries in BSECO with MCDM in terms of basic energy indicator are made.
- The MCDM approach is used consist of CRITIC, COPRAS, and the Borda Count method.
- Two scenarios are created in the study.
- Seven different solutions are found.

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**(Received: 15.07.2023; Accepted in Revised Form: 26.02.2024)**

**ABSTRACT:** The objective of the study is to measure and rank the performance of the Black Sea Economic Cooperation Organization (BSECO) member countries for the different four years using Multi-Criteria Decision Making (MCDM) techniques widely used in performance measurement. This is the first study using CRITIC (Criteria Importance through Intercritera Correlation), COPRAS (Compress PRoportional ASssessment- Complex Relative Assessment) and Borda Count Methods to rank countries on basic energy indicators using MCDM. The CRITIC method was used to calculate the critical weights of the criteria established in the first stage of the three-stage work. It is an objective method of MCDM. The performance of BSECO member countries is ranked using the COPRAS method. The weights calculated in the second stage are used for the ranking. In the last stage, using the Borda count method, which is a data fusion technique, a single ranking was obtained by integrating the rankings obtained under different scenarios. According to this result, Albania was the first, Georgia was the second and Armenia was the third. The last place was taken by Türkiye. Thus, MCDM techniques can provide effective and comprehensive results in this kind of problems. It can be observed that the unbiased results are objective measures of the criteria used.

***Keywords:*** *Energy Indicators, Performance Evaluation, BSECO, CRITIC Method, COPRAS Method, Borda Count Method*

## 1. INTRODUCTION

This study uses Multi-Criteria Decision Making (MCDM) to rank the member countries of the Black Sea Economic Cooperation Organization (BSECO) on a basic energy indicator. Energy demand is one of the most important issues in the world today [1]. Energy efficiency indicators are a popular topic for developed and developing countries in the world. However, some countries are striving to consume less energy and reduce their carbon dioxide emissions [1].

The term energy balance consists of supply, transformation and final consumption. Industry, transportation and other sectors are the final consumers of energy. Housing, communications and public services, agriculture/forestry and fisheries are the other sectors.

Energy consumption divided by activity is the energy efficiency indicator. Energy consumption divided by production is the industry indicator. Production consists of value added and physical production (paper, chemicals, other non-metallic mineral products and basic metals). Figure 1 shows the energy indicator pyramid.

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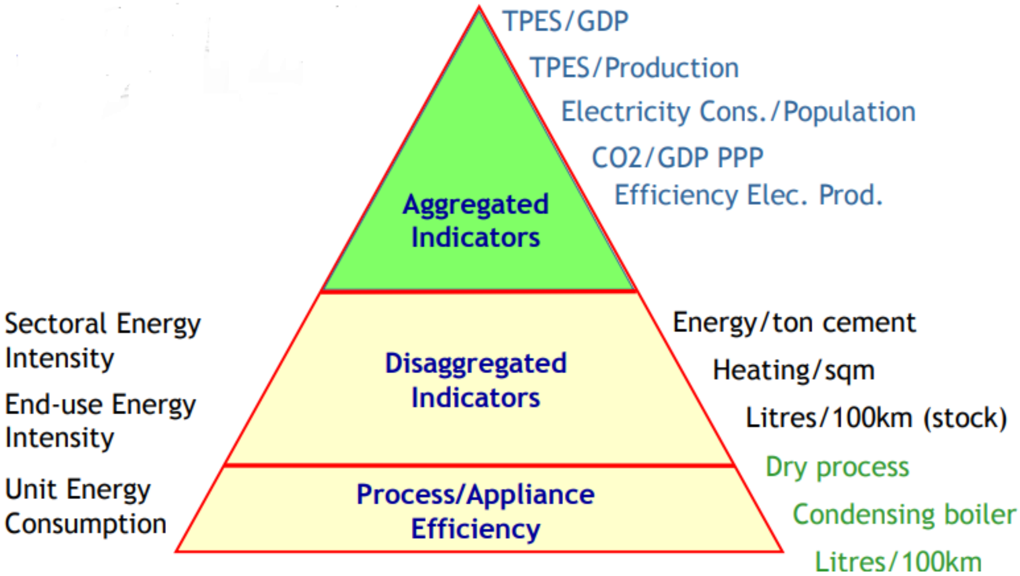


TPES: Total primary energy supply; PPP: Purchasing Power Parity; GDP: Gross Domestic Product

**Figure 1.** Pyramid of Energy Indicators [1]

The service indicator is the ratio of energy consumption to activity. Activity is the sum of value added, floor space and number of employees [1]. Section 3 explains the indicators used in the study.

The climate correction is based on heating degree-days. The heating correction is equal to the heating energy divided by the heating degree-days. Similarly, the residential energy efficiency indicator is equal to the energy consumption divided by the activity. The activity consists of the number of dwellings and the floor area. Residential energy consumption consists of space heating, space cooling, water heating, cooking, lighting, and appliances (energy use, inventory, diffusion) such as refrigerators, freezers, dishwashers, washers, dryers, televisions, and computers [1]. Energy efficient transportation is defined as moving more and farther with less fuel consumption. It is also defined as using public transportation instead of the private automobile.

There are a few studies in the literature on energy indicators for countries. The study by Unander [2] was based on the IEA energy indicator approach. The author presented examples of IEA work with indicators and an overview of the methodology used. The author also provided an example of a simplified indicator analysis in the case of India. Ramanathan [3] mentioned that some research articles on climate change examine the relationships between economic growth and carbon dioxide emissions or energy consumption separately to analyze the impact of economic growth and energy consumption on global carbon dioxide emissions. The relationships among $CO_2$ emissions, GDP growth, and energy consumption are examined simultaneously using data envelopment analysis. Sözen and Nalbant [4] mentioned that Turkey should make significant future plans about the strategy of consumption and production of basic energy sources. The energy indicators for Turkey have been identified. The energy indicators of EUROSTAT and Turkish Statistical Institute were taken and basic energy and economic indicators such as gross production, installed capacity, net energy consumption per person, import, export, consumption of coal, lignite, fuel oil, natural gas and hydropower were used. The study has shown the energy situation of Turkey among the EU countries.

