Energy, Environment, and Sustainability: A Multi-criteria Evaluation of Countries

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Abstract

Energy, the environment, and sustainability are all strongly intertwined concerns. While humanity aims to spread the comfort and welfare it has achieved on a global scale, as well as to achieve more development and comfort through technological advances, it is caught in a stalemate caused by the world's use of resources as if they are limitless, as well as irrevocable environmental damage. The major topic of this dilemma is energy. Using ARAT, CRITIC, SOWIA, CRADIS, and CODAS-Sort, this study aims to evaluate countries on the basis of energy, environment, and sustainability triangle. The results reveal that developed countries are in a better situation than developing and underdeveloped countries in terms of sustainable energy and environmental concerns. The Nordic countries notably lead the rankings and classification results. The primary reason for this is that Nordic countries have strong climate and energy policies. Given the limitations of fossil fuels, the fact that they'll be exhausted in a few decades, and the environmental damage they cause, the development and effective use of renewable energy sources is considered a critical solution option. Because it appears that humanity will struggle to give up its existing level of comfort or lower its energy use. The importance of energy efficiency, diversification of renewable energy

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sources, raising societal awareness, unity in global sustainable environmental policies, aiding societies that are falling behind in achieving welfare and fighting poverty and focusing on energy savings emerge at this point. A strong will and community support will be necessary to adopt and implement these policies.

Keywords: Sustainability, energy, environment, ARAT, CRITIC, SOWIA, CRADIS, CODAS-Sort.

1 Introduction

For decades, the limitation of resources and the irreversible damage to the environment have been the subject of discussion. Humans wish to continue progressing indefinitely while benefiting from the improved living conditions brought about by technology. In this setting, we are confronted with a significant dilemma. It is becoming increasingly difficult to answer the question of whether human beings will be able to make further progress by better utilizing resources and conserving the environment. Energy and the environment are two critical components on both sides of the dilemma. The relationship between energy, the environment, and sustainable development is highlighted by the requirement for a society seeking sustainable development to ideally focus solely on energy sources that do not have negative environmental consequences [1].

As the world's population grows, so does the demand for more energy [2]. In the context of environmental pollution and transmitting natural resources to future generations, the ever-growing global population, and the increasing energy requirements for the maintenance of technological advancements force academics, companies, and countries to look for new solutions. Environmentally friendly energy sources, such as the usage of renewable resources like water, sun, wind, biomass, geothermal, hydrogen, and fuel cells, are among the studies' focus points [2].

One of the dimensions that will be considered, along with energy and environmental dimensions, is economic development and welfare. Development and energy are strongly interrelated. Many different indicators, such as the human development index and economic growth metrics, are used to try to measure the development of societies. Also, per capita energy consumption is regarded as a measure of a country's wealth. The demand for energy consumption for high development is gradually increasing in developing countries. The desire to enhance energy access remains a significant motivator of poverty reduction in developing countries. Modern energy supply makes it easier to increase human living conditions and industry efficiency. It also contributes by lowering the amount of time spent on biomass collection, particularly for women and children, and thus provides an opportunity for children's education and promoting gender equality [3]. The widespread use of fossil energy has allowed developed countries to achieve their current levels. However, it is now clear that fossil fuels or fuels with adverse environmental effects cannot be used to promote sustainable development [2, 4]. Sustainable development can be achieved through the use of renewable energy and assuring citizens' access to inexpensive, reliable, sustainable, and contemporary energy [5]. At this point, assessing countries in terms of their energy consumption and environmental impacts will serve as critical due diligence. Countries will be assessed using a multi-criteria decision-making methodology in the context of energy and environmental data in this study. ARAT (Interval and Iterative Preference/Priority Scale) and CRITIC (Criteria Importance Through Inter-criteria Correlation) methods will be combined and used to weight the criteria in this context. In the integration phase, the SOWIA (Subjective and Objective Weight Integrated Approach) method will be employed. The countries will be ranked using the CRADIS (Compromise Ranking of Alternatives from Distance to Ideal Solution) method and be classified employing the CODAS-Sort (COmbinative Distance-based Assessment-Sort) method.

By combining subjective and objective criterion weights in the evaluation of countries based on energy, environmental, and sustainability performances, the study aims to provide a comparative analysis of countries from different perspectives. The literature on research investigating energy usage, environmental effects, and sustainability issues will be included in the following section of the study. Following that, details on the study's methodology will be presented. The findings, conclusions, and suggestions will be given at the end of this study.

2 Literature

Energy-related technological developments, which began with the industrial revolution, are continuing to increase. The current agreement that fossil fuels are not sustainable, as well as concerns about environmental protection and resource transfer to future generations, need a thorough examination of the energy issue. The next part will go over some of the most important research on energy, the environment, and sustainability.

Dinçer and Rosen [1] concluded that energy efficiency would contribute more to sustainability than a mix of non-fossil, nuclear, and renewable energy sources in their study related to energy, environment, and sustainable development. Carbon and fuel taxes, it was noted, will continue to be a critical component of measures aimed at lowering carbon dioxide and other pollution emissions. It was suggested that governments should create incentives for consumers to use energy-efficient and ecologically friendly products.

Rees [6] stated that the global economy's ecological footprint is greater than the planet's capacity to absorb it, and hence humanity has reached a critical juncture. Given that one-quarter of the population lives in poverty and that population and material demands are increasing, it has been noted that ensuring sustainability requires overcoming major challenges.

Fossil fuels, according to Cook [7], will be critical in meeting the world's energy demands soon, although natural gas will be the favored fossil fuel. Nuclear power has the potential to play a role, but it will not be able to do so in most countries unless societal attitudes shift dramatically. Cook [7] believes that the change to solar energy will have an impact on the mining industry, and that there is an implicit link between energy and minerals. Even though resource development has been at an all-time high in recent years, most countries' exploration programs have fallen due to low commodity prices, expanding reserves, and decreasing commodity demand.

Goldemberg [8] stated that diversifying energy carriers for heat, fuel, and electricity generation, improving access to clean energy sources, balancing the use of fossil fuels, saving fossil fuels or non-renewable resources for other applications and future generations, and providing flexibility of power systems as electricity demand changes are all advantages of using renewable energy sources in a modern and effective way. The renewable energy was viewed as the main solution to reduce pollution and emissions caused by traditional energy systems, reduce reliance on imported fuels and cut costs, create new jobs, and give energy to areas that are not connected to the utility grid. It was underlined that the natural energy flow in the world's ecosystem has significantly greater potential than the energy consumption required for human requirements.

Chappells and Shove [9] examined the detrimental effects on the environment of energy consumed for comfort via air conditioning and how these negative effects might be addressed by building design. It was suggested that communities should consider the definition of comfort and the lifestyles that go with it. Also, the importance of avoiding an unsustainable future was emphasized.

Omer [2] highlighted that buildings account for 40% of global yearly energy consumption, hence there are some recommendations for optimal building energy usage. The importance of designing more energy-efficient buildings in terms of heating, lighting, cooling, ventilation, and hot water supply was emphasized, as was switching to natural or hybrid ventilation instead of air conditioning, using renewable energy in buildings and agricultural greenhouses, and reducing reliance on fossil fuels. Furthermore, it was argued that encouraging innovative renewable practices and developing the renewable energy market will contribute to ecosystem protection by lowering emissions at both the local and global levels.

