

Article

Benchmarking Sustainability-Oriented Green Transition Performance in OECD Countries: A CRITIC-ARAS Framework for SDG-Based Policy Assessment

Mustafa Terzioğlu ¹, Neylan Kaya ², Aslıhan Ersoy Bozcuk ², Burçin Tutcu ¹, Günay Deniz Dursun ³, Güler Ferhan Ünal Uyar ² and Güray Tonguç ^{4,*}

¹ Accounting and Tax Department, Korkuteli Vocational School, Akdeniz University, Antalya 07058, Türkiye; mterzioglu@akdeniz.edu.tr (M.T.); burcintutcu@akdeniz.edu.tr (B.T.)

² Department of Business Administration, Faculty of Economics and Administrative Sciences, Akdeniz University, Antalya 07058, Türkiye; neylankaya@akdeniz.edu.tr (N.K.); aebozcuk@akdeniz.edu.tr (A.E.B.); guleruyar@akdeniz.edu.tr (G.F.Ü.U.)

³ Capital Markets Department, Faculty of Economics and Administrative Sciences, Beykent University, İstanbul 34398, Türkiye; gunaydursun@beykent.edu.tr

⁴ Department of Management Information Systems, Faculty of Applied Sciences, Akdeniz University, Antalya 07058, Türkiye

* Correspondence: guraytonguc@akdeniz.edu.tr

Abstract

Achieving the Sustainable Development Goals (SDGs) requires countries to simultaneously advance renewable energy transitions, environmental innovation, carbon efficiency, and sustainable governance mechanisms. Although previous research has extensively examined sustainability transitions and environmental sustainability, comparative assessments integrating renewable energy, environmental innovation, carbon efficiency, fiscal instruments, and fossil fuel dependency remain limited. Using 2023 data from 31 OECD countries, the study analyzes eight sustainability-related indicators through an integrated CRITIC-ARAS multi-criteria decision-making framework. The CRITIC method is employed to determine objective criterion weights, while the ARAS method evaluates countries' performance relative to an ideal sustainability profile. The findings reveal considerable differences in sustainability performance across OECD countries. CO₂ emissions from air transport per capita emerge as the most influential criterion within the weighting structure. According to the results, Slovenia, Iceland, and Norway demonstrate the strongest transition performance. Countries with higher renewable electricity generation, stronger environmental innovation support, lower transport-related emissions, and lower fossil fuel dependency generally achieve better outcomes. Sensitivity analysis supports the overall stability of the ranking structure under alternative weighting scenarios, although the exclusion of the highest-weighted criterion produces noticeable ranking shifts for some countries. The results indicate that sustainability performance depends not only on environmental outcomes but also on countries' ability to coordinate renewable energy policies, environmental innovation, fiscal instruments, and decarbonization strategies. From a policy perspective, the findings emphasize the importance of renewable energy expansion, environmental taxation, transport decarbonization, environmental R&D support, and fossil fuel subsidy reform for strengthening long-term sustainable development strategies. This study contributes to the sustainability assessment literature by providing a comparative and policy-oriented framework for benchmarking sustainability-oriented green transition performance across countries through integrated environmental, energy-related, and innovation-based indicators.



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Keywords: sustainability-oriented green transition; sustainability assessment; Sustainable Development Goals (SDGs); environmental governance; decision-support framework; OECD countries; CRITIC-ARAS

1. Introduction

Climate change, biodiversity loss, environmental degradation, resource scarcity, and rising energy insecurity have transformed sustainable development into one of the central policy challenges of the twenty-first century. In response, countries are increasingly expected to redesign their development models by simultaneously ensuring economic resilience, environmental sustainability, and long-term energy security. Consequently, development can no longer be evaluated solely through traditional macroeconomic indicators such as GDP growth or industrial expansion. Contemporary policy approaches increasingly emphasize carbon reduction, clean energy expansion, environmental innovation, and low-carbon technological transformation. This shift reflects the growing recognition that broader sustainability and green economy indicators are required to complement conventional economic performance measures [1,2].

Within this process, green transition policies have become central components of sustainable development strategies. However, the shift toward low-carbon economies extends beyond environmental regulation alone. Recent studies emphasize that low-carbon transitions constitute complex socio-technical transformation processes involving energy systems, environmental governance, innovation capacity, and policy coordination rather than merely emissions reduction efforts [3]. This transition also involves the expansion of renewable energy expansion, environmental taxation, innovation support, sustainable transport systems, and the gradual reduction in fossil fuel dependency. Therefore, the green transition should not be interpreted merely as an environmental outcome or a narrow green finance issue, but rather as countries' ability to coordinate environmental, technological, fiscal, and energy-related policies. Recent sustainability research increasingly emphasizes governance-oriented approaches, arguing that sustainable development outcomes depend on institutional coordination, policy coherence, and the integration of environmental, economic, and social objectives within broader governance frameworks [4]. This perspective is particularly important because countries may achieve similar economic outcomes while demonstrating significantly different levels of environmental transformation depending on institutional effectiveness, policy coordination, and technological readiness. As a result, evaluating transition pathways requires analytical approaches capable of simultaneously considering environmental, energy-related, fiscal, and innovation-oriented dimensions. This multidimensional perspective is consistent with SDG assessment frameworks emphasizing the need for integrated indicators capable of capturing complex sustainability interactions [5]. Recent studies also emphasize that indicator-based sustainability frameworks provide more comprehensive and policy-relevant assessments by integrating multiple environmental, social, and governance dimensions [5,6].

OECD countries provide an important context for such evaluation because of their advanced institutional structures and influential role in global sustainability policies. Moreover, OECD countries play a critical role in advancing the Sustainable Development Goals (SDGs), particularly those related to clean energy, innovation, responsible production, and climate action. Nevertheless, OECD economies display substantial differences regarding renewable energy deployment, environmental innovation, carbon efficiency, transport-related emissions, and fossil fuel dependency. These dimensions are broadly consistent with the OECD Green Growth Indicators framework, which emphasizes resource productivity,

environmental efficiency, natural asset preservation, and policy responses as key components of sustainable economic transformation [7].

Although previous studies extensively examine sustainability transitions, environmental sustainability, and economic growth, relatively limited attention has been devoted to comparative assessments of green transition pathways at the country level. Existing studies often focus either on econometric relationships or on limited environmental indicators, while insufficiently addressing the interaction between energy transition, environmental taxation, innovation systems, transport emissions, and fossil fuel dependency reduction. Existing studies have proposed alternative approaches for measuring green growth and sustainability performance in OECD countries [1,2]. Recent policy-oriented sustainability assessments have also highlighted the importance of benchmarking governmental effectiveness and indicator consistency in evaluating SDG progress across countries [8]. Moreover, limited evidence exists regarding how objective weighting and utility-based ranking frameworks jointly influence country-level sustainability benchmarking outcomes. However, these studies generally focus on specific sustainability dimensions or composite indices and fail to capture the integrated effects of renewable energy, environmental innovation, environmental taxation, transport-related emissions, and fossil fuel dependency within a unified assessment framework.

To address this gap, this study evaluates 31 OECD countries using a CRITIC-ARAS multi-criteria decision-making approach based on 2023 data. Eight indicators associated with carbon efficiency, energy productivity, renewable energy, environmental innovation, environmental taxation, transport-related emissions, and fossil fuel dependency are included in the analysis. The CRITIC method is employed to determine objective criterion weights, while the ARAS method ranks country performances relative to an ideal transition profile. This integrated structure allows the study to combine objective weighting with proportional utility-based ranking, thereby improving analytical transparency and policy interpretability. Sensitivity analysis and Spearman rank correlation tests are additionally conducted to examine the robustness of the findings under alternative weighting scenarios.

Accordingly, this study addresses two research questions: (1) How do OECD countries differ in their sustainability-oriented green transition performance when renewable energy, environmental innovation, carbon efficiency, fiscal instruments, transport-related emissions, and fossil fuel dependency are evaluated within an integrated assessment framework? (2) Which sustainability dimensions exert the greatest influence on cross-country sustainability performance?

The study contributes to the literature in three ways. First, it expands the sustainability assessment literature by evaluating green transition through environmental, fiscal, energy-related, and innovation-oriented dimensions simultaneously. Second, it develops a transparent and reproducible sustainability assessment framework based on the integrated CRITIC-ARAS approach and supported by robustness analysis. Third, it provides policy-relevant insights for monitoring progress toward SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

2. Literature Review

2.1. Sustainability-Oriented Green Transition, Green Finance, and Sustainable Development

Climate change, biodiversity loss, and energy insecurity have transformed sustainable development into a major global policy issue. Accordingly, sustainability is increasingly evaluated through countries' ability to balance environmental protection, economic resilience, and energy security rather than solely through economic growth indicators.