Liu [5] mentioned that sustainability indicators are necessary to reflect various aspects of sustainability; the development of a general sustainability indicator including many basic sustainability indicators becomes critical. The method of selecting, quantifying, evaluating and weighting the basic indicators as well as the methods of the general sustainability indicator are reviewed. The study discusses the advantages and disadvantages of each method. Based on this discussion and the analysis of uncertainties in sustainability assessment, an effective framework and its procedures for the development of a global sustainability indicator for renewable energy systems are presented. What has been proposed to constitute energy access and energy access indicators has been reviewed by Mensah et al [6]. There was also a brief review of the different types of energy access indicators and an analysis of access to modern energy in Ghana as measured by the energy access indicators used in Ghana. Iddrisu and Bhattacharyya [7] mentioned that energy plays a vital role in the modern lifestyle of any country. Understanding the sustainability of a country's energy system remains an important policy issue. It has been reviewed the comprehensiveness of existing metrics in tracking and tracing energy sustainability and the authors proposed a composite index, the Sustainable Energy Development Index. It is stated that the Sustainable Energy Development Index focuses on determining the level of sustainability of both intra- and inter-generational needs. The methodology, data availability and first country comparisons were discussed. It was found that the Sustainable Energy Development Index has a positive correlation with both the Human Development Index and the Energy Development Index, but provides a better understanding of the different dimensions of energy sustainability. Alvarez et al [8] mentioned that sustainable development is one of the main guiding principles of European Union policies. It was said that sustainable development is based on a framework of three pillars - economic development, social development and environmental protection, and argued that energy seems to be the cornerstone of economic growth; the Europe 2020 strategy emphasizes the importance of making the European Union more sustainable by establishing a long-term approach with clear guidelines on climate change. A synthetic index of sustainable energy development for the European Union (EU)-15 is proposed. It is based on 33 variables. Ogonowski [9] analyzed the development of renewable energy among the countries of the European Union for ten selected indicators in the field of climate change, environment, and energy for the years 2011-2019. Renewable energy data from 28 EU countries were analyzed using the vector measure construction method. Saraji et al. [10] ranked Energy Union members using the Pythagorean Fuzzy SWARA TOPSIS framework to assess the EU's progress towards sustainable energy. Ten experts working in different fields were selected to identify the criteria. A sensitivity analysis was performed based on twenty scenarios. Hasheminasab et al. [11] presented a detailed framework to assess energy poverty by considering energy demand, clean energy production, strategic location and energy equity between countries. Energy poverty is evaluated in three categories. The first is society's energy demand, access, and affordability; the second is ensuring access to energy resources and harmonizing energy markets with import policies; and the third is sustainability and emissions from energy production. By addressing these three categories, energy will be accessible, affordable and sustainable for future generations. The comprehensive EP framework has been applied in a case study of 27 EU countries with real data based on the EU database. The Threshold Based Feature Ratio Analysis method was used to weight the criteria.

This study measures the performance of BSECO member countries using MCDM methods. The MCDM approach is used for decision problems with a large number of conflicting criteria [12, 13]. MCDM is the most widely used method for energy problems in the literature in recent years. Some of the papers on MCDM for energy problems have been briefly summarized. Ertay et al. [14] used MACBETH and AHP based multi-criteria methods to evaluate renewable energy alternatives under fuzziness in Turkey. There are 4 main attributes and 15 sub-attributes used in the evaluation. Wang [15] developed a robust multi-criteria technique for order preference by similarity to an ideal solution based building energy efficiency benchmarking approach. Malkawi et al [16] evaluated energy options and ranked them with respect to several clusters of criteria including financial, technical, environmental, ecological, social and risk assessment. Ervural et al [17] studied the problem of energy planning and formulated this problem with a multiobjective decision model under a set of realistic constraints. Vasic [18] applied multi-criteria analysis to energy policy design and used preference ranking method for evaluation enrichment. Sarucan et al. [19] tested the ranking of BSECO countries for only one scenario with MCDM according to the basic energy indicator. Engin et al. [20] analyzed the alternatives of renewable energy sources with the MCDM methods for Turkey. Rao et al. [21] measured energy poverty with a multidimensional and comprehensive set of indicators by combining GRA- SRA method and did a case study of N11 countries with data from 2001 to 2017. Onifade [22] examined the environmental impact of energy indicators on the ecological footprint of African economies, mainly oil exporters, for the period between 1990 and 2016. To the best of our knowledge, this is the first study in the literature to measure the performance of BSECO member countries in terms of basic energy indicators for two scenarios (base and active) and different four years using an MCDM approach. It is also the first study to rank countries on basic energy indicators using CRITIC's MCDM, COPRAS and Borda Count Methods.

The paper is organized as follows: Section 2, presents the material and methods. The material is the level of development and the actual energy indicators of the BSECO member countries. The method is the proposed MCDM approach consists of CRITIC, COPRAS method and the Borda Count method. Section 3, is the application of the proposed MCDM approach to measure the performance of BSECO member countries in terms of basic energy indicators. Section 4 is the discussion of the results and future research.

## 2. MATERIAL AND METHOD

### 2.1. Material

A model of multilateral political and economic initiative is the BSECO [23]. BSECO was first established on June 25, 1992, when Turkish President Turgut Özal and the leaders of the ten other countries of the region met in Istanbul. They signed the Istanbul Summit Declaration and the Bosphorus Declaration. The Permanent International Secretariat (Headquarters) of BSECO was established in Istanbul in March 1994. BSECO was given an international legal identity. It was transformed into a full-fledged regional economic organization with the entry into force of its Charter on May 1, 1999 [23]. The member countries of BSECO are as follows [24].

- The Republic of Albania,
- The Republic of Armenia,
- The Republic of Azerbaijan,
- Bulgaria,
- Georgia,
- Greece,
- The Republic of Moldova,
- Romania,
- Russian Federation,
- The Serbia,
- The Republic of Türkiye,
- Ukraine.

The objective of BSECO is to promote interaction and harmony among its members, to ensure peace and to promote friendly and good-neighbourly relations in the Black Sea region [23]. The main areas of cooperation of BSECO are energy, agriculture and agro-industry, banking and finance, fight against organized crime, culture, customs, education, emergency assistance, environmental protection, exchange of statistical data and economic information, health care and pharmaceuticals, information and communication technologies, institutional renewal and good governance, science and technology, SMEs, tourism, trade and economic development, and transport. BSECO's mission is summarized as follows [23];

- To strengthen dialogue and cooperation among Member Countries,
- To further develop and diversify bilateral and multilateral cooperation among Member Countries,
- To improve the business environment in the Member Countries,
- To develop economic cooperation among Member Countries.

The BSECO region spans two continents. It covers an area of nearly 20 million square kilometers and represents a region of nearly 335 million people. BSECO covers a geographical area that includes the territories of the countries bordering the Black Sea, the Balkans and the Caucasus. The annual volume of intra-community trade in BSECO is almost USD 187 billion [23]. The BSECO region is the world's second largest source of oil and natural gas after the Persian Gulf region. It is also rich in proven reserves of minerals, metals and other natural resources. BSECO is becoming Europe's most important corridor for the transportation and transfer of energy [23]. BSECO Member Countries and Observers & Sectorial Dialogue Partners are shown in Figure 2.