Given the predominance of energy usage, its relevance in economic development and living standards, and its impact on the environment, according to Rosen [10], energy sustainability is critical for overall sustainability. The need of using sustainable energy sources, employing sustainable energy carriers, enhancing efficiency, reducing environmental effect, and improving socioeconomic acceptability was underlined to ensure energy sustainability. Furthermore, it was suggested that the use of modern technologies such as exergy analysis for improving efficiency and life cycle analysis for reducing pollution gives considerable benefits in attempts to attain energy sustainability.

Dale and Ong [4] stated that human well-being is highly dependent on energy supply. The authors predicted that fossil fuels will become increasingly scarce and expensive, and that liquid biofuels may be a suitable option for low-cost, long-term energy. Cellulosic biomass was viewed as a possible liquid fuel source in this context.

The importance of cogeneration systems in energy savings and efficiency, as well as the analysis of gas-powered cogeneration systems, were discussed by Çakır et al. [11]. It was also claimed that employing sustainable energy will assure resource protection without having negative consequences for future generations.

Jorgenson et al. [12] looked at the energy intensity of human well-being and economic progress in Central and Eastern European countries. They asserted that nonrenewable energy and other natural resources are depleting, and that humans rely on a variety of ecosystem services to support human well-being for economic development. To promote sustainability, the energy intensity should be decreased for human well-being. The Central and Eastern European countries have transitioned from socialist command economies to market demand economies, and while human wellbeing has risen, energy intensity has dropped as energy efficiency has increased.

Dinçer and Acar [13] evaluated clean energy solutions based on a variety of sustainability factors. Nuclear energy was said to be the best option for power generation, while geothermal energy was said to be the best option for non-air pollution criteria. The initial alternatives in terms of heating and cooling modes were geothermal and biomass energies. Furthermore, nuclear power was ranked first among hydrogen-producing energy sources.

Sarkodie and Adams [14] stated that the quality of political institutions plays a significant role in social, governance, and economic preparedness to mitigate the effects of climate change. It was stated that structural adjustments in total energy consumption, economic growth, and political institutional quality all play a crucial influence in environmental quality. It was suggested that fossil fuel-rich countries should diversify their energy portfolios by adding renewable energy sources, which will promote environmental sustainability, enhance air quality, and minimize their economies' exposure to price fluctuations. Also, it was emphasized that a paradigm shift away from energy and carbon-intensive industries and toward a service-oriented economy will result in structural economic transformation, which will aid in mitigating climate change and its effects.

Despite the incentives for renewable energy, Qazi et al. [15] claimed that the world's reliance on fossil fuels remains high. It was emphasized that a low level of awareness is a major barrier to the adoption of renewable energy technologies. It was also claimed that integrating renewable energy sources into power generating can help relieve global energy crises.

Asongu [16] said that most African countries appear to be unable to achieve economic and environmental sustainability, as well as consistent economic growth and stable energy supply. According to the study, economic growth, urbanization, electricity use, fossil fuel energy consumption, and total natural resource rent all had an impact on pollutant emissions in Africa. Pollutant emissions and urbanization, as well as electricity consumption and non-renewable energy consumption, were all claimed to be related. It was suggested for African countries to decouple pollutant emissions from economic growth, make a paradigm shift from fossil fuels to renewables, as well as the utilization of carbon storage and capture systems.

Armin Razmjoo et al. [17] emphasized that one of the most important targets for sustainable development that can be met with renewable energy and UN-Habitat III goals is electricity generation for residential areas. The significance of renewable energy in ensuring energy sustainability was highlighted in this context.

Bekun et al. [18] investigated China's economic growth in light of globalization, energy consumption, and environmental sustainability. Energy saving strategies are said to have a detrimental influence on economic growth, whereas energy consumption has a negative impact on the environment. Renewable energy sources such as hydro, wind, photovoltaic, and biomass energy sources should be adopted in China's energy portfolio mix by utilizing more efficient and up-to-date energy technologies. The authors stated that the renewable energy provides the reduction of air pollution in China. Furthermore, with the establishment of renewable energy sources, it was emphasized that considerable capital is required to run the industry with little or no environmental risks. In this context, focusing on environmental policy would necessitate a strong political will and widespread public support. The government and other stakeholders should find alternative substitute solutions for energy consumption in the short term to ensure economic growth while minimizing environmental impact.

To ensure sustainability and solve resource shortages, Zhang et al. [19] underlined the necessity of remanufacturing and life cycle assessment. Remanufacturing was recognized as a cost-effective method of reducing energy and material consumption while also lowering emissions.

In their assessment of Belt and Road Initiative (BRI) countries, Shakib et al. [20] said that increases in energy consumption, economic growth, population, and foreign direct investment inflows increase CO_2 emissions and have detrimental environmental consequences. However, it was argued that using renewable energy sources, which are cleaner than fossil fuels, and encouraging agricultural development can reduce emissions and considerably increase environmental welfare.

The concepts of energy, environment, and sustainability are interconnected, as evidenced by studies from the literature, and their profound relationships with one another are investigated from various perspectives. The impact of energy on economic growth and comfort, as well as renewable energy sources that can be used instead of fossil energy, are reviewed in these studies. This study will add to this by conducting the assessment of countries in the sustainable energy-environment dichotomy. Hence, the important criteria in the energy, environment, and sustainability spiral are expected to be determined, as well as the relative strengths and weaknesses of the countries based on comparative evaluations. To achieve these aims, multi-criteria decision-making methods such as ARAT, CRITIC, SOWIA, CRADIS, and CODAS-Sort will be used. These methods have been used in the literature to evaluate different problems. For instance, SOWIA has been used to evaluate bio-medical waste disposal methods, Indian technical institution performance, usability evaluation of live auction portal, supply chain strategy determination, and optimal site selection of electric vehicle charging station problems [21–25]. ARAT was used in studies of rental house selection and assessing countries based on citizen trust in government administration [26, 27]. The CRITIC method has been successfully applied in a variety of fields, including urban rail transit operation safety evaluation, location planning of electric vehicle charging stations, hospital site selection, evaluation of the financial performance of tourism companies, blockchain platform evaluation, and 5G industry evaluation [28–33]. CRADIS method was used to assess the markets of pear varieties, and select healthcare waste incinerators [34, 35]. CODAS-Sort was used in the examination of environment quality, province entrepreneurship classification, natural resource evaluation, and supplier selection [36–39]. ARAT, CRADIS, and CODAS-Sort are among the most recently created methods, and as a result, they are not widely used. It is believed that this aspect of the study will contribute to the literature. Also, with these methods, it is expected that a comprehensive evaluation will be obtained from various perspectives. Detailed information about the study's methodology will be provided in the next section.

3 Methodology

Multi-criteria decision-making includes all the processes involved in evaluating multiple criteria and alternatives in the solution of decision problems. It may be able to rank, classify, eliminate, assign alternatives, or determine the weight values of the criteria at the end of this process. Multi-criteria decision-making methods ARAT, CRITIC, SOWIA, CRADIS and CODAS-Sort will be used to evaluate countries in the context of sustainability, energy, and the environment. For this purpose, ARAT and CRITIC will be used in the SOWIA integrated model to determine the weights of the criteria. CRADIS will be used to rank the countries, and CODAS-Sort will be used to classify them. The methodology employed in the study is depicted in Figure 1 in such a way that the application processes connected with the methods can be seen.