The transition toward low-carbon economies involves renewable energy expansion, technological innovation, environmental regulation, and sustainable finance mechanisms. Green finance has therefore emerged as an important policy instrument supporting environmentally sustainable investment [9]. However, recent studies indicate that sustainability outcomes cannot be adequately explained solely through financial mechanisms or green investment flows.

Unlike conventional environmental performance studies focusing mainly on ecological outcomes, recent approaches increasingly emphasize carbon reduction, clean energy systems, environmental innovation, and fossil fuel dependency reduction. Similarly, green growth literature highlights the importance of decoupling economic growth from environmental degradation through renewable energy and emission reduction policies [1]. Sustainability indicator studies also criticize GDP-centered evaluations and advocate broader sustainability assessment approaches [2].

OECD-focused studies further demonstrate that countries follow different transition pathways depending on renewable energy deployment, environmental technologies, and policy structures [10,11]. These findings suggest that sustainability outcomes depend on the interaction of environmental, technological, and energy-related factors rather than on a single dimension alone.

2.2. Green Finance, Green Growth, and Sustainability Indicator Literature

Green finance literature mainly focuses on financing mechanisms supporting renewable energy investments, low-carbon technologies, and environmentally sustainable economic activities [9]. Existing studies generally conclude that green finance and environmental innovation positively contribute to environmental sustainability.

Nevertheless, sustainability assessment extends beyond financial mechanisms alone. While green growth studies primarily emphasize environmentally sustainable economic growth, broader sustainability evaluations additionally incorporate environmental taxation, carbon efficiency, innovation capacity, renewable energy systems, and fossil fuel dependency reduction.

Unlike conventional green growth approaches, this study evaluates countries through a combined set of environmental, fiscal, energy-related, and innovation-oriented indicators. In this respect, sustainability indicator literature provides the theoretical basis for the indicator structure adopted in the study.

Previous OECD-based studies indicate that sustainability outcomes differ substantially depending on their renewable energy capacity, technological transformation, and emission reduction policies [10,11]. Similarly, multidimensional sustainability indices increasingly integrate renewable energy indicators, carbon productivity, environmental taxation, and innovation-related variables into broader evaluation structures [2].

Recent studies further show that sustainability performance depends not only on green investment expansion but also on structural transformation capacity. Li [12], for example, found that fossil fuel efficiency has a stronger long-term impact on sustainability than green finance alone.

2.3. SDG Assessment and Environmental Policy Performance Literature

The Sustainable Development Goals (SDGs) have broadened sustainability assessment by integrating environmental, economic, technological, and institutional dimensions into a unified policy agenda. Green transition policies are particularly associated with SDG 7 (clean energy), SDG 9 (innovation), SDG 12 (responsible production), and SDG 13 (climate action).

The indicators used in this study are closely linked to these SDGs. Renewable energy supply and renewable electricity generation correspond to SDG 7, environmental R&D expenditures relate to SDG 9, while carbon efficiency, environmental taxation, and fossil fuel support indicators are associated with SDG 12 and SDG 13.

Environmental policy literature increasingly argues that sustainability outcomes depend not only on environmental regulation but also on policy coordination, institutional effectiveness, and innovation support mechanisms. Guijarro [13] emphasized the complexity of environmental performance assessment, while Piwowski et al. [14] and Dang and Dang [15] demonstrated the usefulness of multi-criteria sustainability evaluation methods in international comparisons.

Peiró-Signes et al. [16] additionally showed that environmental sustainability performance affects countries' economic resilience and risk structures. Overall, the literature suggests that sustainability assessment should be interpreted through broader policy and development perspectives rather than solely as environmental outcomes.

Similarly, governance-oriented sustainability research argues that successful green transitions depend on countries' capacity to coordinate environmental, energy, innovation, and fiscal policies within integrated governance structures rather than relying on isolated policy interventions [4].

2.4. Conceptual Framework

This study evaluates the green transition through countries' ability to align environmental sustainability objectives with energy policies, innovation systems, and economic development strategies.

The proposed framework is based on five dimensions:

- carbon efficiency and emission reduction;
- renewable energy systems;
- environmental innovation;
- environmental fiscal policies;
- fossil fuel dependency reduction.

Unlike conventional environmental performance or green finance studies, the proposed approach combines these dimensions within a single comparative assessment structure.

The study's conceptual contribution lies in evaluating countries through the interaction of environmental, fiscal, energy-related, and innovation-oriented indicators rather than relying on isolated environmental measures.

These dimensions are operationalized through eight indicators. Carbon efficiency is represented through C1 and C7; energy-related indicators through C2–C4; environmental innovation through C5; fiscal policy through C6; and fossil fuel dependency through C8.

Methodologically, the study adopts a CRITIC-ARAS approach. The CRITIC determines objective criterion weights based on indicator variability and interrelationships, while ARAS ranks countries relative to an ideal transition profile. Based on the theoretical discussion presented above, Figure 1 illustrates the conceptual framework adopted in this study for assessing sustainability-oriented green transition performance.

As illustrated in Figure 1, sustainability-oriented green transition performance is conceptualized as a multidimensional construct shaped by the interaction of energy systems, innovation systems, and fiscal governance mechanisms. Within this framework, countries' transition performance is evaluated in relation to their contribution to key sustainability objectives represented by SDG 7, SDG 9, SDG 12, and SDG 13.

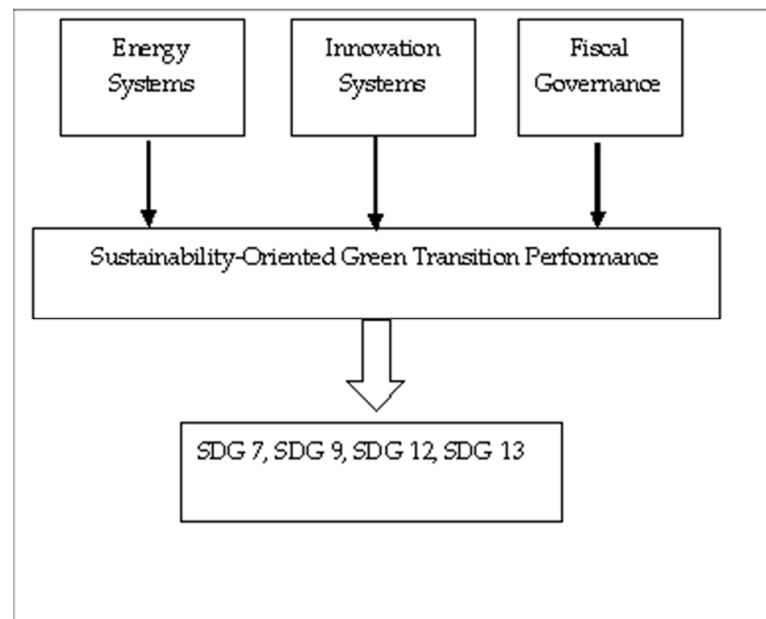


Figure 1. Conceptual Framework of Sustainability-Oriented Green Transition Performance.

2.5. The Use of MCDM Methods in Sustainability Assessment

Sustainability-oriented transition performance represents a complex decision problem involving multiple interconnected sustainability dimensions. Because renewable energy transition, carbon efficiency, environmental innovation, and fiscal governance may interact with or conflict one another, single-indicator approaches are often insufficient for evaluating sustainability transition capacity.

In this context, multi-criteria decision-making (MCDM) methods have become increasingly important in the sustainability assessment literature. Almeida-Filho et al. [17] emphasized that MCDM approaches provide effective analytical frameworks for evaluating complex sustainability-related decision problems involving heterogeneous indicators simultaneously.

MCDM methods are particularly suitable for sustainability assessment because they allow environmental, technological, fiscal, and energy-related dimensions to be evaluated within an integrated framework. Consequently, they provide more comprehensive and policy-oriented sustainability evaluation structures compared with isolated environmental or econometric analyses.

Accordingly, this study adopts a multi-criteria decision-making framework integrating indicators related to carbon efficiency, renewable energy transition, environmental innovation, environmental fiscal governance, transport-related emissions, and fossil fuel dependency reduction.

2.6. CRITIC Method

The CRITIC (Criteria Importance Through Intercriteria Correlation) method, developed by Diakoulaki et al. [18], is an objective weighting approach that simultaneously considers both indicator variability and inter-criterion relationships. Indicators with higher variability and lower correlation with other criteria receive greater weights.