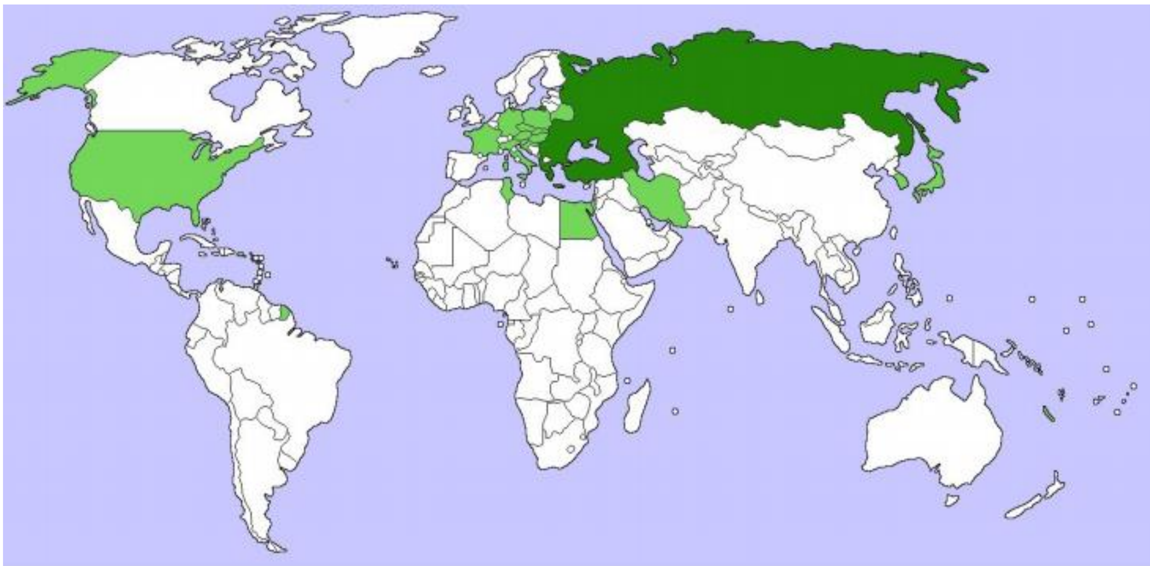

**Figure 2.** The member countries of BSECO and Observers & Sectorial Dialogue Partners [23]

### 2.2. MCDM Methods

#### 2.2.1. CRITIC Method

Diakoulaki et al [25] developed the CRITIC method. In this method, the weights of the criteria are determined taking into account both the standard deviation of the criteria and the correlation between the criteria [26]. The method consists of four steps [27], [28]. These steps are described below:

*Step 1:* Normalization of the decision matrix

In this step, the decision matrix ($D=(d_{ij})_{mxn}$) consisting of m alternative and n criteria is normalized ($x_{ij}$) with the help of the Eq. 1 and 2. If the criterion is utility-oriented, the Eq. 1; if the criterion is cost direction, the Eq. 2 is used. Where:

$d_j^{min}$: The alternative with the lowest value according to the jth criterion

$d_j^{max}$: The alternative with the highest value according to the jth criterion

$d_{ij}$: Elements of the decision matrix

$$x_{ij} = \frac{d_{ij}-d_j^{min}}{d_j^{max}-d_j^{min}} \quad i = 1,2,\dots,m; j = 1,2,\dots,n \tag{1}$$

$$x_{ij} = \frac{d_j^{max}-d_{ij}}{d_j^{max}-d_j^{min}} \quad i = 1,2,\dots,m; j = 1,2,\dots,n \tag{2}$$

*Step 2:* Calculation of correlation coefficients

The linear correlation coefficients ($\rho_{jk}$) are calculated with the help of the Eq. 3 to measure the degree of correlation between the criteria. Correlation coefficients in the study are calculated by the "correlation" function of Microsoft Excel.

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(x_{ij}-\overline{x_j})(x_{ik}-\overline{x_k})}{\sqrt{\sum_{i=1}^{m}(x_{ij}-\overline{x_j})^2 \sum_{i=1}^{m}(x_{ij}-\overline{x_k})^2}} \quad j,k = 1,\dots,n \tag{3}$$

*Step 3:* Calculation of the amount of information and standard deviation

The cumulative information of the criterion ($T_j$) is calculated according to the Eq. 4 and the standard deviation ($\sigma_j$) according to the Eq. 5.

$$T_j = \sigma_j \sum_{k=1}^{n} \left(1 - \rho_{jk}\right) \qquad (j = 1, \dots, n) \tag{4}$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} (x_{ij} - \overline{x}_j)^2}{m-1}} \qquad (j = 1, \dots, n) \tag{5}$$

where m denotes alternatives, i.e. countries in Eq. 5.

*Step 4:* Calculation of criteria weights

The Eq. 6 determines the weights of the criteria.

$$w_j = \frac{T_j}{\sum_{j=1}^{n} T_j} \tag{6}$$

### 2.2.2. COPRAS Method

Zavadskas and Kaklauskas developed the COPRAS method in 1996. This method ranks the alternatives by classifying the criteria in terms of costs and benefits. It is used for evaluation of criteria, maximization of benefit-based criteria and minimization of cost-based criteria [29]. The COPRAS method consists of seven steps [28], [30], [31], [32].

These steps are as follows:

*Step 1:* Decision matrix formation

The decision matrix produced in the first step of the CRITIC method is used.

*Step 2:* Normalization of the decision matrix

The Eq. 7 is used to normalize the decision matrix. In this equation, $d_{ij}$ denotes the elements of the decision matrix.

$$d_{ij}^{*} = \frac{d_{ij}}{\sum_{i=1}^{m} d_{ij}} \quad j = 1,2, \dots, n \tag{7}$$

*Step 3:* Calculation of weighted decision matrix (B)

The columns of the normalized decision matrix and the weight values of the criteria ($w_j$) multiplied. The weighted decision matrix is thus calculated (Eq. 8).

$$B = b_{ij} = d_{ij}^{*} * w_j \quad (i = 1,2, \dots, m; \; j = 1,2, \dots, n) \tag{8}$$

*Step 4:* Calculation of useful and useless criteria

The sum of the values in the weighted normalized decision matrix for useful criteria (maximized) is denoted by $U_{i+}$ $(Eq. 9)$ , and the sum of the values in the weighted normalized decision matrix for useless criteria (minimized) is denoted by $U_{i-}(Eq. 10)$.

$$U_{i+} = \sum_{j=1}^{k} b_{ij} \quad (i = 1,2, \dots, m; \; j = 1,2, \dots, k; k \; is \; useful \; criteria) \tag{9}$$

$$U_{i-} = \sum_{j=k+1}^{n} b_{ij} \quad (i = 1,2, \dots, m; \; j = k+1, k+2, \dots, n; n \; is \; useless \; criteria) \tag{10}$$

*Step 5:* Calculation of relative importance values ($Q_i$)

The relative importance values ($Q_i$) are calculated by the Eq. 11.

$$Q_i = U_{i+} + \frac{\sum_{i=1}^{m} U_{i-}}{(U_{i-}) \sum_{i=1}^{m} \frac{1}{U_{i-}}} \tag{11}$$

*Step 6:* Calculation of the highest relative importance values

The highest relative importance values ($Q_{max}$) are calculated by the Eq. 12.

$$Q_{max} = max \; \{Q_i\}, i = 12, \dots , m \tag{12}$$

*Step 7:* Calculation of performance index

For each alternative, the performance index indicated by $P_i$ is calculated using the Eq. (13).

$$P_i = \frac{Q_i}{Q_{max}} \%100 \tag{13}$$

The performance index is expressed in terms of Pi. Among the alternatives, the alternative with a Pi index equal to 100 is considered the best alternative. In addition, the performance index values are sorted in descending order when ranking the preferred alternatives.