The criteria were weighted using SOWIA based on ARAT and CRITIC, as seen in Figure 1. SOWIA aims to benefit from the advantages of both objective and subjective weighting methods. CRITIC, which is based on the correlations between criteria and standard deviation, was employed for objective weighting. As a result, it is expected that the data structure will

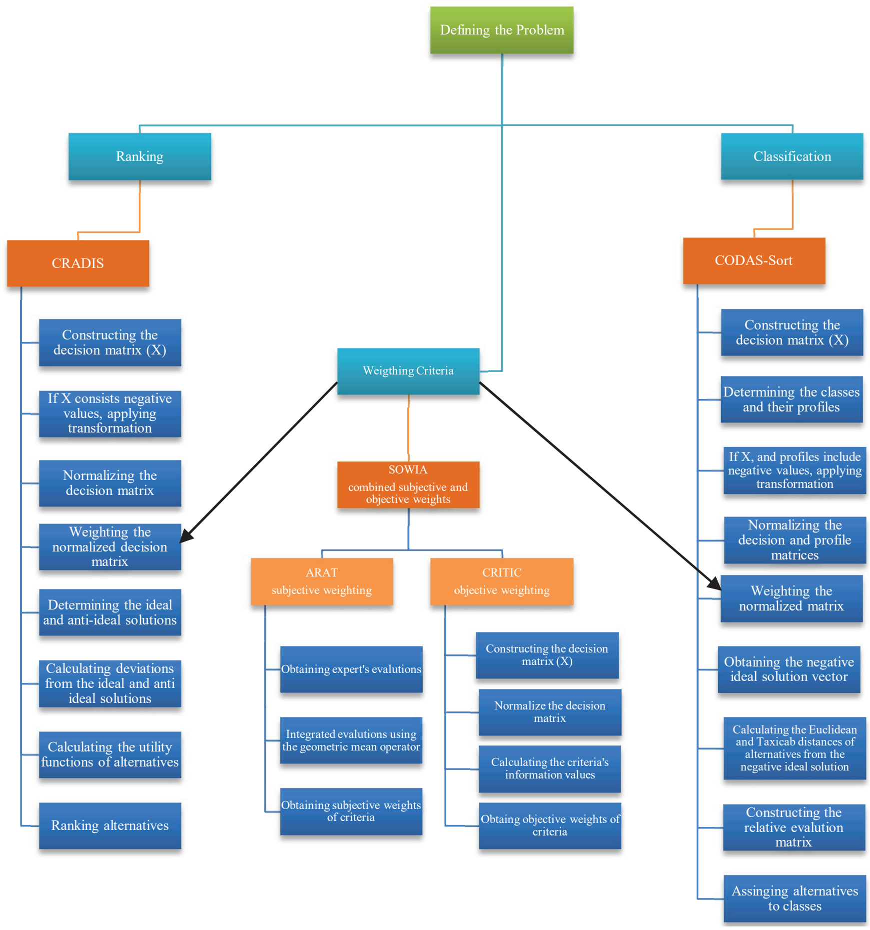

Figure 1 The scheme of methodology.

be effectively reflected in the weighing process using CRITIC. Because of its iterative evaluation process, ability to compare pair and multiple criteria, transitivity, intelligibility, and ease of use, ARAT was chosen for subjective weighting. To rank the countries, the CRADIS method will be used, which combines the benefits of the ARAS, MARCOS, and TOPSIS methods. CODAS-Sort, based on the anti-ideal solution, was chosen for the classification process because it allows for the determination of central profiles and the assignment of the class that is closest to the central profile.

The methodology used in the study ensures that the structure of the data and expert evaluations are used together by integrating the benefits of subjective and objective weighting processes in determining the criteria weight values. Furthermore, the results of ranking and classification processes will be used to perform comparative evaluations from different perspectives. The next subsections will provide explanations for SOWIA, ARAT, CRITIC, CRADIS, and CODAS-Sort methods.

3.1 SOWIA

The regulation of the important levels of the criteria on the solution of the problem by assigning values directly by the decision maker(s) or expert(s) or by values calculated by techniques created for this purpose is known as weighting. In other words, the weighting allows the effects of the criteria on the problem solution to be calibrated. In this context, objective weighting methods that consider solely the decision matrix values and subjective weighting methods that consider the evaluator's importance levels are often used in the weighting process. There are also mixed weighting methods, which combine weight values derived using multiple methods [40–42]. In this study, CRITIC from objective methods and ARAT from subjective methods are used in the weighing process. Then, SOWIA from mixed methods will be employed to combine these two methods' results.

Das et al. [22] developed SOWIA for combining the results of subjective and objective weighting methods. w_{j_S} is the subjective weight value, w_{j_O} is the objective weight value, and Equation (1) is used to calculate the integrated weight value (w_j) in SOWIA.

$$w_j = \alpha w_{j_S} + (1 - \alpha) w_{j_O} \tag{1}$$

The decision maker uses the value in Equation (1) to regulate the effect of subjective-objective weight values. α takes a value in the range of 0–1. In this case, $\alpha = 0.5$ demonstrates that subjective and objective weight values are given equal weight. Because of the weight values obtained using SOWIA, both objective and subjective weighing methods will be effective in solving the problem.

3.1.1 CRITIC

CRITIC is a method developed by Diakoulaki et al. [43] to weight criteria objectively by considering their correlations and standard deviations. The application of the CRITIC can be applied in four steps as explained below [43].

Step 1. Constructing the decision matrix: The decision matrix is constructed as specified in Equation (1), where the performance or attribute of alternative *i* in the criterion j is denoted by x_{ij}.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, \quad \begin{matrix} i = 1, \ldots, m \\ j = 1, \ldots, n \end{matrix} \tag{2}$$

Step 2. Normalizing the decision matrix: Equation (3) is used to normalize the decision matrix, where J^+ denotes benefit criteria and J^- cost criteria.

$$n_{ij} = \begin{cases} \dfrac{x_{ij} - \min_i \ x_{ij}}{\max_i \ x_{ij} - \min_i \ x_{ij}}, & j \in J^+ \\ \dfrac{\max_i \ x_{ij} - x_{ij}}{\max_i \ x_{ij} - \min_i \ x_{ij}}, & j \in J^- \end{cases} \tag{3}$$

Step 3. Calculating the criteria's information values: Each j criterion's correlations (r_{jk}) with the other k criteria are determined using the Pearson correlation coefficient. For criteria with ordinal measures, the Spearman rank correlation coefficient can be employed. Over the correlation values, conflict values ($1-r_{jk}$) are determined. The amount of information of each j criterion, C_j, is then calculated with Equation (4) using the standard deviation value (σ_j) of each criterion as a contrast measure.

$$C_j = \sigma_j \sum_{k=1}^{n} (1 - r_{jk}) \tag{4}$$

Step 4. Calculating criteria weights: The quantity of information contained in the criterion will rise as the C_j value increases. In the final stage, the normalized C_j values are used to calculate the weight value of each criterion, as shown in the equation Equation (5).

$$w_{j_o} = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{5}$$

The aim of the CRITIC is to objectively reflect the importance levels of related or conflicting criteria on the solution of the problem. To put it another way, CRITIC's fundamental assumption is that a criterion with a poor correlation with other criteria and a high variability includes more information, hence the weight value should be larger in this case.