CRITIC is particularly suitable for this study because sustainability-oriented transition indicators are highly interconnected. Unlike subjective weighting approaches based on expert judgment, CRITIC derives criterion weights directly from the informational structure of the dataset, thereby reducing subjective bias and improving analytical transparency.

Previous studies have shown that CRITIC-based weighting structures produce stable and reliable results in complex sustainability assessment problems [19]. Therefore, the

method strengthens the methodological robustness of the sustainability-oriented transition framework proposed in this study. Compared with entropy-based weighting approaches, CRITIC additionally considers inter-criterion correlation, allowing the weighting structure to reflect not only dispersion but also redundancy among sustainability indicators. This feature makes CRITIC particularly appropriate for multidimensional sustainability assessment. This methodological logic is consistent with broader MCDA frameworks emphasizing the importance of balancing informational variability, aggregation effects, and inter-criterion relationships in composite indicator construction [20,21].

2.7. ARAS Method

The ARAS (Additive Ratio Assessment) method, developed by Zavadskas and Turskis [22] and extended by Turskis and Zavadskas [23], evaluates alternatives relative to an ideal solution through proportional utility assessment procedures.

ARAS was preferred because it allows countries to be evaluated proportionally against an ideal sustainability-oriented transition profile, making the findings interpretable for policy benchmarking. Unlike distance-based approaches, ARAS produces utility degree values reflecting countries' relative sustainability transition capacities. Compared with distance-based ranking methods such as TOPSIS and VIKOR, ARAS provides more direct proportional utility values, making cross-country sustainability performance easier to interpret for policy benchmarking purposes.

The method is particularly suitable for multidimensional sustainability assessment because countries may simultaneously demonstrate strengths and weaknesses across different sustainability dimensions. Therefore, the integration of CRITIC and ARAS methods enables a transparent and policy-oriented sustainability assessment framework for OECD countries.

2.8. Research Gap and Contribution

Although previous studies have extensively examined the green finance, environmental sustainability, and economic growth relationships, limited attention has been devoted to integrated assessments of sustainability-oriented green transition capacity at the country level.

Most existing studies either focus on econometric relationships or evaluate environmental sustainability through narrow indicator structures. In addition, relatively few studies integrate objective weighting methods with comparative sustainability assessment techniques.

To address these limitations, the study evaluates sustainability-oriented green transition performance through an integrated CRITIC-ARAS framework designed to measure multidimensional sustainability transition capacity rather than merely producing environmental rankings.

The study contributes to the literature in three main respects. First, it offers a theoretical contribution by conceptualizing sustainability-oriented green transition performance as a multidimensional sustainability governance capacity rather than as a fragmented environmental or financial outcome. Second, it provides a methodological contribution by integrating the CRITIC and ARAS methods within a transparent and reproducible sustainability assessment framework, further supported by sensitivity analysis and Spearman rank correlation tests. Third, it offers a policy-oriented contribution by developing an OECD-based assessment framework that identifies structural strengths and weaknesses related to renewable energy transition, environmental innovation, environmental fiscal governance, carbon efficiency, and fossil fuel dependency reduction. Furthermore, there is limited evidence exists regarding how multiple sustainability dimensions jointly contribute

to SDG-oriented green transition performance across OECD countries. This study addresses this gap by integrating environmental, energy-related, fiscal, and innovation-based indicators within a unified sustainability assessment framework.

3. Materials and Methods

3.1. Data Set

In this study, a total of eight indicators were selected to evaluate the sustainability-oriented green transition performance among OECD countries. The indicator selection process was guided by both the literature on sustainability transitions and the availability of internationally comparable data related to carbon efficiency, renewable energy transition, environmental innovation, environmental fiscal governance, and fossil fuel dependency reduction. The selected indicators collectively represent the multidimensional structure of sustainability-oriented transition capacity and enable integrated assessment of environmental, energy, fiscal, and innovation-related sustainability dimensions. In addition, the selected indicators were chosen to reflect key sustainability dimensions associated with SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

The data used in the analysis were compiled from the Organization for Economic Co-operation and Development (OECD) database and the International Monetary Fund (IMF) database based on the most recent internationally comparable year available, namely, 2023. The OECD database was primarily used to obtain indicators related to renewable energy transition, environmental taxation, environmental R&D expenditures, transport-related emissions, and fossil fuel support, while the IMF database was used to complement macroeconomic and sustainability-related performance indicators where necessary. The preference for 2023 data reflects the aim of evaluating countries' most recent sustainability-oriented transition capacities within a consistent and comparable international framework.

The sample was limited to 31 OECD countries due to the availability of complete and internationally comparable data for all selected indicators in 2023. Although the OECD includes a larger number of member countries, several countries were excluded from the analysis because of missing or incomplete observations for one or more indicators included in the study. Restricting the sample to countries with complete data ensured methodological consistency and comparability across all criteria within the multi-criteria decision-making framework.

Considering both the theoretical relevance of the indicators and the constraints related to data availability, codes were assigned to the eight indicators included in the analysis. Table 1 presents the indicators, their codes, optimization directions, measurement descriptions, and related SDG linkages. Collectively, these indicators operationalize the conceptual dimensions of sustainability-oriented green transition performance proposed in the study and provide the empirical basis for evaluating countries' sustainability transition capacities and their progress toward key sustainability objectives represented by SDG 7, SDG 9, SDG 12, and SDG 13.

As shown in Table 1, the selected indicators capture the key dimensions of sustainability-oriented green transition performance, including carbon efficiency, renewable energy transition, environmental innovation, environmental fiscal governance, and fossil fuel dependency reduction. The indicator set was designed to reflect the multidimensional nature of sustainability assessment while ensuring consistency with the study's conceptual framework. Furthermore, the indicators are directly linked to SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), thereby enabling the evaluation of countries' green transition performance within a broader sustainable development perspective.

Table 1. Sustainability Indicators, Codes, Optimization Directions, Measurement Descriptions, and Related SDG Linkages.

Dimensions	Codes	Directions	Indicators	Related SDG
Production-based CO ₂ productivity, GDP per unit of energy-related CO ₂ emissions	C1	Max	It indicates the amount of GDP generated per unit of energy-related CO ₂ emissions. This indicator reflects the extent to which an economy produces economic output while reducing its carbon intensity.	SDG 13 (Climate Action)
Energy productivity, GDP per unit of TES	C2	Max	It indicates the amount of GDP generated per unit of Total Energy Supply (TES). This indicator measures the efficiency with which energy resources are utilized within the economy.	SDG 7 (Affordable and Clean Energy)
Renewable energy supply (% energy supply)	C3	Max	It indicates the share of renewable energy sources within the Total Energy Supply (TES). This indicator reflects the sustainability level of the energy system.	SDG 7 (Affordable and Clean Energy)
Renewable electricity generation (% electricity generation)	C4	Max	It indicates the share of electricity generated from renewable sources within total electricity production. This indicator reflects the clean energy transition of the electricity sector.	SDG 7 (Affordable and Clean Energy)
Environment-related government R&D budget (% government allocations for R&D)	C5	Max	It indicates the share of environment-related research and development expenditures within the public R&D budget. This indicator reflects the level of support provided for environmental innovation.	SDG 9 (Industry, Innovation and Infrastructure)
Environment related tax revenue (% GDP)	C6	Max	It indicates the share of environment-related tax revenues within GDP. This indicator reflects the effectiveness of green fiscal policies and the taxation of environmental externalities.	SDG 12 (Responsible Consumption and Production)
CO ₂ emissions from air transport per capita	C7	Min	It indicates the amount of CO ₂ emissions from air transport per capita. This indicator reflects the environmental impact of the transportation sector.	SDG 13 (Climate Action)
Total fossil fuel support (% of tax revenue)	C8	Min	It indicates the share of total fossil fuel support within tax revenues. This indicator reflects the level of dependence on fossil fuels and the extent of environmentally harmful subsidies.	SDG 12 (Responsible Consumption and Production); SDG 13 (Climate Action)

3.2. Methodology

This study evaluates the sustainability-oriented green transition performance among 31 OECD countries using an integrated multi-criteria decision-making framework based on 2023 data. The methodological framework was designed to measure countries' multidimensional sustainability transition capacities by simultaneously incorporating environmental, energy-related, fiscal, technological, and carbon efficiency-oriented indicators within a unified analytical structure.

The methodological process consists of four main stages. In the first stage, sustainability-oriented transition indicators were identified based on the literature and internationally comparable data availability. Subsequently, a decision matrix was constructed using the indicator values obtained from the OECD and IMF databases.