### 2.2.3. The Borda Count Method

The Borda counting method was introduced as a voting technique by Jean-Charles de Borda in 1784 [33]. The Borda counting method is a data combining technique that reduces two or more sequences to a single sequence [34]. In this method, voters choose from n alternatives. The least preferred alternatives by the voters are assigned a score of zero, the most preferred alternative is assigned a score of 1, and the most preferred alternative is assigned a score of (n-1). Using Eq. 14, the Borda scores of each alternative are calculated. The alternatives are then ranked according to their Borda scores [33].

$$A_i = \sum_{j=1}^{n} B_{ij} \ , \qquad (i = 1, \cdots, m) \qquad (14)$$

where;

$A_i$ : Borda score of each decision alternative,

$B_{ij}$ : Borda point of different orders of the ith alternative

## 3. IMPLEMENTATION

Many studies have been conducted to measure the relationship between basic energy indicators and economic parameters. These studies show that there is a linear relationship between the level of development of countries and the actual energy indicators. It is also possible to evaluate countries in terms of basic variables such as energy production, consumption and emissions. Indicators such as electricity consumption, GDP, economic growth, energy prices, primary energy produced and consumed are considered in the studies [35], [36], [37], [38].

In this study, the performance of the 12 BSECO countries was ranked according to two scenarios in terms of basic proportional energy indicators using the COPRAS method. COPRAS is one of the multi-criteria decision making methods. The first scenario is the base scenario. The second is the active scenario.

Base scenario: The performance of countries in different years to be ranked according to the criterion weight values in the base year 2000. Criteria weight value to be found by the CRITIC method to calculate the performance of the countries in the desired years. It is a ranking of the performance of the BSECO countries in the study according to the periods of five years (i.e. 2000, 2005, 2010 and 2015).

Active scenario: The active scenario is defined as the ranking of the performance of the countries according to the weight values of the criteria in the year to be measured. This means that the weight values of the criteria are calculated separately for the mentioned years using the CRITIC method, taking into account the data of the years 2000, 2005, 2010 and 2015. The weight values of the respective year are taken into account when sorting the performance of the countries.

One of the main objectives of the study is to monitor the performance of Turkey, which is among the member countries of the BSECO organization in terms of basic energy indicators. In this context, Turkey, Ukraine, Moldova, Russia, Romania, Serbia, Greece, Georgia, Bulgaria, Azerbaijan, Armenia and Albania is composed of 12 member countries to decide. The aim of the meeting of BSECO member countries is to discuss and work on the main issues such as stabilization of relations between the countries and increase of economic cooperation. The study covers the energy data of the member countries for the years 2000, 2005, 2010 and 2015.

A comprehensive view of energy production, transformation, factors' influencing energy choices and the impact of energy use on $CO_2$ emissions is provided by the International Energy Agency (IEA) [39]. The study uses the IEA indicators. These indicators are total primary energy supply (TPES), electricity consumption and $CO_2$ emissions.

The energy statistics published by the IEA [39] provide the data to be used in the study and the basic energy indicator ratios. Analyzing the statistics, it can be seen that the data are published according to the following indicators: population, GDP, GDP (Purchasing Power Parity - PPP), electricity generation, net import, TPES, electricity consumption, amount of $CO_2$ emissions, TPES/Population, TPES/GDP, TPES/GDP(PPP), electricity consumption/Population, $CO_2$/TPES, $CO_2$/Population, $CO_2$/GDP, $CO_2$/GDP(PPP). The criteria to be used in the study have been determined according to the proportional indicators with regard to the significance of the performance of BSECO member countries. The following codes are used for eight proportional indicators:

- C1: TPES/Population
- C2: TPES/GDP
- C3: TPES/GDP (PPP)
- C4: Electricity Consumption/Population
- C5: $CO_2$/TPES
- C6: $CO_2$/Population
- C7: $CO_2$/GDP
- C8: $CO_2$/GDP (PPP)

### 3.1. Assignment of weights by CRITIC method

The methods of weight assignment have been studied under three main headings: subjective methods, objective methods, and integrated methods [40]. Subjective methods weight criteria based on the preferences and judgments of decision makers. Examples include Delphi, Analytical Hierarchy Process (AHP), Weighted Least Squares, and LINMAP (Linear Programming Techniques for Multidimensional Analysis of Preferences). Objective methods are those that do not take into account the judgment of the decision maker. They were developed by researchers to minimize the effects of subjective weighting. They include entropy, standard deviation, and equal weighting. In integrated methods, weighting is done by using both the judgments of the decision makers and the numerical data of the decision matrix in an integrated manner. The subjective and objective integrated approaches developed and named by different researchers can be found in the literature [40]. In a study in which the criteria were determined on a proportional basis, the weight values were determined using the CRTIC method [41]. In this study, the CRITIC method was preferred. This is because the energy indicators were considered on a proportional basis and their weighting should be objective. The CRITIC method, which is one of the objective weighting methods, was chosen so that expert opinion would not be used in the study. It's important to use subjective weighting methods when the expertise and experience of the decision maker on an issue is needed. However, in cases where the decision maker or ideas change, problems arise regarding the reliability of the solution to the problem. In such negative situations, objective methods are preferred to subjective weighting methods. More realistic results are obtained by using objective methods that do not consider the decision maker's judgments in weighting the criteria [28]. Building the decision matrix is the first step in this method. The decision matrix for the base and active scenarios for the year 2000 is shown in Table 1. The IEA website [39] provided the data in Table 1.

Table 2 was obtained after the criteria C1, C2, C3 and C4 in this matrix were normalized by Eq. 1 and the rest of the criteria were normalized by Eq. 2.

**Table 1**. The basic energy indicator decision matrix for 2000

| | Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternatives** | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** | **C7** | **C8** |
| Turkey | 1.18 | 0.15 | 0.09 | 1.63 | 2.65 | 3.14 | 0.39 | 0.24 |
| Ukraine | 2.72 | 1.50 | 0.58 | 2.78 | 2.20 | 6.00 | 3.30 | 1.27 |
| Moldova | 0.79 | 0.82 | 0.35 | 1.64 | 2.27 | 1.80 | 1.85 | 0.79 |
| Russia | 4.22 | 0.61 | 0.34 | 5.20 | 2.38 | 10.06 | 1.45 | 0.81 |
| Romania | 1.61 | 0.33 | 0.16 | 1.99 | 2.38 | 3.84 | 0.78 | 0.39 |
| Serbia | 1.69 | 0.54 | 0.25 | 3.89 | 3.13 | 5.30 | 1.68 | 0.77 |
| Greece | 2.51 | 0.11 | 0.10 | 4.59 | 3.25 | 8.14 | 0.35 | 0.33 |
| Georgia | 0.65 | 0.45 | 0.20 | 1.45 | 1.61 | 1.05 | 0.73 | 0.33 |
| Bulgaria | 2.28 | 0.57 | 0.26 | 3.67 | 2.27 | 5.16 | 1.29 | 0.58 |
| Azerbaijan | 1.40 | 0.86 | 0.32 | 2.04 | 2.42 | 3.39 | 2.08 | 0.78 |
| Armenia | 0.65 | 0.47 | 0.23 | 1.29 | 1.70 | 1.11 | 0.79 | 0.39 |
| Albania | 0.58 | 0.26 | 0.11 | 1.45 | 1.72 | 1.00 | 0.44 | 0.19 |