3.1.2 ARAT

Aytekin [44] developed the Interval and Iterative Preference/Priority Scale (ARAT, as the abbreviation of the Turkish phrase “ARalıklı ve Aşamalı Tercih önem ölçeği”) to represent the preferences of decision-makers. Also, ARAT gives a proper data format for the solution of the problem by scaling the criteria in multi-criteria decision problems according to the preferences of the decision-maker or expert and determining the importance levels of the criteria.

ARAT ensures that the decision maker’s preferences for each criterion are determined iteratively. Preferences are rated from 0 to 10 on a scale that is theoretically infinitely divisible. In the first phase, the values on this scale range from 0 to 10, with 0 representing the most negative and 10 representing the most positive value. Hence, the veto value in ARAT is zero, indicating that the relevant criterion or alternative is not considered in the problem. A score of 10 denotes strong preference, whereas a score of five denotes moderate preference. Iterations are used to complete the finalization of preference-importance values. The next section summarizes the ARAT’s implementation steps for weighting the criteria [26, 27, 44].

Step 1. Defining the criteria: The criteria to be employed in solving the decision problem ($j = 1, \ldots, n$) are defined.

Step 2. Assigning the criteria’s initial importance values: Each criterion’s importance levels on the decision problem are represented by importance values (ι_j) assigned by the decision maker. The ARAT scale with values ranging from 0 to 10 is employed for this purpose.

Step 3. Evaluating criteria by grouping them according to their previous importance levels: First, criteria with the same importance level are grouped together in this step. Then it is presented to the decision maker again to determine fractional importance values and to review the previous importance values. The important values determined in the previous step might be revised by the decision maker. The decision maker, on the other hand, may state that the importance values determined in the previous step are satisfactory for all criteria. The finalization of the important values of the criteria is completed in this scenario. Otherwise, until the decision maker is satisfied, the process of defining important values is continued in stages.

Step 4. Determination of the weight values of the criteria: Equation (6) is used to obtain the weight values of criteria, where ι_j shows the exact importance value determined for criterion j. While the weight values are in the range of 0–1, the importance levels of the criteria increase as their weights approach one.

$$w_{j_s} = \frac{\iota_j}{\sum_{j=1}^{n} \iota_j} \tag{6}$$

The details of the CRADIS and CODAS-Sort methods to be used for sorting and classification will be described in the following sub-sections after the explanations of the methods used for the weighting process.

3.2 CRADIS

Puška et al. [35] developed the CRADIS method to solve decision problems by evaluating ideal and anti-ideal solutions. The CRADIS method is described as a combination of the ARAS, MARCOS, and TOPSIS methods. The CRADIS process steps are given below [35].

Step 1. Constructing the decision matrix: The decision matrix is constructed as specified in Equation (1).

Step 2. Normalizing the decision matrix: The 0–1 Interval Normalization Using Max-Min technique is used in the CRADIS method to conduct normalization. For this purpose, Equation (3) is used to normalize the decision matrix. If the criteria include 0 and negative values, this technique will not be able to achieve proper normalization [45]. If the decision matrix contains 0 and negative values, a transformation process will be required for the positive value decision matrix [27]. The T-score specified in Equation (7) can be employed for this purpose, where μ_j is the arithmetic mean, and σ_j is the standard deviation of the criterion j.

$$t_{ij} = 10\frac{(x_{ij} - \mu_j)}{\sigma_j} + 50 \tag{7}$$

If transformation is needed, and when this process has been completed, the normalized decision matrix is obtained using Equation (8). Otherwise, x_{ij} is used instead of t_{ij} in Equation (8).

$$n_{ij} = \begin{cases} \dfrac{t_{ij}}{\max_i t_{ij}}, & j \in J^+ \\ \dfrac{\min_i t_{ij}}{t_{ij}}, & j \in J^- \end{cases} \tag{8}$$

Step 3. Weighting the normalized decision matrix: The weighted normalized decision matrix is constructed using Equation (9).

$$v_{ij} = n_{ij} w_j \tag{9}$$

Step 4. Determination of ideal and anti-ideal solution vectors: Artificial solution vectors, denoting ideal and anti-ideal solutions, are formed after the weighting process, and will be used as references in the evaluation of alternatives. In this context, a_i^+ denotes the ideal solution, and a_i^- shows the anti-ideal solution. a_i^+ and a_i^- are obtained using Equations (10)–(11).

$$a_i^+ = \max_i v_{ij} \tag{10}$$

$$a_i^- = \min_i v_{ij} \tag{11}$$

Step 5. Calculation the deviations from ideal and anti-ideal solutions: The deviations of the alternatives from the ideal solution are computed using Equation (12), and their deviations from the anti-ideal solution are determined by Equation (13).

$$d_i^+ = a_i^+ - v_{ij} \tag{12}$$

$$d_i^- = v_{ij} - a_i^- \tag{13}$$

Step 6. Obtaining the deviation grades of alternatives: The deviation grades are defined as the sum of the deviations of the alternatives from the ideal and anti-ideal solutions. For this purpose, Equation (14) calculates the grades of deviation of the alternatives from the ideal solution, while Equation (15) calculates the grades of deviation from the anti-ideal solution.

$$s_i^+ = \sum_{j=1}^{n} d_i^+ \tag{14}$$

$$s_i^- = \sum_{j=1}^{n} d_i^- \tag{15}$$

Step 7. Calculating the utility function for alternatives: Equations (16)–(17) are used to compute the grades of deviation for alternatives from optimal alternatives (s_*^+, s_*^-), where $s_*^+ = \min_i s_i^+$, and $s_*^- = \max_i s_i^-$.

$$K_i^+ = \frac{s_*^+}{s_i^+} \tag{16}$$

$$K_i^- = \frac{s_i^-}{s_*^-} \tag{17}$$

Step 8. Ranking alternatives: The average deviation of the alternatives from the degree of utility (Q_i) is obtained using Equation (18).

$$Q_i = \frac{K_i^+ + K_i^-}{2} \tag{18}$$

The alternatives are ranked according to Q_i values in descending order [35].

3.3 CODAS-Sort

Keshavarz Ghorabaee et al. [46] developed the CODAS method on the assumption that the alternative farthest from the negative ideal would be the best. Ouhibi and Frikha [47] later developed the CODAS derivative/extension CODAS-Sort, which is applicable in classification problems. The CODAS-Sort implementation steps are detailed below [37, 47].

Step 1. Constructing the decision matrix: The decision matrix is constructed as specified in Equation (1).

Step 2. Determining the classes and constructing the profile matrix for each class: The process of assigning alternatives to predetermined classes is carried out in multi-criteria sorting methods. The decision maker, expert person or group can determine the number of classes and their characteristics. Also, scientific methods can be used for this purpose. As a result, b profiles for each p class are determined in j criteria, while classes are denoted as $S = 1, \ldots, p$. According to Ouhibi and Frikha [47], the profiles can be determined using either the border or center profiles. The boundary profiles indicate the threshold values between classes, whereas the center profiles represent the general characteristic of the relevant class. If a boundary profile is employed, the alternative i is assigned the class S based on whether its overall assessment score exceeds or falls below the boundary profiles. If the center profile is applied, the alternative i is assigned the class S based on the closeness of its general evaluation score to the general evaluation scores of the profiles.

