International Scientific Spectrum

Journal homepage: www.iscis-journal.org
ISSN: 3104-3305

Promoting Global Climate Change Governance: A Neutrosophic Multi-Criteria Decision Analytics for Policy Evaluation

Galip Cihan Yalçın[1], Karahan Kara[2,3,1], Elif Gürdal Limon[4], Metin Aksoy[4], Ömer Uğur[5], Vladimir Simic[6,7,8,*], Onur Limon[9], Ahmet Görgen[10], Dragan Pamucar[11,12,13]

1 Department of Business, Faculty of Economics and Administrative Sciences, OSTIM Technical University, 06374 Ankara, Türkiye
2 Faculty of Economics and Administrative Sciences, İzmir Katip Çelebi University, 35620 İzmir, Türkiye
3 Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, SIMATS, Chennai, India
4 Department of International Relations, Gumushane University, Gümüşhane, Türkiye
5 Department Of Political Science and Public Administration, Gumushane University, Gümüşhane, Türkiye
6 University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, 11010 Belgrade, Serbia
7 Department of Computer Science and Engineering, College of Informatics, Korea University, Seoul 02841, Republic of Korea
8 Faculty of Engineering and Technology, Sunway University, 47500 Selangor Darul Ehsan, Malaysia
9 Gumushane University Rectorate, Gumushane University, Gümüşhane, Türkiye
10 Faculty of Economics and Administrative Sciences, İzmir Democracy University, 35140 İzmir, Türkiye
11 Department of Operations Research and Statistics, Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia
12 UNEC Applied Artificial Intelligence Research Center, Azerbaijan State University of Economics (UNEC), Baku, Azerbaijan
13 Yuan Ze University, College of Engineering, Department of Industrial Engineering and Management, Taoyuan City 320315, Taiwan

ARTICLE INFO

Article history:
Received 4 May 2026
Received in revised form 9 August 2026
Accepted 29 August 2026
Available online 31 August 2026

Keywords:
Climate Change Governance; Policy Selection; Type-2 Neutrosophic Numbers; Skewness Impact Through Distributional Evaluation Method; Deviation-Based Pairwise Assessment Ratio Technique

ABSTRACT

The increasing emission of greenhouse gases in modern life has motivated individuals and societies to take action to prevent or slow down climate change. International collaborations have also prioritized climate change by incorporating it into their agendas and developing relevant policies. This research proposes a multi-criteria decision-making approach based on neutrosophic sets, specifically the type-2 neutrosophic number (T2NN)–Schweizer-Sklar–skewness impact through distributional evaluation (SITDE)–deviation-based pairwise assessment ratio technique (DEPART) model, for the climate change policy selection process. Within neutrosophic multi-criteria decision analytics, the most suitable policy is identified based on expert evaluations of the climate change policy selection criteria. The proposed neutrosophic multi-criteria decision analytics is applied by developing eight alternative climate change policies for the European Union (EU). Based on the findings, practical implications and recommendations are provided for EU policymakers.

1. Introduction

The climate crisis transcends the conventional understanding of an environmental issue defined merely by elevated atmospheric carbon concentrations [1]. Instead, it constitutes a profound structural rupture that unveils the inherent social and ecological constraints of development models

* *Corresponding author.*
E-mail address: vsima@sf.bg.ac.rs

https://doi.org/10.66972/iscis21202615

predicted on continuous economic growth [2]. This crisis challenges the foundational assumptions of industrial modernity, calling into question the long-term viability of growth-centric policy frameworks [3]. Moreover, it highlights the transformative approaches that integrate sustainability with social equity [4].

The degradation of natural systems can no longer be considered an isolated environmental anomaly; rather, it has emerged as a systemic crisis that poses a profound challenges to the sustainability of the global order [5]. In response to this escalating challenge, the European Union (EU) has moved beyond formulating a reactive political stance and has strategically positioned climate change as a central pillar of its normative influence [6]. This repositioning has contributed to the transformation of the EU's economic model and the redefinition of its role as a global actor [7]. Nevertheless, it is important to recognize that the EU's founding philosophy was primarily centered on securing intra-continental peace and fostering deeper economic integration. Environmental concerns were not initially part of the Union’s core agenda. Indeed, the institutional framework established by the 1957 Treaty of Rome prioritized economic objectives such as market integration, competition regulation, and the coordination of common agricultural policies [8].

However, since the 1980s, the growing global prominence of environmental issues (particularly the multidimensional impacts of climate change, the unsustainability of resource-intensive growth models, and mounting strategic concerns over energy security) has compelled the EU to adopt a more comprehensive and forward-looking approach to climate policy [9]. This shift reflects both an adaptation to emerging global challenges and a recalibration of the EU’s internal priorities and external identity in ecological transformation.