**Table 2**. Normalized decision matrix

| | Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternatives** | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** | **C7** | **C8** |
| Turkey | 0.165 | 0.029 | 0.000 | 0.087 | 0.366 | 0.764 | 0.986 | 0.954 |
| Ukraine | 0.588 | 1.000 | 1.000 | 0.381 | 0.640 | 0.448 | 0.000 | 0.000 |
| Moldova | 0.058 | 0.511 | 0.531 | 0.090 | 0.598 | 0.912 | 0.492 | 0.444 |
| Russia | 1.000 | 0.360 | 0.510 | 1.000 | 0.530 | 0.000 | 0.627 | 0.426 |
| Romania | 0.283 | 0.158 | 0.143 | 0.179 | 0.530 | 0.687 | 0.854 | 0.815 |
| Serbia | 0.305 | 0.309 | 0.327 | 0.665 | 0.073 | 0.525 | 0.549 | 0.463 |
| Greece | 0.530 | 0.000 | 0.020 | 0.844 | 0.000 | 0.212 | 1.000 | 0.870 |
| Georgia | 0.019 | 0.245 | 0.224 | 0.041 | 1.000 | 0.994 | 0.871 | 0.870 |
| Bulgaria | 0.467 | 0.331 | 0.347 | 0.609 | 0.598 | 0.541 | 0.681 | 0.639 |
| Azerbaijan | 0.225 | 0.540 | 0.469 | 0.192 | 0.506 | 0.736 | 0.414 | 0.454 |
| Armenia | 0.019 | 0.259 | 0.286 | 0.000 | 0.945 | 0.988 | 0.851 | 0.815 |
| Albania | 0.000 | 0.108 | 0.041 | 0.041 | 0.933 | 1.000 | 0.969 | 1.000 |

The correlation coefficients of the criteria are calculated according to Eq. 3 using the data from Table 2. Table 3 shows the obtained correlation values.

**Table 3**. Correlation matrix of criteria

| | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** | **C7** | **C8** |
|---|---|---|---|---|---|---|---|---|
| C1 | 1.000 | 0.260 | 0.397 | **0.884** | -0.431 | -0.964 | -0.336 | -0.504 |
| C2 | | 1.000 | **0.980** | 0.018 | 0.169 | -0.119 | -0.974 | -0.926 |
| C3 | | | 1.000 | 0.157 | 0.126 | -0.252 | -0.960 | -0.956 |
| C4 | | | | 1.000 | -0.638 | -0.947 | -0.145 | -0.333 |
| C5 | | | | | 1.000 | 0.632 | 0.031 | 0.413 |
| C6 | | | | | | 1.000 | 0.232 | 0.413 |
| C7 | | | | | | | 1.000 | **0.974** |
| C8 | | | | | | | | 1.000 |

A high correlation coefficient indicates that there is a direct relationship between the criteria and that the criteria are interdependent, according to [27], [40]. Ramík and Perzina [42] stated that it would be misleading to evaluate the criteria without considering the interdependence. This is because the weights of the interdependent criteria are calculated. One of the two interdependent criteria was removed from the study because it would have a greater impact on the decision to be made.

If the value of the correlation is negative and close to zero, then the criteria are independent of each other; if it is one and close to one, then we can say that the criteria are interdependent. Looking at the values in Table 3, we can see that C1 and C4, C2 and C3, and C7 and C8 are interdependent. This is the most important characteristic of the desired criteria. Since they do not influence each other, criteria C1, C3, and C8 were omitted from the study. This reduces the number of criteria to five. Table 4 shows the criteria and notations, the units and the optimization status of the criteria to be used in the later part of the work. When the transactions for the years 2000, 2005, 2010 and 2015 were carried out, eight criteria were reduced to five.

**Table 4.** Energy indicator criteria

| **Energy indicator ratios** | **Measurement unit** | **Optimization status** |
|---|---|---|
| C2: TPES/GDP | toe/1000 $ | Max |
| C4: Electricity Consumption/Population | MWh/Per person | Max |
| C5: $CO_2$/TPES | $tCO_2$/toe | Min |
| C6: $CO_2$/Population | $tCO_2$/Per person | Min |
| C7: $CO_2$/GDP | kg $CO_2$/$ | Min |

Table 5 shows the results of steps 2, 3 and 4 of the method for the year 2000.

In the step of generating the weighted decision matrix of the COPRAS method, the weight values obtained according to the CRITIC method are used.

The decision matrices for the basic energy indicators for the years 2005, 2010 and 2015 are shown in Tables 6, 7 and 8.

**Table 5**. Correlation coefficients, total information, standard deviation and weight values for 2000

| | C2 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|
| **C2** | 1.000 | 0.018 | 0.169 | -0.119 | -0.974 |
| **C4** | 0.018 | 1.000 | -0.638 | -0.947 | -0.145 |
| **C5** | 0.169 | -0.638 | 1.000 | 0.632 | 0.031 |
| **C6** | -0.119 | -0.947 | 0.632 | 1.000 | 0.232 |
| **C7** | -0.974 | -0.145 | 0.031 | 0.232 | 1.000 |
| $T_j$ | 1.280 | 1.908 | 1.142 | 1.290 | 1.374 |
| $\sigma_j$ | 0.261 | 0.334 | 0.300 | 0.307 | 0.283 |
| $w_j$ | 0.183 | 0.273 | 0.163 | 0.184 | 0.196 |

**Table 6**. The basic energy indicator decision matrix for 2005

| | Criteria | | | | |
|---|---|---|---|---|---|
| **Alternatives** | **C2** | **C4** | **C5** | **C6** | **C7** |
| Turkey | 0.13 | 1.99 | 2.57 | 3.16 | 0.33 |
| Ukraine | 1.10 | 3.25 | 2.06 | 6.24 | 2.27 |
| Moldova | 0.70 | 2.05 | 2.20 | 2.14 | 1.55 |
| Russia | 0.48 | 5.77 | 2.27 | 10.32 | 1.08 |
| Romania | 0.27 | 2.37 | 2.40 | 4.35 | 0.64 |
| Serbia | 0.46 | 3.92 | 3.08 | 6.66 | 1.43 |
| Greece | 0.10 | 5.30 | 3.15 | 8.67 | 0.31 |
| Georgia | 0.31 | 1.78 | 1.43 | 0.97 | 0.45 |
| Bulgaria | 0.46 | 4.17 | 2.34 | 6.07 | 1.07 |
| Azerbaijan | 0.54 | 2.39 | 2.16 | 3.46 | 1.17 |
| Armenia | 0.33 | 1.50 | 1.64 | 1.37 | 0.54 |
| Albania | 0.23 | 1.72 | 1.76 | 1.27 | 0.41 |