In this study, center profiles were employed. After determining the number of classes, b profile values for each criterion are specified. The profile matrix Y is presented in Equation (19), where $b = 1, \dots p$ [37].

$$Y = [y_{bj}]_{pxn} = \begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ x_{b1} & \cdots & x_{bn} \end{bmatrix} \quad \begin{matrix} b = 1, \dots, p \\ j = 1, \dots, n \end{matrix} \tag{19}$$

Step 3. Normalizing the decision and profile matrices: The 0–1 Interval Normalization Using Max-Min technique is used in the CODAS method to conduct normalization. As stated in the CRADIS method's implementation steps, this normalization technique does not provide effective results in decision matrices with 0 and negative values. In this case, in Equation (7), the transformation process is used to ensure that the decision and profile matrices have positive values. Assuming that the decision and profile matrices have positive values, Equations (20)–(21) are used for normalization.

$$f_{ij} = \begin{cases} \dfrac{x_{ij}}{max\ \{\max_i\ x_{ij}, \max_b\ y_{bj}\}}, & j \in J^+ \\ \dfrac{min\ \{\min_i\ x_{ij}\ , \min_b\ y_{bj}\}}{x_{ij}}, & j \in J^- \end{cases} \tag{20}$$

$$f_{bj} = \begin{cases} \dfrac{y_{bj}}{max\ \{\max_i\ x_{ij}\ , \max_b\ y_{bj}\}}, & j \in J^+ \\ \dfrac{min\ \{\min_i\ x_{ij}\ , \min_b\ y_{bj}\}}{y_{bj}}, & j \in J^- \end{cases} \tag{21}$$

Step 4. Weighting the decision and profile matrices: Normalized decision and profile matrices are weighted using Equations (22)–(23).

$$r_{ij} = w_j f_{ij} \tag{22}$$

$$r_{bj} = w_j f_{bj} \tag{23}$$

Step 5. Obtaining negative ideal solution values: To obtain negative ideal solutions for each criterion, ns_j values are acquired using Equation (24), whereas ms_j values are produced using Equation (25).

$$ns_j = \min_i\ r_{ij} \tag{24}$$

$$ms_j = \min_b\ r_{bj} \tag{25}$$

While assigning alternatives to classes, the CODAS-Sort method takes into account class profiles and anti-ideal solution values. This reduces the impact of class profiles on class assignment.

Step 6. Calculating the Euclidean and Taxicab distances: From negative ideal solution values, Equations (26)–(27) are used to determine the Euclidean (E_i) and Taxicab (T_i) distances of the alternatives, and Equations (28)–(29) are used to calculate the Euclidean (E_b) and Taxicab (T_b) distances of the profiles.

$$E_i = \sqrt{\sum_{j=1}^{n} (r_{ij} - ns_j)^2} \tag{26}$$

$$T_i = \sum_{j=1}^{n} |r_{ij} - ns_j| \tag{27}$$

$$E_b = \sqrt{\sum_{j=1}^{n} (r_{bj} - ms_j)^2} \tag{28}$$

$$T_b = \sum_{j=1}^{n} |r_{bj} - ms_j| \tag{29}$$

Step 7. Constructing the relative evaluation matrix: The relative evaluation (G) matrix is obtained using Equations (30)–(31).

$$G = [h_{ib}]_{mxp} \tag{30}$$

$$h_{ib} = (E_i - E_b) + ((\psi left(E_i - E_b)) \times (T_i - T_b)) \tag{31}$$

ψ is the threshold function in Equation (31). The ψ function ensures that Taxicab distances are also taken into account, as a result of comparing the τ value with the Euclidean distance value of the profile b and the alternative i. Keshavarz Ghorabaee et al. [46] suggested to set the τ value between 0.01 and 0.05. Equation (32) defines the ψ function.

$$\psi(x) = \begin{cases} 1 & \text{if } |x| \geq \tau \\ 0 & \text{if } |x| < \tau \end{cases} \tag{32}$$

Step 8. Completing the classification process: If center profiles are employed in the classification process, Equation (33) assigns alternatives to the classes.

$$\begin{aligned} &i \in S_1 \quad \text{if } |h_{i1}| < |h_{ik}| \quad k = 2, \dots, p \\ &i \in S_k \quad \text{if } |h_{ik}| < |h_{i1}| \quad b = 1, \dots, k, \dots, p \end{aligned} \tag{33}$$

Equation (33) assigns the alternative i to the class whose h_{ib} value is the smallest in absolute value. Equation (34), on the other hand, is employed in classification when boundary profiles are used. The h_{ib} value used in the evaluation at this point is the smallest absolute value in the G matrix, as in the center profiles.

$$\begin{aligned} &i \in S_b \quad\quad \text{if } (h_{ib}) \geq 0 \quad b = 1, \dots, p \\ &i \in S_{b-1} \quad \text{if } (h_{ib}) < 0 \end{aligned} \tag{34}$$

Thus, the assignment of alternatives to classes is completed in CODAS-Sort.

4 Results

Data from the World Bank, UN and EPI were used to evaluate countries in terms of sustainable energy and the environment [48–50]. The values acquired from the objective and subjective weighting methods were combined with SOWIA in the criteria weighting. In the subjective criteria weighting using ARAT, the evaluations of two experts were obtained. Table 1 displays the importance ratings of criteria determined by the experts and the subjective weight values using ARAT, the weight values derived by CRITIC, and the final weight values provided by SOWIA.

C3, C4, C5, C6, C7, C8, C9, C10, C12 are cost criteria, while the others are benefit-oriented. The expert evaluations were integrated by the geometric mean during weighting process performed using ARAT. Table 1 demonstrates that C14 is the most important criterion as a result of subjective weighting, while C10 is the most important criterion as a result of objective weighting. The most important criterion, according to the weight values obtained by determining $\alpha = 0.5$ with SOWIA, is C2. C14 is the second most important criterion, and C10 is the ninth most important criterion according to SOWIA results. The ratio of the value of the stock of energy resources to the remaining reserve lifetime is known as energy depletion (capped at 25 years). It is relevant to coal, crude oil, and natural gas [50]. In this context, the designation of the C2 criterion as the most important criterion shows the importance of the

Table 1 The weights of criteria

Notation	Criteria	ARAT Importance Ratings		Weights		
		Expert 1	Expert 2	ARAT	CRITIC	SOWIA
C1	Access to electricity	7.4311	6.1	0.0407	0.0459	0.0433
C2	Adjusted savings: energy depletion	8.4211	9	0.0526	0.0512	0.0519
C3	CO2 emissions from gaseous fuel consumption	5.3221	5.2	0.0318	0.0495	0.0407
C4	CO2 emissions from liquid fuel consumption	7.1312	7.1	0.0430	0.0495	0.0462
C5	Fuel exports	8.3422	8.2	0.0500	0.0487	0.0494
C6	Fuel imports	7.5421	8.8	0.0492	0.0452	0.0472
C7	Methane emissions in energy sector	7.4122	7.9	0.0462	0.0491	0.0477
C8	Nitrous oxide emissions in energy sector	8.2212	9	0.0520	0.0483	0.0501
C9	Pump price for diesel fuel	8.2311	7	0.0459	0.0531	0.0495
C10	Pump price for gasoline	7.2411	7.2	0.0436	0.0540	0.0488
C11	Renewable energy consumption	8.2111	7.1	0.0461	0.0516	0.0488
C12	Time required to get electricity	8.2112	8.2	0.0496	0.0467	0.0481
C13	Energy supply	7.6212	7.9	0.0469	0.0527	0.0498
C14	Contribution of renewables to electricity production	9.3211	9.4	0.0566	0.0449	0.0507
C15	Renewable electricity production	8.6211	7.9	0.0499	0.0453	0.0476
C16	Environmental performance	7.4211	8.2	0.0471	0.0428	0.0450
C17	Air quality	8.6112	9.8	0.0555	0.0425	0.0490
C18	Ozone exposure	7.7112	7.9	0.0472	0.0427	0.0449
C19	Waste management	6.2211	9.4	0.0462	0.0436	0.0449
C20	Biodiversity habitat index	9.11	7	0.0482	0.0486	0.0484
C21	Climate change	9.31	7.9	0.0518	0.0441	0.0480

remaining resources for long-term energy and environmental sustainability. C14, the second most important criterion, indicates the beneficial influence of renewable energy over environmentally hazardous and unsustainable energy sources.