In the second stage, the CRITIC (Criteria Importance Through Intercriteria Correlation) method was applied to determine objective criterion weights. The CRITIC method evaluates the informational contribution of each criterion by considering the variability

of indicators and the conflict structure among them. Accordingly, criteria with higher discriminatory power and lower redundancy are assigned greater importance within the weighting structure.

The CRITIC method was first used to determine objective criterion weights, and these weights were subsequently integrated into the ARAS method to rank countries according to their relative transition performance levels. In the third stage, the ARAS (Additive Ratio Assessment) method was employed to comparatively evaluate countries relative to an ideal sustainability-oriented transition profile. Through the integration of CRITIC and ARAS methods, the study combines objective weighting with proportional utility-based ranking, thereby enabling a transparent and policy-oriented sustainability assessment framework.

Finally, in the fourth stage, sensitivity analysis and Spearman rank correlation tests were conducted to evaluate the robustness and stability of the findings under alternative weighting scenarios. Different weighting structures were developed to examine the extent to which country rankings changed under varying policy priorities and weighting assumptions. This stage strengthens the methodological reliability of the study and provides additional evidence regarding the consistency of the ranking results.

Figure 2 presents the overall research framework and illustrates the sequential stages of the methodological process adopted in the study. The figure demonstrates how literature review, indicator selection, data collection, objective weighting, comparative ranking, and robustness analysis are integrated into a unified sustainability-oriented assessment framework. Accordingly, the proposed methodology evaluates sustainability-oriented green transition performance not merely as an environmental ranking exercise but as a multidimensional sustainable development governance assessment.

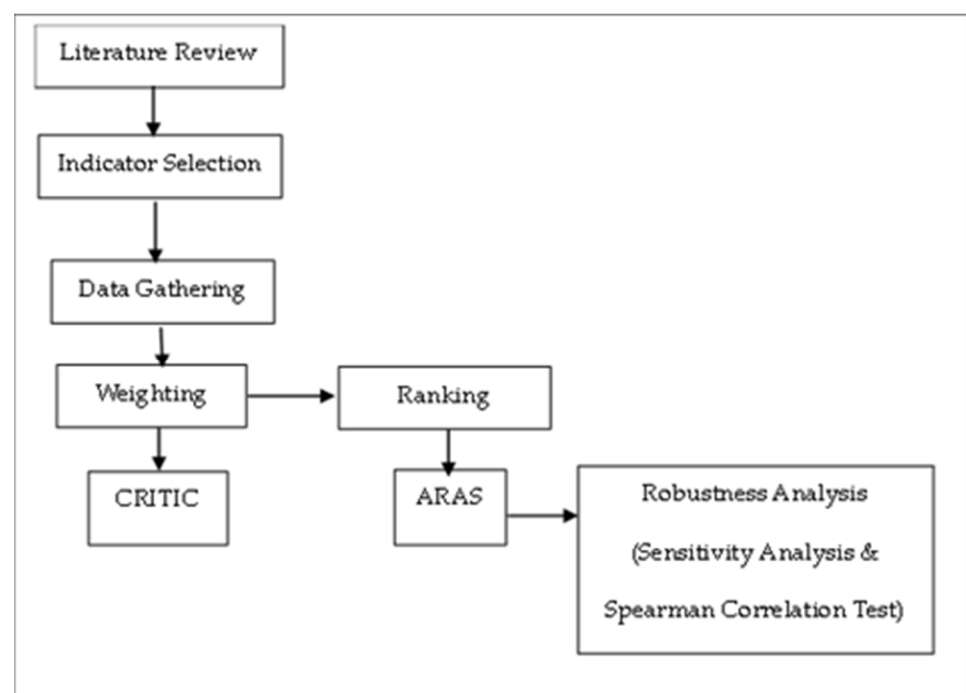


Figure 2. Research framework of the study.

Figure 2 presents the integrated sustainability assessment framework employed in the study. The framework combines literature-based indicator selection, objective weighting through the CRITIC method, comparative country evaluation using the ARAS method, and robustness analysis. This sequential process enables a transparent and reliable assessment of sustainability-oriented green transition performance across OECD countries.

3.2.1. Application of the CRITIC Method

The CRITIC (Criteria Importance Through Intercriteria Correlation) method determines the importance levels of criteria by considering both the standard deviation of criteria values and the correlations among them [18]. Accordingly, the CRITIC method provides an objective weighting structure by assigning greater importance to criteria that contain higher information content and stronger discriminating power.

The steps of the CRITIC method are as follows:

Step 1: Construction of the decision matrix

The decision matrix includes the values of each criterion for each alternative (country).

$$X = [x_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & \dots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{bmatrix} \quad i = 1, 2, \dots, m \quad j = 1, 2, \dots, n \quad (1)$$

Step 2: Normalization of the decision matrix

The decision matrix is normalized depending on whether the criteria are benefit-oriented or cost-oriented.

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (\text{Benefit-oriented}) \quad (2)$$

$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (\text{Cost-oriented}) \quad (3)$$

Step 3: Construction of the correlation matrix

A correlation matrix is calculated based on the normalized values.

$$\rho_{jk} = \frac{\sum_{i=1}^m (r_{ij} - \bar{r}_j)(r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^m (r_{ij} - \bar{r}_j)^2 \sum_{i=1}^m (r_{ik} - \bar{r}_k)^2}} \quad j, k = 1, 2, \dots, n \quad (4)$$

Step 4: Calculation of the information measure (C_j)

The standard deviation and correlation values are used to determine the amount of information each criterion

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^m (r_{ij} - \bar{r}_j)^2}{m - 1}} \quad (5)$$

$$C_j = \sigma_j \sum_{k=1}^n (1 - \rho_{jk}) \quad j = 1, 2, \dots, n \quad (6)$$

Step 5: Determination of criteria weights

Objective weights are calculated based on the information content of each criterion.

$$W_j = \frac{C_j}{\sum_{k=1}^n C_k} \quad j, k = 1, 2, \dots, n \quad (7)$$

The CRITIC method ensures that criteria with higher variability and lower correlation with others receive higher importance.

3.2.2. Application of the ARAS Method

The ARAS (Additive Ratio Assessment) method, developed by Zavadskas and Turskis [22] and further extended by Turskis and Zavadskas [23], evaluates alternatives according to their relative utility levels with respect to an ideal alternative.

The steps of the ARAS method are as follows:

Step 1: Construction of the decision matrix including the ideal alternative

In the ARAS method, the decision matrix is arranged as follows by including the ideal alternative (A_0). The decision matrix including the ideal alternative is presented in Equation (8).

$$X = \begin{bmatrix} x_{01} & \dots & x_{0n} \\ x_{11} & \dots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{bmatrix} \quad i = 0, 1, 2, \dots, m \quad j = 1, 2, \dots, n \quad (8)$$

$$x_{0j} = \max x_{ij} \text{ (Benefit-oriented)}$$

$$x_{0j} = \min x_{ij} \text{ (Cost-oriented)}$$

Step 2: Normalization of the decision matrix

The matrix is normalized for both benefit and cost criteria.

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

$$\bar{x}_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_{i=0}^m \frac{1}{x_{ij}}} \text{ (Cost-oriented)} \quad (10)$$

Step 3: Weighted normalized decision matrix

Each normalized value is multiplied by its corresponding weight.

$$\sum_{j=1}^n w_j = 1 \quad (11)$$

$$\hat{x}_{ij} = \bar{x}_{ij} w_j \quad (12)$$

Step 4: Calculation of the optimality function

The total performance score for each alternative is computed.

$$S_i = \sum_{j=1}^n \hat{x}_{ij} \quad (13)$$

Step 5: Calculation of the utility degree

The relative utility of each alternative is calculated based on the optimal solution.

$$K_i = \frac{S_i}{S_0} \quad (14)$$

$$0 \leq K_i \leq 1$$

Step 6: Ranking of alternatives

Countries are ranked from highest to lowest utility value.

The CRITIC-ARAS framework was preferred because it combines objective weighting based on data variability and inter-criterion conflict with utility-based ranking relative to an ideal solution, providing greater transparency and reducing subjective bias compared with alternative MCDM techniques such as TOPSIS or VIKOR.

4. Results

4.1. CRITIC Weighting Results

In the first stage of the analysis, a decision matrix was constructed using the eight sustainability-oriented green transition indicators collected for 31 OECD countries using

2023 data. Table 2 presents the original decision matrix, which serves as the basis for the subsequent CRITIC weighting and ARAS ranking procedures.

As shown in Table 2, considerable variation exists across OECD countries with respect to carbon efficiency, renewable energy utilization, environmental innovation, and fossil fuel dependency indicators. These differences justify the application of an objective weighting approach to determine the relative informational contribution of each criterion. Accordingly, CRITIC weights were calculated based on the variability and interrelationships among the indicators.