**Table 7**. The basic energy indicator decision matrix for 2010

| | Criteria | | | | |
|---|---|---|---|---|---|
| **Alternatives** | **C2** | **C4** | **C5** | **C6** | **C7** |
| Turkey | 0.14 | 2.47 | 2.49 | 3.64 | 0.34 |
| Ukraine | 0.97 | 3.56 | 2.01 | 5.80 | 1.96 |
| Moldova | 0.60 | 1.72 | 2.24 | 2.20 | 1.35 |
| Russia | 0.42 | 6.41 | 2.22 | 10.70 | 0.94 |
| Romania | 0.21 | 2.55 | 2.13 | 3.69 | 0.44 |
| Serbia | 0.40 | 4.36 | 2.94 | 6.29 | 1.16 |
| Greece | 0.09 | 5.33 | 3.02 | 7.50 | 0.28 |
| Georgia | 0.27 | 1.98 | 1.60 | 1.27 | 0.43 |
| Bulgaria | 0.35 | 4.56 | 2.48 | 6.00 | 0.88 |
| Azerbaijan | 0.22 | 1.60 | 2.03 | 2.60 | 0.44 |
| Armenia | 0.27 | 1.68 | 1.63 | 1.37 | 0.44 |
| Albania | 0.18 | 1.94 | 1.85 | 1.35 | 0.33 |

**Table 8**. The basic energy indicator decision matrix for 2015

| | Criteria | | | | |
|---|---|---|---|---|---|
| **Alternatives** | **C2** | **C4** | **C5** | **C6** | **C7** |
| Turkey | 0.12 | 2.96 | 2.46 | 4.10 | 0.29 |
| Ukraine | 0.74 | 3.21 | 2.10 | 4.20 | 1.56 |
| Moldova | 0.48 | 1.40 | 2.24 | 2.13 | 1.08 |
| Russia | 0.41 | 6.59 | 2.07 | 10.19 | 0.85 |
| Romania | 0.17 | 2.64 | 2.18 | 3.51 | 0.37 |
| Serbia | 0.37 | 4.54 | 3.02 | 6.27 | 1.11 |
| Greece | 0.09 | 5.21 | 2.79 | 5.95 | 0.26 |
| Georgia | 0.31 | 2.73 | 1.81 | 2.26 | 0.57 |
| Bulgaria | 0.34 | 4.86 | 2.35 | 6.10 | 0.80 |
| Azerbaijan | 0.24 | 2.24 | 2.15 | 3.19 | 0.52 |
| Armenia | 0.27 | 1.90 | 1.53 | 1.56 | 0.41 |
| Albania | 0.17 | 2.09 | 1.75 | 1.32 | 0.29 |

Tables 9, 10, and 11 show the correlation coefficients, total information, standard deviation, and weight values for 2005, 2010, and 2015, respectively.

**Table 9**. Correlation coefficients, total information, standard deviation and weight values for 2005

| | C2 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|
| **C2** | 1.000 | 0.055 | 0.180 | -0.136 | -0.961 |
| **C4** | 0.055 | 1.000 | -0.622 | -0.970 | -0.190 |
| **C5** | 0.180 | -0.622 | 1.000 | 0.666 | 0.063 |
| **C6** | -0.136 | -0.970 | 0.666 | 1.000 | 0.278 |
| **C7** | -0.961 | -0.190 | 0.063 | 0.278 | 1.000 |
| $T_j$ | 1.279 | 1.867 | 1.073 | 1.303 | 1.419 |
| $\sigma_j$ | 0.263 | 0.326 | 0.289 | 0.313 | 0.295 |
| $w_j$ | 0.184 | 0.269 | 0.155 | 0.188 | 0.204 |

**Table 10**. Correlation coefficients, total information, standard deviation and weight values for 2010

| | C2 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|
| **C2** | 1.000 | 0.107 | 0.130 | -0.198 | -0.970 |
| **C4** | 0.107 | 1.000 | -0.624 | -0.970 | -0.234 |
| **C5** | 0.130 | -0.624 | 1.000 | 0.614 | 0.086 |
| **C6** | -0.198 | -0.970 | 0.614 | 1.000 | 0.321 |
| **C7** | -0.970 | -0.234 | 0.086 | 0.321 | 1.000 |
| $T_j$ | 1.297 | 1.859 | 1.157 | 1.261 | 1.430 |
| $\sigma_j$ | 0.263 | 0.325 | 0.305 | 0.298 | 0.298 |
| $w_j$ | 0.185 | 0.265 | 0.165 | 0.180 | 0.204 |

**Table 11**. Correlation coefficients, total information, standard deviation and weight values for 2015

| | C2 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|
| **C2** | 1.000 | 0.040 | 0.094 | -0.146 | -0.957 |
| **C4** | 0.040 | 1.000 | -0.488 | -0.955 | -0.149 |
| **C5** | 0.094 | -0.488 | 1.000 | 0.509 | 0.180 |
| **C6** | -0.146 | -0.955 | 0.509 | 1.000 | 0.264 |
| **C7** | -0.957 | -0.149 | 0.180 | 0.264 | 1.000 |
| $T_j$ | 1.322 | 1.616 | 1.000 | 1.190 | 1.408 |
| $\sigma_j$ | 0.266 | 0.291 | 0.270 | 0.275 | 0.302 |
| $w_j$ | 0.202 | 0.247 | 0.153 | 0.182 | 0.215 |

### 3.2. Ordering the alternatives by Implementation of COPRAS Method

The COPRAS method is used to evaluate by maximizing benefit criteria and minimizing cost criteria [29]. In order to achieve this goal in the selected energy indicators or criteria, the COPRAS method was preferred. The COPRAS method is applied at this stage according to two defined scenarios. In each scenario, the problem is solved according to the years 2000, 2005, 2010 and 2015. In total, seven different solutions are obtained. For the year 2000 dataset, the implementation steps of the COPRAS method are carried out. For both the base scenario and the active scenario, the solution obtained after the year 2000 dataset is a common solution. This is because the weight values of the criteria in the base scenario are obtained with reference to the year 2000 data and are used in other years. In the active scenario, the weight values are calculated separately for each year. Therefore, the year 2000 is common to both scenarios.

*Step1:* Formation of the decision matrix

In the first step of the CRITIC method, the decision matrix generated in Table 1 is used by removing the columns C1, C3, and C8.

*Step2:* Normalization of the decision matrix

The decision matrix is normalized by the Eq. 7. The normalized decision matrix is shown in Table 12.