The class profiles to divide countries into high (S1), medium (S2), and poor (S3) classes in terms of sustainable environment and energy were determined using the formulas as given below.

$$\text{For benefit criteria}$$

$$b_1 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.95\right]$$

$$b_2 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.75\right]$$

$$b_3 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.05\right]$$

$$\text{For cost criteria}$$

$$b_1 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.05\right]$$

$$b_2 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.25\right]$$

$$b_3 = \min_i x_{ij} + \left[\left(\max_i x_{ij} - \min_i x_{ij}\right) * 0.95\right]$$

Table 2 shows the center profile values for each class.

In the analyzes performed with CRADIS and CODAS-Sort, Equation (7) was employed to construct a positive-valued decision matrix. Table 3 shows the rankings acquired using CRADIS and the classes obtained with CODAS-Sort.

Australia, Canada, Finland, Iceland, Norway, Sweden, and United Kingdom are the countries in the higher sustainable environment-energy class (S1), as seen in Table 3. Benin, Burundi, Guinea, Rwanda, and Sierra Leone are the countries in the low-energy-sustainable-environment class (S3). Other countries are classified as having a medium level of environmental and energy sustainability (S2). According to the CRADIS results, Iceland, Norway,

Table 2 The central profiles for classes

	C1	C2 (Million USD)	C3	C4	C5	C6	C7
b_1	95,6	114329,1	5,6	106634,9	5	2,2	36979
b_2	77,8	90259,8	28,2	531986,4	25	9,5	184895
b_3	15,5	6017,3	107,1	2020716,5	95	34,7	702601
	C8	C9	C10	C11	C12	C13	C14
b_1	2373	0,2	0,3	91,6	29,2	117418,5	95
b_2	11865	0,6	0,6	72,3	117,8	92700,5	75
b_3	45087	2,0	1,7	4,8	427,9	6187,5	5
	C15	C16	C17	C18	C19	C20	C21
b_1	95	79,6	94,4	75,5	95	79,8	90,9
b_2	75	68,2	76,6	59,6	75	69,4	74,3
b_3	5	28,0	14,3	4,0	5	33,0	16,2

and Sweden are ranked first, second, and third, respectively, whereas India, Bangladesh, and Senegal are ranked in the last three places.

In terms of sustainable energy and environmental standards, the results show that developed countries are in a better situation than developing and underdeveloped countries. This finding is consistent with literature [12, 14, 16, 20, 51–58]. The Nordic countries are obviously at the top of the rankings and classification results. The main reason for this is that Nordic countries have implemented effective climate and energy policies. Denmark is a pioneer in the usage of wind power, bioenergy in Finland and Sweden, hydropower in Norway, and geothermal energy in Iceland. By 2050, the Nordic countries want to be ”fossil-free”. Also, Nordic countries implement solid regulations in the areas of power, heating, and building decarbonization [57, 58]. Carbon pricing or tax has been in place for about two decades in Australia, the United Kingdom, and Canada, among the most prominent countries in the results. Furthermore, these countries pursue policies related to energy efficiency, clean technology innovation, electricity market reform, and clean technology industry support [54]. In comparison to other countries, Benin, Burundi, Rwanda, Sierra Leone, and Senegal performed low. The fact that these countries are all from Sub-Saharan Africa is the most common characteristic they share. Although it has been said that energy consumption plays an important role in increasing both economic growth and financial development in Sub-Saharan African countries, excessive pollution has been noticed as a result [52]. The fact that more than two-thirds of the population is

Table 3 Ranking and classification results

Code	Country	Ranking	Class	Code	Country	Ranking	Class	Code	Country	Ranking	Class
A1	Afghanistan	120	S2	A47	France	29	S2	A93	New Zealand	7	S2
A2	Albania	27	S2	A48	Gambia	132	S2	A94	Nicaragua	49	S2
A3	Algeria	45	S2	A49	Georgia	58	S2	A95	Niger	121	S2
A4	Angola	109	S2	A50	Germany	31	S2	A96	Nigeria	133	S2
A5	Argentina	64	S2	A51	Ghana	114	S2	A97	North Macedonia	41	S2
A6	Armenia	116	S2	A52	Greece	72	S2	A98	Norway	2	S1
A7	Australia	18	S1	A53	Guatemala	33	S2	A99	Oman	102	S2
A8	Austria	8	S2	A54	Guinea	122	S3	A100	Pakistan	129	S2
A9	Azerbaijan	119	S2	A55	Honduras	53	S2	A101	Panama	12	S2
A10	Bahrain	98	S2	A56	Hungary	110	S2	A102	Paraguay	17	S2
A11	Bangladesh	137	S2	A57	Iceland	1	S1	A103	Peru	36	S2
A12	Belarus	79	S2	A58	India	138	S2	A104	Philippines	54	S2
A13	Belgium	66	S2	A59	Indonesia	88	S2	A105	Poland	61	S2
A14	Belize	52	S2	A60	Iran, Islamic Rep.	95	S2	A106	Portugal	34	S2
A15	Benin	131	S3	A61	Iraq	125	S2	A107	Qatar	89	S2
A16	Bolivia	86	S2	A62	Ireland	22	S2	A108	Romania	39	S2
A17	Bosnia and Herzegovina	68	S2	A63	Israel	97	S2	A109	Russian Federation	40	S2
A18	Botswana	105	S2	A64	Italy	71	S2	A110	Rwanda	111	S3
A19	Brazil	42	S2	A65	Jamaica	107	S2	A111	Saudi Arabia	28	S2
A20	Brunei Darussalam	65	S2	A66	Japan	46	S2	A112	Senegal	136	S2
A21	Bulgaria	92	S2	A67	Jordan	56	S2	A113	Serbia	93	S2
A22	Burkina Faso	134	S2	A68	Kazakhstan	94	S2	A114	Sierra Leone	87	S3
A23	Burundi	130	S3	A69	Kenya	57	S2	A115	Singapore	69	S2
A24	Cambodia	100	S2	A70	Korea, Rep.	63	S2	A116	Slovak Republic	47	S2
A25	Cameroon	104	S2	A71	Kuwait	44	S2	A117	Slovenia	23	S2
A26	Canada	11	S1	A72	Kyrgyz Republic	38	S2	A118	South Africa	101	S2
A27	Central African Republic	117	S2	A73	Lao PDR	84	S2	A119	Spain	50	S2
A28	Chile	21	S2	A74	Latvia	20	S2	A120	Sri Lanka	78	S2
A29	China	124	S2	A75	Lebanon	96	S2	A121	Sudan	75	S2
A30	Colombia	14	S2	A76	Lesotho	76	S2	A122	Sweden	3	S1
A31	Congo, Dem. Rep.	43	S2	A77	Lithuania	19	S2	A123	Switzerland	6	S2
A32	Congo, Rep.	118	S2	A78	Luxembourg	5	S2	A124	Tajikistan	51	S2
A33	Costa Rica	9	S2	A79	Madagascar	128	S2	A125	Thailand	90	S2
A34	Cote d’Ivoire	135	S2	A80	Malawi	83	S2	A126	Timor-Leste	127	S2
A35	Croatia	35	S2	A81	Malaysia	30	S2	A127	Tunisia	82	S2
A36	Cyprus	99	S2	A82	Mali	115	S2	A128	Turkey	103	S2