In the study, the criteria were objectively weighted using the CRITIC method based on the variability and interrelationships of the indicators (see Table 3). The resulting weight ranking is as follows: $C7 > C4 > C5 > C1 > C6 > C2 > C8 > C3$. The findings indicate that the indicators contribute differently to the evaluation of sustainability-oriented green transition performance among OECD countries.

Among all criteria, CO₂ emissions from air transport per capita (C7) received the highest weight (0.1606). This finding suggests that transport-related carbon emissions constitute one of the most distinctive dimensions of sustainability-oriented transition capacity among OECD countries. From a methodological perspective, the high weight assigned to this criterion indicates that this variable exhibits both substantial variability across countries and relatively low correlation with the remaining indicators. Therefore, air transport-related emissions provide strong discriminatory information within the sustainability-oriented transition framework. Substantively, this result also highlights the growing importance of transport decarbonization policies in achieving long-term sustainable development and climate transition objectives.

The second and third highest weights belong to Renewable electricity generation (% of electricity generation) (C4) and Environment-related government R&D budget (% of government allocations for R&D) (C5), with weights of 0.1389 and 0.1346, respectively. These findings indicate that renewable electricity transition and environmental innovation capacity represent critical structural components of sustainability-oriented transition performance. In particular, the relatively high importance of renewable electricity generation demonstrates that clean energy transformation plays a central role in differentiating countries' sustainability capacities. Similarly, the strong weight associated with environmental R&D expenditures emphasizes the importance of innovation-oriented sustainability strategies and public support mechanisms for environmental technological transformation.

Production-based CO₂ productivity (C1) and environment-related tax revenue (C6) also received relatively high weights, indicating the importance of carbon-efficient production structures and environmental fiscal governance within sustainability-oriented transition processes. These findings suggest that sustainability performance is shaped not only by energy transition policies but also by broader fiscal and production-related governance mechanisms.

By contrast, Renewable energy supply (% of energy supply) (C3) received the lowest weight (0.1044). The relatively lower importance of this criterion suggests that renewable energy supply exhibits a comparatively more homogeneous distribution among OECD countries and shares stronger correlations with other sustainability indicators. Consequently, although renewable energy supply remains an important sustainability dimension, its discriminatory contribution within the CRITIC weighting structure appears relatively limited compared with transport emissions, renewable electricity generation, and environmental innovation indicators.

Table 2. Decision Matrix for OECD Countries.

Country	Criteria							
	Production-Based CO ₂ Productivity, GDP per Unit of Energy-Related CO ₂ Emissions	Energy Productivity, GDP per Unit of TES	Renewable Energy Supply (% Energy Supply)	Renewable Electricity Generation (% Electricity Generation)	Environment-Related Government R&D Budget (% Government Allocations for R&D)	Environment Related Tax Revenue (% GDP)	CO ₂ Emissions from Air Transport per Capita	Total Fossil Fuel Support (% of Tax Revenue)
Austria	10.64	18,592.96	35.45	84.50	1.04	2.03	440.08	3.80
Belgium	9.55	15,395.94	10.91	33.33	0.65	1.91	225.98	1.91
Chile	7.62	13,800.83	34.19	63.58	5.73	1.35	169.62	0.22
Czechia	6.46	13,507.14	12.53	14.68	2.71	5.02	67.53	3.11
Denmark	16.74	27,817.59	44.80	86.60	1.35	2.33	271.99	0.58
Estonia	8.55	13,187.70	33.05	48.83	1.52	2.41	185.30	0.70
Finland	10.22	9179.81	38.05	51.88	8.10	2.26	486.89	0.96
France	14.08	17,247.13	13.65	26.93	1.73	2.11	256.81	2.85
Germany	9.32	20,997.00	19.33	53.34	2.88	1.62	285.89	4.89
Greece	7.85	18,937.44	18.97	49.08	1.66	3.01	170.03	2.46
Hungary	10.07	15,725.80	13.46	26.37	1.96	1.82	388.68	0.25
Iceland	15.85	4066.62	89.14	99.98	0.43	1.81	4654.02	0.10
Ireland	19.75	45,456.89	14.49	45.26	2.46	0.90	3042.01	3.48
Israel	7.97	18,570.49	5.68	11.41	0.70	1.96	231.77	1.09
Italy	10.74	22,514.11	19.43	44.30	2.49	2.53	58.89	3.65
Japan	6.05	14,943.71	7.92	22.82	2.68	1.17	173.94	5.09
Latvia	11.39	16,242.89	46.76	77.70	8.60	2.41	632.59	2.65
Lithuania	11.70	18,288.76	26.62	81.57	0.53	1.63	46.38	2.36
Luxembourg	12.82	26,909.51	12.95	89.80	1.78	1.30	5378.33	2.03
Mexico	6.41	14,666.00	8.86	18.58	1.09	0.84	82.80	5.94

Table 2. Cont.

Country	Criteria							
	Production-Based CO ₂ Productivity, GDP per Unit of Energy-Related CO ₂ Emissions	Energy Productivity, GDP per Unit of TES	Renewable Energy Supply (% Energy Supply)	Renewable Electricity Generation (% Electricity Generation)	Environment-Related Government R&D Budget (% Government Allocations for R&D)	Environment Related Tax Revenue (% GDP)	CO ₂ Emissions from Air Transport per Capita	Total Fossil Fuel Support (% of Tax Revenue)
Netherlands	10.88	19,947.3	13.72	46.80	1.51	2.40	566.60	9.45
Norway	11.27	14,329.57	55.25	98.47	2.70	1.39	439.99	0.11
Poland	6.01	16,036.85	13.89	27.62	0.51	2.13	110.47	2.86
Portugal	12.86	21,965.66	31.88	74.33	4.28	2.26	451.32	3.86
Slovak Republic	7.56	12,508.91	11.71	22.70	3.01	1.98	15.90	14.20
Slovenia	8.92	16,436.06	19.28	40.49	3.62	2.98	5.71	3.77
Spain	10.89	19,676.88	19.03	51.39	3.17	1.50	271.42	1.84
Sweden	20.37	14,176.73	48.05	69.41	2.48	1.56	245.57	0.70
Switzerland	22.59	31,085.28	26.06	63.16	0.33	1.26	578.03	1.12
Türkiye	7.57	18,817.84	17.78	42.28	0.18	2.60	279.04	0.79
United States	12.79	25,366.49	14.87	46.59	2.47	1.99	445.98	2.88

Table 3. CRITIC-Based Criteria Weights.

C1	C2	C3	C4	C5	C6	C7	C8
0.1291	0.1093	0.1044	0.1389	0.1346	0.1168	0.1606	0.1058

Overall, the CRITIC weighting results indicate that sustainability-oriented green transition performance is primarily shaped by indicators associated with transport decarbonization, renewable electricity transition, environmental innovation, and carbon-efficient production structures. These findings reinforce the argument that sustainability-oriented transition capacity represents a multidimensional governance phenomenon involving interconnected environmental, technological, fiscal, and energy-related policy dimensions.

The CRITIC weights reported in Table 3 were subsequently incorporated into the ARAS methodology to evaluate the relative sustainability-oriented green transition performance of OECD countries. The resulting country rankings and performance scores are presented and discussed in the following subsection.

4.2. ARAS Ranking Results

The weights obtained through the CRITIC method were used as inputs in the ARAS method and applied in the weighting of the normalized matrices. In the study, country rankings were derived using the ARAS method. The results obtained through the ARAS method are presented in Table 4.

Table 4. ARAS Results for OECD Countries.

Country	ARAS		
	<i>Si</i>	<i>Ki</i>	Rank
Optimal Value	0.1328		
Austria	0.0264	0.1986	17
Belgium	0.0178	0.1346	27
Chile	0.0392	0.2955	5
Czechia	0.0271	0.2040	15
Denmark	0.0363	0.2734	7
Estonia	0.0260	0.1958	19
Finland	0.0367	0.2763	6
France	0.0215	0.1624	25
Germany	0.0243	0.1829	23
Greece	0.0244	0.1839	22
Hungary	0.0265	0.1999	16
Iceland	0.0516	0.3886	2
Ireland	0.0286	0.2157	13
Israel	0.0162	0.1224	30
Italy	0.0293	0.2209	12
Japan	0.0172	0.1295	29
Latvia	0.0416	0.3130	4
Lithuania	0.0294	0.2218	11

Table 4. Cont.