**Table 12**. The normalized decision matrix for the year 2000

| | Criteria | | | | |
|---|---|---|---|---|---|
| **Alternatives** | **C2** | **C4** | **C5** | **C6** | **C7** |
| Turkey | 0.022 | 0.052 | 0.095 | 0.063 | 0.026 |
| Ukraine | 0.225 | 0.088 | 0.079 | 0.120 | 0.218 |
| Moldova | 0.123 | 0.052 | 0.081 | 0.036 | 0.122 |
| Russia | 0.091 | 0.164 | 0.085 | 0.201 | 0.096 |
| Romania | 0.049 | 0.063 | 0.085 | 0.077 | 0.052 |
| Serbia | 0.081 | 0.123 | 0.112 | 0.106 | 0.111 |
| Greece | 0.016 | 0.145 | 0.116 | 0.163 | 0.023 |
| Georgia | 0.067 | 0.046 | 0.058 | 0.021 | 0.048 |
| Bulgaria | 0.085 | 0.116 | 0.081 | 0.103 | 0.085 |
| Azerbaijan | 0.129 | 0.065 | 0.086 | 0.068 | 0.137 |
| Armenia | 0.070 | 0.041 | 0.061 | 0.022 | 0.052 |
| Albania | 0.039 | 0.046 | 0.061 | 0.020 | 0.029 |

*Step 3:* Calculation of weighted decision matrix

The weighted decision matrix is found by multiplying each column of the normalized decision matrix by the weight values of 0.183, 0.273, 0.163, 0.184 and 0.196, respectively (Table 13). These weight values be also used when the base scenario results for 2005, 2010 and 2015 are being calculated. The weight values to be used in the active scenario are given in Table 14 as of years. The weight values in this table are taken from Tables 5, 9, 10, and 11.

**Table 13**. Weighted decision matrix for 2000

| | Criteria | | | | |
|---|---|---|---|---|---|
| **Alternatives** | **C2** | **C4** | **C5** | **C6** | **C7** |
| Turkey | 0.004 | 0.014 | 0.015 | 0.012 | 0.005 |
| Ukraine | 0.041 | 0.024 | 0.013 | 0.022 | 0.043 |
| Moldova | 0.022 | 0.014 | 0.013 | 0.007 | 0.024 |
| Russia | 0.017 | 0.045 | 0.014 | 0.037 | 0.019 |
| Romania | 0.009 | 0.017 | 0.014 | 0.014 | 0.010 |
| Serbia | 0.015 | 0.034 | 0.018 | 0.020 | 0.022 |
| Greece | 0.003 | 0.040 | 0.019 | 0.030 | 0.005 |
| Georgia | 0.012 | 0.013 | 0.009 | 0.004 | 0.009 |
| Bulgaria | 0.016 | 0.032 | 0.013 | 0.019 | 0.017 |
| Azerbaijan | 0.024 | 0.018 | 0.014 | 0.012 | 0.027 |
| Armenia | 0.013 | 0.011 | 0.010 | 0.004 | 0.010 |
| Albania | 0.007 | 0.013 | 0.010 | 0.004 | 0.006 |

**Table 14.** Weight values to be used in the active scenario

| Years | C2 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|
| 2000 | 0.183 | 0.273 | 0.163 | 0.184 | 0.196 |
| 2005 | 0.184 | 0.269 | 0.155 | 0.188 | 0.204 |
| 2010 | 0.185 | 0.265 | 0.165 | 0.180 | 0.204 |
| 2015 | 0.202 | 0.247 | 0.153 | 0.182 | 0.215 |

*Step 4:* Calculation of useful and useless criteria

The sum of the values in the weighted normalized decision matrix for the useful criteria (for C1 and C2 with maxima status of optimization) is denoted by U*i*+, the sum of the values in the weighted normalized decision matrix for the useless criteria (for C3, C4 and C5 with minima status of optimization) is denoted by U*i*– (Table 15).

*Step 5:* Calculation of relative importance values (Qi)

Relative importance values ($Q_i$) are calculated with the help of the Eq. 8. It is seen in the third column in Table 15.

**Table 15**. $U_{i+}$, $U_{i-}$, $Q_i$, $P_i$ Values

| | $U_{i+}$ | $U_{i-}$ | $Q_i$ | $P_i$ | Rank |
|---|---|---|---|---|---|
| Turkey | 0.018 | 0.032 | 0.071 | 66.40 | 11 |
| Ukraine | 0.065 | 0.078 | 0.087 | 81.09 | 4 |
| Moldova | 0.037 | 0.044 | 0.076 | 70.31 | 8 |
| Russia | 0.062 | 0.070 | 0.086 | 80.14 | 5 |
| Romania | 0.026 | 0.038 | 0.071 | 66.03 | 12 |
| Serbia | 0.048 | 0.060 | 0.077 | 71.71 | 7 |
| Greece | 0.043 | 0.053 | 0.075 | 69.38 | 9 |
| Georgia | 0.025 | 0.023 | 0.100 | 92.98 | 2 |
| Bulgaria | 0.047 | 0.049 | 0.082 | 76.47 | 6 |
| Azerbaijan | 0.041 | 0.054 | 0.073 | 67.99 | 10 |
| Armenia | 0.024 | 0.024 | 0.094 | 87.81 | 3 |
| Albania | 0.020 | 0.019 | 0.107 | 100.00 | 1 |

*Step 6*: Calculation of the highest relative importance values

Using the Eq. 9, the highest relative importance value is calculated as 0.107.

*Step 7*: Calculation of performance index

The performance index calculated by the Eq. 10 is shown in the fourth column in Table 15. With this calculation, the steps of the method end. Thus, the performance rank of the countries is determined.

Table 15 ranks the proportional energy indicator performance of the BSECO countries in seven steps according to the COPRAS method for the base and active scenarios. The base year is 2000. The country performance index Pi was used for the ranking in descending order. The first three places are taken by Albania, Georgia and Armenia. Romania ranked last. Turkey was ranked 11th.

Table 16 shows the performance of the BSECO countries according to the COPRAS method under the base scenario.

The top three countries in Table 16 are Georgia, Albania and Armenia for 2005 and 2010, and Albania, Armenia and Russia for 2015. The bottoms three are Romania for 2005, Turkey for 2010 and Moldova for 2015.

**Table 16.** Result list of base scenario

| BASE SCENARIO | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2000 | | 2005 | | 2010 | | 2015 | |
| **Pi** | **Order** | **Pi** | **Order** | **Pi** | **Order** | **Pi** | **Order** |
| 100.0 | Albania | 100.0 | Georgia | 100.0 | Georgia | 100.0 | Albania |
| 92.98 | Georgia | 88.87 | Albania | 96.85 | Albania | 96.04 | Armenia |
| 87.81 | Armenia | 85.12 | Armenia | 95.56 | Armenia | 88.47 | Russia |
| 81.09 | Ukraine | 78.66 | Ukraine | 92.17 | Ukraine | 86.18 | Georgia |
| 80.14 | Russia | 77.57 | Russia | 89.31 | Russia | 83.69 | Ukraine |
| 76.47 | Bulgaria | 72.09 | Bulgaria | 79.94 | Bulgaria | 80.05 | Bulgaria |
| 71.71 | Serbia | 68.90 | Moldova | 77.24 | Azerbaijan | 77.91 | Greece |
| 70.31 | Moldova | 67.93 | Greece | 76.68 | Romania | 75.83 | Romania |
| 69.38 | Greece | 67.78 | Azerbaijan | 76.63 | Greece | 73.73 | Serbia |
| 67.99 | Azerbaijan | 65.92 | Turkey | 75.96 | Serbia | 73.50 | Azerbaijan |
| 66.40 | Turkey | 64.81 | Serbia | 73.47 | Moldova | 72.92 | Turkey |
| 66.03 | Romania | 62.99 | Romania | 73.18 | Turkey | 69.40 | Moldova |

The performance of the BSECO countries is shown in Table 17. This is done by applying the steps of the COPRAS method according to the active scenario.