(*Continued*)

Table 3 Continued

Code	Country	Ranking	Class	Code	Country	Ranking	Class	Code	Country	Ranking	Class
A37	Czech Republic	32	S2	A83	Malta	70	S2	A129	Uganda	62	S2
A38	Denmark	10	S2	A84	Mexico	67	S2	A130	Ukraine	108	S2
A39	Dominican Republic	85	S2	A85	Mongolia	126	S2	A131	United Arab Emirates	112	S2
A40	Ecuador	15	S2	A86	Montenegro	59	S2	A132	United Kingdom	26	S1
A41	Egypt, Arab Rep.	48	S2	A87	Morocco	91	S2	A133	United States	80	S2
A42	El Salvador	25	S2	A88	Mozambique	74	S2	A134	Uruguay	16	S2
A43	Estonia	13	S2	A89	Myanmar	113	S2	A135	Uzbekistan	123	S2
A44	Ethiopia	81	S2	A90	Namibia	24	S2	A136	Vietnam	55	S2
A45	Fiji	37	S2	A91	Nepal	60	S2	A137	Zambia	77	S2
A46	Finland	4	S1	A92	Netherlands	73	S2	A138	Zimbabwe	106	S2

not connected to the electricity system, has limited access to natural gas, and has a low share of renewable energy in the total energy supply are all factors contributing to Bangladesh's poor performance [51]. With its reliance of coal-based energy, India is one of the world's major producers of greenhouse gas emissions among the poor performing countries [55].

While tackling climate change has become a central subject of many policy initiatives, European Union (EU) member states are working hard to meet their emission goals [53]. The reduction in carbon dioxide emissions in industrialized countries is related to a paradigm shift and structural transformation from high energy-intensive and carbon-intensive industries to service and information-intensive economy. Agriculture, transportation, and services, according to Sarkodie and Strezov [56], are driving up CO_2 emissions in developing and least developing countries. Also, because environmental policies and regulations in emerging and underdeveloped countries are weaker than in developed countries, nonrenewable energy resources and carbon-intensive sectors are allowed to spread. In developed countries, increased awareness of environmental sustainability, technological advancement, and strong environmental rules and policies result in a reduction in the use of nonrenewable energy resources and carbon dioxide emissions [56].

The results implicitly show that the Kuznets curve may be valid on a global scale. According to the Kuznets curve, environmental pollution increases when economic growth increases initially. After a certain threshold value, the increase in the level of economic development also provides an increase in environmental awareness, and thus environmental pollution begins to decrease [59]. On the other hand, in this era of climate change, new ways that are both sustainable and environmentally friendly are required for the development, and welfare of developing and underdeveloped countries. Decision-makers in developing and underdeveloped countries should prioritize energy efficiency, renewable energy and nuclear energy investments and research, as well as policies that promote economic development. According to experts, the growth of renewable and nuclear energy sources would assist meet industrialization's energy needs while also reducing pollution [60].

4.1 Validation of Results

The validity and reliability of the solution to the decision problem, which is the subject of the study, will be examined using a comparative sensitivity analysis. Sensitivity analysis explores how the solution to a decision problem changes as the parameters or model inputs change. The decision maker can use sensitivity analysis to determine which parameter, data, and component in the decision problem is functional or critical to the solution. As a result, he has the option of changing his preferences or judgments throughout the problem-solving process [61, 62]. In this context, the consequences of changing the weights of criteria on ranking and classification results and the solutions acquired by other methods compared to the study's methodology are investigated. Twenty different sets were created to investigate the effects of criteria weight changes. As shown in Table 4, these sets were created by taking the weight values of the other criteria only once for each criterion.

The original weight values obtained in this study are represented by Set 0 in Table 4. Changing the criteria weighting coefficients had no effect on the CODAS-Sort results.Consequently, the CODAS-Sort results can be described as stable and reliable. Figure 2 depicts the variations of the results obtained using CRADIS based on changing the criteria weight coefficients in the analysis carried out in the context of the ranking results.

The different colours of the rays in Figure 2 represent the ranking differences of alternatives between the sets. In this context, it is clear to say that, in general, set changes do not have a significant impact on the rankings of the alternatives. Also, Set 0 has a strong rank connection with the Set 1–20 ($r_s \geq 0, 99$). The results show that the CRADIS method is consistent across changes in set of criteria weight coefficients.

By conducting classification and ranking operations using different methods, the validity and reliability of the solutions obtained by the CODAS-Sort and CRADIS methods were investigated. The TOPSIS-Sort-C [63, 64]

Table 4 Changing criteria weights for sensitivity analysis

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
SET 0	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480
SET 1	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433
SET 2	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519
SET 3	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407
SET 4	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462
SET 5	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494
SET 6	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472
SET 7	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477
SET 8	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501
SET 9	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495
SET 10	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488
SET 11	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488
SET 12	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481
SET 13	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498
SET 14	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507
SET 15	0,0450	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476
SET 16	0,0490	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450
SET 17	0,0449	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490
SET 18	0,0449	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449
SET 19	0,0484	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449
SET 20	0,0480	0,0433	0,0519	0,0407	0,0462	0,0494	0,0472	0,0477	0,0501	0,0495	0,0488	0,0488	0,0481	0,0498	0,0507	0,0476	0,0450	0,0490	0,0449	0,0449	0,0484

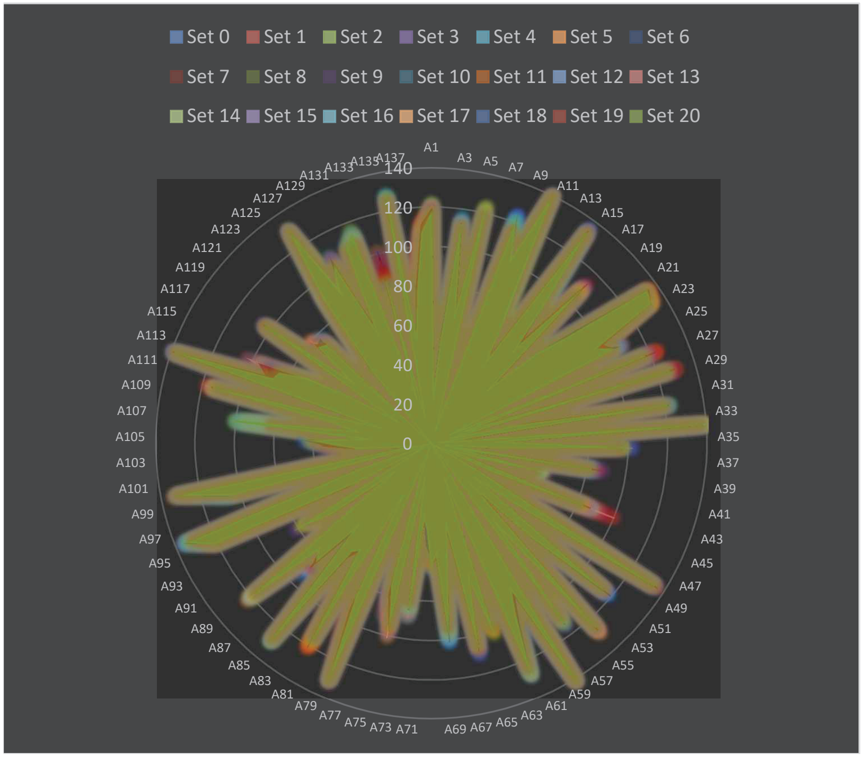

Figure 2 The effect of changing the criteria weighting coefficients on the CRADIS ranking results.