Country	ARAS		
	<i>Si</i>	<i>Ki</i>	Rank
Luxembourg	0.0260	0.1961	18
Mexico	0.0153	0.1152	31
Netherlands	0.0216	0.1630	24
Norway	0.0492	0.3708	3
Poland	0.0177	0.1334	28
Portugal	0.0327	0.2467	10
Slovak Republic	0.0360	0.2711	8
Slovenia	0.0753	0.5668	1
Spain	0.0254	0.1917	20
Sweden	0.0341	0.2572	9
Switzerland	0.0285	0.2147	14
Türkiye	0.0211	0.1594	26
United States	0.0251	0.1891	21

As presented in Table 4, the ARAS method, using the criterion weights obtained from the CRITIC approach, generated relative efficiency values (*Si*), utility degrees (*Ki*), and comparative sustainability-oriented green transition rankings among OECD countries. The optimal solution value was calculated as 0.1328, and each country's performance was evaluated relative to this ideal sustainability-oriented transition profile.

The findings reveal substantial differences among OECD countries in terms of sustainability-oriented green transition capacity. Rather than reflecting only environmental outcomes, the results indicate broader differences in countries' energy transition structures, environmental governance quality, innovation capacity, fiscal sustainability instruments, and decarbonization performance.

Based on the ARAS results, OECD countries can be broadly classified into three performance groups: high-performing countries, medium-performing countries, and relatively low-performing countries.

The first group consists of high-performing countries demonstrating strong sustainability-oriented transition capacity. Slovenia ranked first with an *Si* value of 0.0753 and a *Ki* value of 0.5668, indicating the highest level of sustainability-oriented green transition performance among the evaluated OECD countries. Slovenia's leading position is primarily associated with its exceptionally low CO₂ emissions from air transport per capita, which constituted the most influential criterion within the CRITIC weighting structure. In addition, Slovenia demonstrates relatively balanced performance across renewable energy transition, environmental governance, and carbon efficiency-related indicators. This result suggests that Slovenia's sustainability-oriented transition success reflects not only environmental outcomes but also a broader policy coordination capacity. This finding is consistent with previous studies showing that lower transport-related emissions and stronger renewable energy integration contribute significantly to countries' green transition performance.

Iceland ranked second (*Ki* = 0.3886), followed by Norway (*Ki* = 0.3708). Although these countries exhibit certain weaknesses in some indicators, they achieve exceptionally strong performance in renewable energy transition and renewable electricity generation. Iceland's sustainability profile is particularly characterized by its near-total reliance on

renewable electricity generation and strong low-carbon energy structure. Similarly, Norway demonstrates substantial strengths in renewable energy deployment, electricity transition, and fossil fuel dependency reduction policies. These findings indicate that leading countries may achieve high sustainability-oriented transition performance through different but complementary policy pathways.

Other countries within the high-performing group include Latvia, Chile, Finland, Denmark, the Slovak Republic, Sweden, and Portugal. A common characteristic of these countries is their relatively strong renewable energy capacity, environmental policy effectiveness, and comparatively favorable carbon efficiency structures. However, their sustainability profiles differ depending on the relative strengths of specific sustainability dimensions. For example, Nordic countries generally perform strongly in renewable energy transition and environmental governance, whereas some Central and Eastern European countries benefit from lower transport-related emissions structures and improving energy transition capacities.

The second group consists of medium-performing countries such as Italy, Lithuania, Ireland, Switzerland, Czechia, Austria, Spain, and Luxembourg. These countries generally demonstrate relatively balanced sustainability structures but experience limitations in highly weighted indicators such as renewable electricity generation, transport-related emissions, environmental innovation intensity, or carbon efficiency. Their results suggest that partial sustainability progress alone is insufficient to achieve top-tier transition performance. Instead, countries require more integrated policy coordination across energy transition, environmental governance, and innovation systems in order to improve their sustainability-oriented transition capacity.

The third group includes relatively low-performing countries such as Mexico, Israel, Japan, Poland, Belgium, and Türkiye. These countries generally demonstrate structural weaknesses in one or more critical sustainability dimensions, particularly renewable energy transition, carbon efficiency, environmental innovation, transport-related emissions, or fossil fuel dependency reduction.

Türkiye ranked in the lower-middle segment of the distribution with a Ki value of 0.1594. The findings suggest that Türkiye demonstrates moderate performance in certain sustainability dimensions, particularly renewable electricity generation and environmental taxation, but experiences structural limitations in highly weighted indicators associated with transport-related emissions, environmental innovation capacity, and carbon efficiency. The relatively stable ranking position of Türkiye across alternative scenarios further indicates that its sustainability-oriented transition performance reflects structural policy characteristics rather than temporary weighting effects. This finding implies that improving Türkiye's sustainability transition capacity may require stronger environmental innovation support mechanisms, deeper renewable energy integration, and more comprehensive decarbonization strategies.

At the lower end of the ranking distribution, Mexico, Israel, Japan, Poland, and Belgium demonstrate comparatively weak sustainability-oriented transition performance. Their lower rankings are primarily associated with weaker performance in highly weighted criteria, particularly renewable electricity transition, transport-related emissions, and environmental innovation indicators. The persistence of low rankings across alternative weighting scenarios also suggests that these weaknesses are structural rather than methodological. These findings suggest that fragmented policy implementation and slower renewable energy adaptation may constrain the green transition capacity of these countries compared with higher-performing OECD economies.

Overall, the ARAS results demonstrate that sustainability-oriented green transition performance depends on multidimensional governance capacities rather than on a single

environmental or economic factor. Countries achieving high performance generally combine renewable energy transition, carbon-efficient production structures, environmental innovation, and effective sustainability governance mechanisms within integrated long-term transition strategies. Consequently, the findings reinforce the argument that sustainability-oriented green transition performance should be interpreted as a broader sustainable development governance capacity rather than merely an environmental ranking outcome.

4.3. Sensitivity Analysis and Robustness Evaluation

In order to test the reliability of the findings obtained in this study and the sensitivity of the model to the weighting structure, a comprehensive sensitivity analysis was conducted. Within this framework, the criterion weights derived from the CRITIC method were adopted as the base scenario (S0), and the effects of changes in the weighting structure on the ARAS ranking results were examined through alternative scenarios constructed under different assumptions.

First, to test the model's dependence on the weighting method, an equal-weighting scenario (S1), in which all criteria were assigned equal importance, was developed. This scenario served as a reference by demonstrating the results obtained when no prioritization was applied instead of an objective weighting approach. Second, to analyze the model's sensitivity to the criterion with the highest weight, a scenario in which the most important criterion was suppressed (S2) was constructed. In this scenario, the weight of the most influential criterion was reduced, and the resulting difference was redistributed among the remaining criteria. This approach enabled the assessment of the extent to which the model depends on a single dominant criterion.

In the third scenario (S3), the relative importance of the criterion with the lowest weight was increased. This approach aims to reveal whether increasing the importance of a normally low-impact criterion leads to meaningful changes in country rankings. In the fourth scenario (S4), a radical modification in the weighting structure was introduced by interchanging the criteria with the highest and lowest weights. This scenario is particularly important for testing the stability of the model under extreme conditions.

In the fifth scenario (S5), a policy-oriented approach was adopted by increasing the weights of criteria representing the energy transition (particularly renewable energy indicators). This allows for the analysis of how prioritizing energy policies affects the ranking results. In the sixth scenario (S6), the weights of criteria representing carbon emissions were increased to establish an emission-focused evaluation framework. This scenario aims to demonstrate how prioritizing emission reduction in the fight against climate change influences the performance rankings of countries. Finally, in the seventh scenario (S7), an additional robustness test was performed to further examine the dependence of the model on the most influential criterion. In this scenario, the highest-weighted criterion, C7 (CO₂ emissions from air transport per capita), was completely excluded from the analysis, and the remaining weights were re-normalized before reapplying the ARAS method. This procedure allows for a more rigorous assessment of whether the ranking results are excessively driven by a single dominant indicator.

The weight distributions corresponding to the scenarios are presented in Table 5.

As shown in Table 5, the alternative scenarios introduce both moderate and substantial changes in the criterion weight structure. While S1 assumes equal importance for all criteria, the remaining scenarios emphasize different policy priorities and robustness assumptions. In particular, S5 and S6 increase the relative importance of energy-transition and emission-related indicators, respectively, whereas S7 completely excludes the most influential criterion (C7). These alternative weighting structures provide a suitable basis for evaluating the stability of the ARAS ranking results under different assumptions.

Table 5. Criterion Weights under Alternative Sensitivity Scenarios.