Looking at Table 17, the first three ranks are held by Georgia, Albania and Armenia in 2005 and 2010, and by Albania, Armenia and Russia in 2015. The last rank is held by Romania in 2005 and Moldova in 2010 and 2015.

The Spearman correlation test was performed to measure the similarity of the different rankings presented by the results of the base and active scenarios. The correlation values over the years are shown in Table 18.

There is a very strong relationship between the active and base scenarios, as shown in Table 18.

**Table 17.** The result list of active scenario

| ACTIVE SCENARIO | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2000 | | 2005 | | 2010 | | 2015 | |
| Pi | Order | Pi | Order | Pi | Order | Pi | Order |
| 100.0 | Albania | 100.0 | Georgia | 100.0 | Georgia | 100.0 | Albania |
| 92.98 | Georgia | 89.18 | Albania | 97.05 | Albania | 95.53 | Armenia |
| 87.81 | Armenia | 85.01 | Armenia | 95.65 | Armenia | 85.51 | Russia |
| 81.09 | Ukraine | 77.74 | Ukraine | 91.84 | Ukraine | 85.12 | Georgia |
| 80.14 | Russia | 76.44 | Russia | 88.52 | Russia | 83.79 | Ukraine |
| 76.47 | Bulgaria | 71.22 | Bulgaria | 79.46 | Bulgaria | 77.93 | Bulgaria |
| 71.71 | Serbia | 68.21 | Moldova | 77.57 | Azerbaijan | 75.53 | Greece |
| 70.31 | Moldova | 67.24 | Greece | 76.89 | Romania | 75.24 | Romania |
| 69.38 | Greece | 67.13 | Azerbaijan | 76.29 | Greece | 72.98 | Azerbaijan |
| 67.99 | Azerbaijan | 66.17 | Turkey | 75.42 | Serbia | 72.27 | Turkey |
| 66.40 | Turkey | 64.04 | Serbia | 73.46 | Turkey | 71.88 | Serbia |
| 66.03 | Romania | 62.64 | Romania | 73.27 | Moldova | 69.57 | Moldova |

**Table 18**. Correlation relationship between scenarios

| Years | Correlations Values |
|---|---|
| 2000 | 1.000 |
| 2005 | 0.999 |
| 2010 | 0.999 |
| 2015 | 0.995 |

## 3.3. Aggregation of Ranking, the Implementation of the Borda Count Method

In the final phase of the study, the different rankings from the base and active scenarios were combined using the Borda count method to obtain a final ranking. The rank values of the alternatives were scored to obtain a single ranking from these rankings. The highest score alternative was ranked first. Table 19 shows the result of using this method.

The top three positions in Table 19 are held by Albania, Georgia, and Armenia. Turkey is ranked last. It can be seen that both scenarios have the same country rankings as a result of the Borda counting method. This result is consistent with the values of the correlation coefficients in Table 18.

**Table 19.** Last ranking by Borda Count Method

| Borda Base Scenario | | | Borda Active Scenario | | |
|---|---|---|---|---|---|
| Country | Score | Rank | Country | Score | Rank |
| Albania | 42 | 1 | Albania | 42 | 1 |
| Georgia | 40 | 2 | Georgia | 40 | 2 |
| Armenia | 37 | 3 | Armenia | 37 | 3 |
| Ukraine | 31 | 4 | Ukraine | 31 | 4 |
| Russia | 30 | 5 | Russia | 30 | 5 |
| Bulgaria | 24 | 6 | Bulgaria | 24 | 6 |
| Greece | 15 | 7 | Greece | 15 | 7 |
| Azerbaijan | 12 | 8 | Azerbaijan | 13 | 8 |
| Serbia | 11 | 9 | Serbia | 9 | 9 |
| Moldova | 10 | 10 | Moldova | 9 | 10 |
| Romania | 8 | 11 | Romania | 8 | 11 |
| Turkey | 4 | 12 | Turkey | 6 | 12 |

These results show that there is no change in the performance ranking of the BSECO countries in the two base scenarios. They are based on the CRITIC objective scoring methodology. This methodology is used to determine the weights of the criteria. According to these results, only one scenario can be considered. For the sake of simplicity, those working on this issue can be advised to use the base scenario.

## 4. CONCLUSIONS

This study compares countries on energy indicators. The alternatives are ranked according to the criteria. It is clear that this ranking can vary according to the different methods used for evaluation. As a result of the study, it was seen that an MCDM method can be used to solve this problem to achieve ranking between countries using objective weights.

Two scenarios were constructed in the study and seven different solutions were found. The best performance was achieved in the year 2010 with an average of 83.92% based on the Pi values calculated in the base scenario. In second place was the year 2015 with an average of 81.48% and in third place was the year 2000 with an average of 77.53%. In last place was the year 2005 with an average of 75.05%. According to the pi values of the active scenario, 2010 ranks first with 83.78%, 2015 ranks second with 80.45%, 2000 ranks third with 77.53% and 2005 ranks last with 74.58%.

Albania ranks first, Georgia second and Armenia third in the final results of the Borda counting method. The fact that the emission rate is lower than in other countries is an important factor for the first place of Albania. This is because: Almost all of Albania's electricity comes from hydroelectric plants. This, in turn, has an impact on carbon dioxide emissions.

It cannot be said that our country performs well when the results of the study are examined in terms of the basic proportional energy indicators. It is in the last place in the Borda Count method. It has not moved up from the last three places according to both scenarios. This is due to our energy dependence, the high proportion of fossil fuels used to generate electricity and the low quality of our lignite. Our country ranks last in the performance ranking because of the high emission rates of fossil fuels. In order for our country to move up in the rankings, we need to increase the share of renewable energy in the amount of energy from primary energy sources. We also need to start using nuclear energy immediately and reduce our energy dependence. It is expected that in the next ten years our country will be at the top due to the investments made in the energy sector in recent years.

In future studies, the problem can be solved with different MCDM methods. The results can be compared. Moreover, this work, which is carried out using objective criteria, can be solved in a different scenario, taking into account the subjective judgments of the decision maker.

### Declaration of Ethical Standards

Authors declare to comply with all ethical guidelines including authorship, citation, data reporting, and publishing original research.

### Credit Authorship Contribution Statement

Ahmet SARUCAN: Methodology, Data curation, Writing original draft, Visualization, Investigation, Software.

Mehmet Emin BAYSAL: Writing original draft, Visualization, Investigation, Supervision.

Orhan ENGİN: Data curation, Writing original draft, Visualization, Investigation, Supervision.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships

### Funding / Acknowledgements

The authors declare that they have not received any funding or research grants received in the course of study, research or assembly of the article.

**Data Availability**

Research data has not been made available in a repository.

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