method was used in the classification process, which allows for the employment of central profiles. As a result, all countries were assigned to the S2 class via the TOPSIS-Sort-C method. CODAS-Sort, in this context, can be said to provide a more effective classification for the decision problem solved in this study. The ranking results obtained via CRADIS were compared to the ARAS [65], MARCOS [66], TOPSIS [67] methods on which the CRADIS method is based, as well as the integrated structured CoCoSo [68] and WASPAS [69] methods, as part of a comparative sensitivity analysis. In CoCoSo and WASPAS applications, the λ parameter is set to 0.5. Figure 3 illustrates the results obtained.

Figure 3, which depicts the ranking results, indicates the validity of the rankings obtained by CRADIS. As seen in Figure 3, CoCoSo produced slightly different results from the other methods. The rank correlation

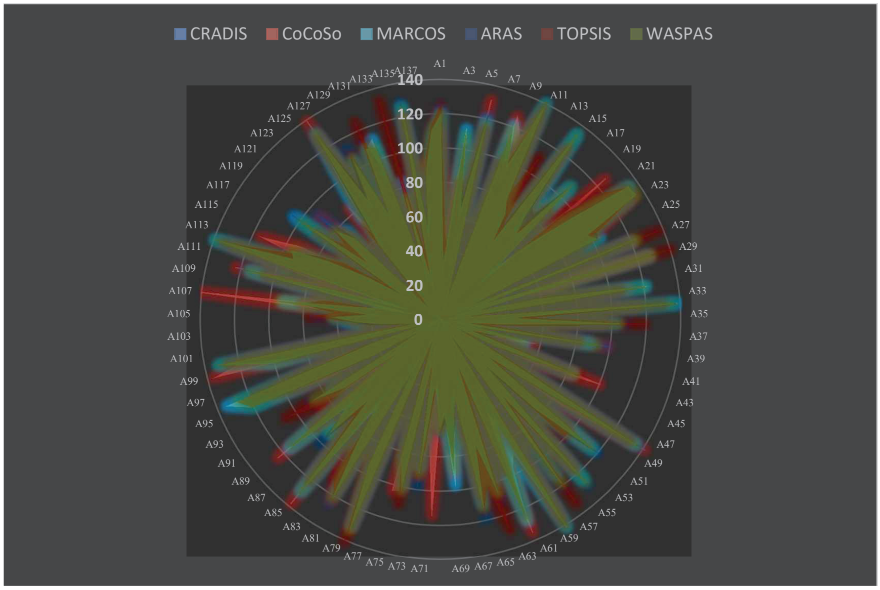

Figure 3 Comparative analysis of ranking results using different methods and CRADIS.

coefficients of the methods also shed light on the similarity and validity of the rankings. As a result, the CRADIS method results has strong rank coefficients with CoCoSo ($r_s = 0,895$), WASPAS ($r_s = 0,993$), MARCOS ($r_s = 1$), ARAS ($r_s = 0,947$), TOPSIS ($r_s = 0,904$) ranking results. The ranking results obtained with CRADIS are valid and reliable for the nature of the problem.

5 Conclusions

Energy, environment, and sustainability are all interconnected concepts that are deeply intertwined. In fact, it is necessary to look at energy and sustainability policies for the protection of the environment, environmental impact and sustainability for energy efficiency, and environmental impact and use of energy for sustainability. In this context, the study used MCDM methodology to evaluate countries within the energy, environment, and sustainability triangle.

The CODAS-Sort classification results revealed that the majority of the countries performed similarly. However, Nordic countries Sweden, Finland, Iceland, and Norway, as well as Commonwealth countries Australia, Canada, and the United Kingdom, outperformed the rest of the world. These countries' success can be attributed to strong environmental protection and renewable energy policies. Countries and regions such as Sub-Saharan Africa, Bangladesh, and India, on the other hand, are negatively differentiated due to a lack of infrastructure and a reliance on nonrenewable energy. The CRADIS results generally correlate with the CODAS-Sort results. Nordic countries placed first on the ranking obtained using CRADIS. In general, the results indicate that developed and wealthy countries differed from the rest of the world in a positive way. Examining top countries' policies and practices can assist underdeveloped and developing countries in identifying and resolving their problems in this context. Furthermore, important lessons must be drawn, particularly for developing countries, from waste of resources, low productivity, a lack of innovation, inadequate infrastructure, a lack of awareness, and political instability in countries that performed poorly in terms of the criteria and within the period considered.

While humanity seeks to spread the comfort and welfare it has achieved on a global scale, to achieve more development and comfort through technological advances, it is locked in a stalemate caused by the world's use of resources as if they are limitless, as well as irrecoverable environmental damage. The main subject of this dilemma is energy. In the last few centuries, fossil fuels or nonrenewable source have primarily been used for energy. Considering the limitation of fossil fuels, the fact that they will be depleted in a few decades, and the environmental damage they do, the development and effective use of renewable energy sources is viewed as a key solution option. Because humanity will find it difficult to give up its current level of comfort or reduce its energy consumption. At this point, the importance of energy efficiency, diversification of renewable energy sources, raising societal awareness, unity in global sustainable environmental policies, providing assistance to societies that are falling behind in achieving welfare and fighting poverty, and focusing on energy savings emerges. To establish and implement the aforementioned policies, strong will and community support will be required.

The study is limited to the period, countries and data examined. However, more research into the numerous dimensions and effects of sustainability is required. Future research may focus on specific renewable energy sources and assess their effects on the environment, sustainability, and welfare. In-depth research in the context of regions or a specific geographic location will also be beneficial. The comparative analysis results, on the other hand, show that the study's methods can be successfully implemented in a variety of fields.

List of Notations and Abbreviations

ARAS	Additive Ratio Assessment
ARAT	Interval and Iterative Preference/Priority Scale
BRI	Belt and Road Initiative
CoCoSo	Combined Compromise Solution
CODAS-Sort	Combinative Distance-based Assessment
CRADIS	Compromise Ranking of Alternatives from Distance to Ideal Solution
CRITIC	Criteria Importance Through Inter-criteria Correlation
MARCOS	Measurement of alternatives and ranking according to Compromise solution
SOWIA	Subjective and Objective Weight Integrated Approach
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
WASPAS	The Weighted Aggregated Sum Product ASsessment

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Biography

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