Criteria	S0	S1	S2	S3	S4	S5	S6	S7
C1	0.1291	0.1250	0.1406	0.1216	0.1291	0.1222	0.1549	0.1538
C2	0.1093	0.1250	0.1208	0.1030	0.1093	0.1035	0.0981	0.1302
C3	0.1044	0.1250	0.1159	0.1566	0.1606	0.1253	0.0937	0.1244
C4	0.1389	0.1250	0.1504	0.1309	0.1389	0.1667	0.1246	0.1655
C5	0.1346	0.1250	0.1461	0.1269	0.1346	0.1274	0.1207	0.1604
C6	0.1168	0.1250	0.1283	0.1101	0.1168	0.1105	0.1047	0.1391
C7	0.1606	0.1250	0.0803	0.1513	0.1044	0.1520	0.1927	x
C8	0.1058	0.1250	0.1173	0.0998	0.1058	0.1001	0.0950	0.1260

Note: S0 represents the CRITIC-based base scenario; S1 represents the equal-weighting scenario; S2 represents the reduced-weight scenario for the highest-weighted criterion; S3 represents the increased-weight scenario for the lowest-weighted criterion; S4 represents the interchange of the highest- and lowest-weighted criteria; S5 represents the energy-transition-oriented scenario; S6 represents the emission-focused scenario; and S7 represents the exclusion of C7 with re-normalization of the remaining criteria weights. “x” indicates that the criterion was excluded from the scenario.

Table 6 presents the changes in country rankings under the base model (S0) and the alternative scenarios (S1–S7).

Table 6. Changes in Country Rankings Across Sensitivity Scenarios.

Country	S0	S1	S2	S3	S4	S5	S6	S7	Max Rank Change
Austria	17	17	16	15	15	15	17	13	4
Belgium	27	27	27	28	27	27	27	27	1
Chile	5	5	5	5	5	5	6	4	1
Czechia	15	16	20	17	19	18	15	21	6
Denmark	7	6	7	6	7	6	7	6	1
Estonia	19	18	18	16	16	17	19	17	3
Finland	6	7	6	7	6	7	8	5	2
France	25	26	25	25	25	26	24	24	1
Germany	23	23	22	23	22	23	23	19	4
Greece	22	22	23	22	23	22	22	22	1
Hungary	16	15	13	18	17	19	16	12	4
Iceland	2	2	1	2	2	2	2	1	1
Ireland	13	12	10	14	12	14	14	9	4
Israel	30	30	30	30	30	30	30	30	0
Italy	12	13	12	12	14	12	12	15	3
Japan	29	29	29	29	29	29	29	28	1
Latvia	4	4	4	4	4	4	4	3	1
Lithuania	11	14	15	11	13	11	11	20	9
Luxembourg	18	19	17	19	18	16	18	11	7
Mexico	31	31	31	31	31	31	31	31	0
Netherlands	24	25	24	24	24	24	25	23	1
Norway	3	3	2	3	3	3	3	2	1

Table 6. *Cont.*

Country	S0	S1	S2	S3	S4	S5	S6	S7	Max Rank Change
Poland	28	28	28	27	28	28	28	29	1
Portugal	10	9	9	10	9	10	10	8	2
Slovak Republic	8	10	14	9	10	9	5	26	18
Slovenia	1	1	3	1	1	1	1	14	13
Spain	20	20	19	20	20	20	20	18	2
Sweden	9	8	8	8	8	8	9	7	2
Switzerland	14	11	11	13	11	13	13	10	4
Türkiye	26	24	26	26	26	25	26	25	2
United States	21	21	21	21	21	21	21	16	5

Table 6 presents the results of the sensitivity analysis, showing the changes in the green performance rankings of OECD countries under different weighting scenarios. Overall, the findings indicate that the ranking structure is largely preserved between the base model (S0) and the alternative scenarios. This suggested that the proposed model remains generally robust under alternative weighting structures. However, more pronounced changes in rankings are observed in scenario S7, in which the most heavily weighted criterion is completely excluded from the analysis.

When scenarios S1–S6 are examined, it can be observed that ranking changes are generally limited across the majority of countries. In particular, Denmark, France, Greece, the Netherlands, Poland, Sweden, Chile, and Norway exhibit maximum rank variations of only 1–2 positions. Similarly, Israel and Mexico maintain completely stable rankings across all scenarios, showing no changes at all. This finding indicates that the performance of these countries is not substantially affected by variations in the weighting structure, and that the base model results remain relatively stable under alternative weighting scenarios.

The stability of countries at the top of the ranking is also noteworthy. In particular, Iceland, Norway, and Latvia consistently remain within the top four positions across all scenarios. This result suggests that these countries demonstrate a strong and consistent sustainability performance not only in specific indicators but across the overall environmental evaluation framework. A similar level of stability is also observed among countries positioned at the lower end of the ranking.

With the inclusion of scenario S7, the sensitivity of the model to the most heavily weighted criterion, C7 (CO₂ emissions from air transport per capita), becomes more evident. In this scenario, C7 was completely removed from the model and the remaining weights were re-normalized. The results show that some countries experience substantial changes in their rankings. In particular, the Slovak Republic drops from 8th place in the base model to 26th place in S7, corresponding to an 18-position change. Similarly, Slovenia falls from 1st to 14th place, corresponding to a 13-position change, while Lithuania declines from 11th to 20th place. These findings suggest that the relatively strong performance of these countries is strongly associated with their performance on the C7 indicator. In other words, air transport-related emissions play a decisive role in their comparative advantage.

On the other hand, some countries benefit from the exclusion of the C7 criterion. Countries such as Austria, Ireland, Luxembourg, and the United States move to higher ranking positions in scenario S7. This suggests that these countries exhibit more balanced performance across other environmental indicators, while being relatively disadvantaged with respect to C7.

Overall, the results indicate that the high stability observed in scenarios S1–S6 confirms the reliability of the model under alternative weighting structures. However, scenario S7 clearly demonstrates the structural influence of the C7 criterion on the ranking results. This finding supports the conclusion that air transport-related emissions constitute a critical and differentiating indicator in the assessment of OECD countries' green performance. Accordingly, the sensitivity analysis leads to two main conclusions: (i) the proposed CRITIC-ARAS model remains generally robust across alternative weighting structures, although sensitive to the exclusion of highly influential criteria; and (ii) transport-related carbon emissions are among the key determinants of performance differentiation across countries. These results highlight the strategic importance of sustainable transport policies and low-carbon aviation strategies in green transition processes.

Table 7 presents the Spearman and Kendall Tau correlation coefficients between the base model and the alternative scenarios.

Table 7. Spearman and Kendall Tau Correlations Between the Base Model and Alternative Scenarios.

Evaluation	Spearman ρ	Kendall Tau
S0–S1	0.992	0.944
S0–S2	0.976	0.914
S0–S3	0.994	0.961
S0–S4	0.989	0.935
S0–S5	0.992	0.957
S0–S6	0.996	0.974
S0–S7	0.839	0.746

Table 7 presents the Spearman rank correlation and Kendall Tau coefficients between the base model (S0) and the alternative scenarios. The results indicate that country rankings are largely preserved across different weighting scenarios, demonstrating that the proposed model exhibits a high level of robustness. The consistently high values of both Spearman and Kendall Tau coefficients confirm a strong agreement between the rankings obtained under alternative scenarios and those of the base model.

When scenarios S1–S6 are examined, Spearman correlation coefficients range between 0.976 and 0.996, while Kendall Tau coefficients vary between 0.914 and 0.974. The consistently high values of both measures indicate that changes in the weighting structure have only a limited effect on country rankings. This finding confirms that the integrated CRITIC-ARAS model produces stable and consistent results under different weighting assumptions, with the overall ranking structure largely preserved. The highest correlation values are observed in the S0–S6 comparison (Spearman $\rho = 0.996$; Kendall Tau = 0.974). This result suggests that even under an emissions-oriented weighting scenario, the ranking structure remains almost unchanged. Similarly, very high correlation values are also obtained in the S0–S3, S0–S1, and S0–S5 comparisons, indicating that the model maintains strong stability even under alternative policy priorities. In contrast, the lowest correlation values are observed in scenario S7, in which the most influential criterion, C7, is completely excluded from the model (Spearman $\rho = 0.839$; Kendall Tau = 0.746). The decline in correlation coefficients indicates that CO₂ emissions from air transport have a significant structural impact on country rankings. Nevertheless, the coefficients remain positive and relatively high, suggesting that the ranking structure is not completely disrupted and that the model is not solely dependent on a single criterion.

Overall, the correlation analysis strongly supports the findings of the sensitivity analysis. In particular, the high correlation values observed in scenarios S1–S6 confirm that

the model produces reliable and stable results under alternative weighting structures. The moderate decline observed in S7 highlights the distinctive importance of the C7 criterion, without undermining the overall robustness of the model. These findings demonstrate that the proposed CRITIC-ARAS framework provides a robust and reliable tool for evaluating sustainability-oriented green transition performance across OECD countries.

5. Discussion and Policy Implications

The findings demonstrate that sustainability-oriented green transition performance cannot be explained solely through environmental regulations or green finance mechanisms. Instead, transition performance emerges as a multidimensional governance outcome shaped by renewable energy transition, environmental fiscal policies, innovation capacity, transport decarbonization, and fossil fuel dependency reduction. Accordingly, differences among OECD countries reflect broader institutional and policy capacities rather than only economic development levels.

5.1. High-Performing Countries

The high-performing group includes Slovenia, Iceland, Norway, Latvia, Finland, and Denmark. These countries generally demonstrate strong renewable electricity generation capacities, lower transport-related emissions, effective environmental governance structures, and stronger environmental innovation systems.

Although these countries share similar ranking positions, their transition profiles differ. Slovenia benefits particularly from low air transport-related emissions, while Iceland and Norway achieve strong performance through highly developed renewable energy and clean electricity systems. Finland and Denmark also stand out due to strong institutional coordination and innovation-oriented sustainability policies. This pattern is consistent with recent sustainability assessment studies showing that countries with stronger renewable integration and coordinated environmental governance tend to perform better in multidimensional sustainability evaluations [6,8].

For this group, future policy priorities should focus on accelerating decarbonization in transport and industry, expanding environmental R&D, strengthening smart energy systems, and supporting circular economy transformation.

5.2. Medium-Performing Countries

The medium-performing group consists of Austria, Ireland, Italy, Czechia, Lithuania, Switzerland, Spain, and Luxembourg. These countries generally display balanced sustainability structures but remain limited with respect to highly weighted criteria such as renewable electricity generation, environmental innovation, and transport-related emissions.

The results suggest that these countries require stronger coordination between renewable energy policies, environmental taxation, and green innovation systems. Expanding renewable electricity capacity and improving carbon efficiency in transportation systems may significantly enhance their sustainability-oriented transition performance. This finding supports previous studies emphasizing that partial progress in selected sustainability dimensions is often insufficient without broader policy coherence and integrated transition strategies [5].

5.3. Low-Performing Countries

The low-performing group includes Mexico, Israel, Japan, Poland, Belgium, and Türkiye. These countries generally demonstrate structural weaknesses in renewable energy transition, environmental innovation, carbon efficiency, and fossil fuel dependency reduction.

Türkiye occupies a lower-middle position and demonstrates moderate performance in some indicators but relatively weaker performance in transport-related emissions, environ-

mental innovation, and carbon efficiency-related criteria. This finding suggests that Türkiye requires stronger renewable energy integration, greater environmental R&D support, and more comprehensive decarbonization policies.

For this group, reducing fossil fuel subsidies, increasing renewable energy investments, strengthening environmental investment mechanisms, and improving low-carbon transportation infrastructure emerge as key policy priorities.

5.4. Policy Implications

Overall, the findings indicate that sustainability-oriented green transition should be interpreted as a broader development and governance challenge rather than merely an environmental issue. Countries with stronger renewable energy systems, environmental innovation capacity, environmental taxation structures, and lower fossil fuel dependency generally achieve better sustainability-oriented transition performance. This finding supports governance-oriented sustainability perspectives suggesting that successful green transitions depend on institutional coordination across energy, innovation, environmental, and fiscal policy domains rather than on individual policy instruments alone [4].

The results also highlight the importance of the following for improving long-term sustainability transition capacity across OECD countries:

- renewable energy expansion;
- environmental taxation;
- environmental R&D support;
- transport decarbonization;
- and fossil fuel subsidy reform

These findings are consistent with prior OECD-based evidence showing that environmental taxation and green innovation significantly support renewable energy adoption and strengthen long-term sustainability transitions [24].

An important finding of the study is the general robustness observed across alternative weighting scenarios. The sensitivity analysis demonstrated that the overall ranking structure remained largely stable under moderate weighting changes, although notable rank shifts emerged when the most influential criterion was excluded, and the Spearman and Kendall Tau coefficients confirmed strong agreement between the base model and alternative scenarios. These findings suggest that the identified performance differences among OECD countries are not driven by a specific weighting configuration but instead reflect underlying structural differences in sustainability-oriented green transition capacity. This result is also consistent with composite indicator studies emphasizing that stable ranking structures under alternative weighting schemes improve the interpretability and policy relevance of country-level benchmarking results [20].

6. Conclusions

This study proposed an integrated CRITIC-ARAS multi-criteria decision-making framework to evaluate the sustainability-oriented green transition performance of OECD countries using 2023 data and eight sustainability-related indicators. The findings revealed substantial cross-country differences in sustainability-oriented transition capacities. In particular, transport-related emissions, renewable electricity generation, environmental R&D expenditures, and carbon efficiency emerged as the most influential determinants of sustainability-oriented transition performance.

The results further demonstrated that sustainability-oriented green transition performance cannot be explained through a single environmental or economic dimension. Instead, sustainability performance reflects a multidimensional governance capacity shaped

by renewable energy transition, environmental innovation, fiscal governance, transport decarbonization, and fossil fuel dependency reduction.

From a theoretical perspective, the study contributes to the literature by conceptualizing sustainability-oriented green transition performance as a multidimensional sustainability governance capacity rather than a fragmented environmental or green finance outcome. In this respect, the study expands the analytical perspective beyond conventional green finance and environmental performance approaches toward a broader sustainable development and governance framework.

From a methodological perspective, the integrated use of CRITIC and ARAS methods provides a transparent, objective, and reproducible sustainability assessment model. The CRITIC method enabled objective weighting of indicators based on informational variability and inter-criterion relationships, while the ARAS method allowed proportional evaluation of countries relative to an ideal sustainability-oriented transition profile. In addition, sensitivity analysis and Spearman rank correlation tests supported the overall robustness and stability of the findings under alternative weighting scenarios. The ranking stability observed across most scenarios further strengthens the reliability of the proposed framework, although some sensitivity remains under the exclusion of highly influential criteria.

From a policy perspective, the findings indicate that improving sustainability-oriented transition performance requires integrated policy approaches simultaneously addressing renewable energy expansion, environmental taxation, environmental innovation, transport decarbonization, and fossil fuel dependency reduction. Countries demonstrating greater renewable electricity generation, lower transport-related emissions, and higher environmental innovation capacity generally achieved better sustainability-oriented transition performance. In practical terms, the country rankings provide policymakers with a comparative benchmarking tool to identify structural strengths and weaknesses in sustainability-oriented transition strategies and to prioritize policy interventions accordingly. This result is consistent with studies emphasizing that transport decarbonization constitutes one of the most challenging and strategically important dimensions of low-carbon transitions due to its close relationship with energy systems, infrastructure, and long-term emissions pathways [3].

Despite these contributions, several limitations should be acknowledged. First, the analysis is limited to cross-sectional data from a single year (2023), preventing the evaluation of long-term sustainability transition dynamics. Second, the sample includes only 31 OECD countries due to the availability of complete and internationally comparable data. Third, the indicator structure is constrained by data availability and the selected sustainability dimensions included in the analysis. In this respect, country rankings are inherently sensitive to the composition of the selected indicators. Although the indicator set was theoretically grounded and based on internationally comparable and available data, alternative indicator structures may lead to different relative performance outcomes. In particular, some relevant sustainability dimensions such as industrial emissions, material productivity, and circular economy indicators could not be included due to cross-country comparability constraints. Moreover, although extensive robustness analyses were conducted, alternative indicator sets and weighting methodologies may produce partially different ranking outcomes. Finally, although the framework incorporates environmental and fiscal sustainability indicators, it does not directly include specific green finance variables such as green bonds, green credit markets, sustainable investment flows, or ESG-based financial indicators.

Future research may extend the proposed framework by employing panel data covering longer time periods, incorporating direct green finance indicators, and comparing

different country groups beyond OECD economies. In addition, future studies may test the robustness of the findings using alternative multi-criteria decision-making approaches such as TOPSIS, VIKOR, PROMETHEE, fuzzy-based decision models, and alternative weighting techniques.

Overall, the study highlights that sustainability-oriented green transition performance represents a multidimensional development and governance challenge requiring coordinated environmental, energy, fiscal, and innovation policies. Accordingly, the proposed framework contributes both to sustainability assessment literature and to broader discussions on sustainable development policy and environmental governance.

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