In its pursuit of prominence as a normative power in the post-Cold War international order, the EU began to reframe environmental and climate policies not merely as issues of internal regulation, but as strategic instruments for extending its global influence and disseminating its core values [10]. Consequently, although climate change was not among the foundational concerns of the Union, it has gradually evolved into a central axis around which the EU’s identity, political orientation, and international role have been redefined.

Within this evolving framework, the EU has adopted ambitious and comprehensive initiatives positioning environmental sustainability not solely as a policy objective, but as a foundational pillar of its broader agenda [11]. This agenda encompasses enhancing economic competitiveness, promoting social justice, and contributing to geopolitical stability. In doing so, the EU seeks to integrate climate action into the heart of its strategic vision, reinforcing its normative leadership in the global governance of sustainability. By 2050, the EU’s strategic vision of achieving a climate-neutral continent offers a comprehensive framework for economic transformation, energy transition, and social inclusion [12,13]. This vision encompasses a broad spectrum of policy domains, including the reduction of carbon emissions, the integration of renewable energy sources, the promotion of circular economy practices, and the restructuring of both agricultural and industrial policies.

The EU's climate policies extend beyond the objective of environmental sustainability. They are embedded within a multi-dimensional strategy aimed at enhancing economic resilience, addressing social inequalities, and strengthening the Union’s normative leadership on the global stage. Thus, climate action is not only a response to environmental imperatives but also a strategic instrument through which the EU seeks to deepen internal cohesion and assert a values-driven leadership role [14].

For the EU to assume and sustain international leadership in climate action, it is essential to implement effective and successful climate change policies. The motivation behind this study lies in the need to generate a diverse set of climate change policy (CCP) alternatives, based on different perspectives, and to identify and recommend the most appropriate policy options for the EU. Accordingly, the primary objective of this research is to develop CCP alternatives tailored for the EU and to prioritize these alternatives based on a comprehensive set of evaluation criteria.

Within this scope, the study aims to address the CCP selection problem using a multi-criteria decision-making (MCDM) approach integrated with neutrosophic logic, thereby proposing and validating a decision support system (DSS). To this end, multi-criteria decision analytics, referred to as the “Schweizer-Sklar based Type-2 Neutrosophic Number” – “Skewness Impact Through Distributional Evaluation” – “Deviation-Based Pairwise Assessment Ratio Technique” model (Schweizer-Sklar-T2NN-SITDE-DEPART), is proposed in this paper. This model enables the ranking of CCP alternatives by incorporating expert opinions and relevant criteria.

The proposed hybrid method allows for the identification of the influence levels of experts with varying degrees of expertise within the decision-making (DM) process. To determine the significance of the criteria, the T2NN–SITDE method [15] is employed. Additionally, to enhance the robustness of T2NN-based operations, the T2NN–Schweizer-Sklar–Weighted Arithmetic Mean (T2NNSSWAM) aggregation operator (AO) [16,17] is used, which is based on Schweizer–Sklar *t*-norm and *t*-conorm functions. For the final ranking of CCP alternatives, DEPART [18] is utilized. Following the introduction of this hybrid methodology, the study proceeds to rank the alternative climate change policies for the EU using the T2NN-Schweizer-Sklar-SITDE-DEPART hybrid approach.

1.1 Study Aims

The main objective of this paper is to present a decision support framework for determining the most appropriate CCP for the EU. In addition, the study aims to achieve the following:

i. To generate alternative CCP proposals for the EU, addressing diverse strategic and thematic dimensions of climate governance.
ii. To identify and define a comprehensive set of CCP selection criteria that reflect the multifaceted goals of EU climate action, including sustainability, equity, innovation, and diplomacy.
iii. To propose and apply a novel multi-criteria decision analytics (T2NN–Schweizer-Sklar–SITDE–DEPART), which integrates neutrosophic set theory into an MCDM framework.
iv. To determine expert participation levels in the DM process using T2NN sets, which allow for precise linguistic evaluation based on expert experience and confidence levels.
v. To prioritize the CCP selection criteria using the T2NN-Schweizer–Sklar-SITDE method, marking the first extension of the SITDE weighting method with T2NN sets and the first integration of the Schweizer–Sklar-based T2NNSSWAM AO into the SITDE approach.
vi. To rank the alternative CCP proposals using the DEPART method, applied here for the first time in conjunction with SITDE-derived criteria weights, offering a robust ranking mechanism based on both positive and negative deviations.
vii. To assess the consistency of the hybrid method by comparing the results with those obtained from fourteen established MCDM methods and verifying the consistency through high correlation levels across methods.
viii. To provide policy implications and strategic recommendations for EU climate policymakers based on the findings, offering insights for more informed, inclusive, and sustainable climate governance.

1.2 Study Contributions

This study provides several theoretical, methodological, and practical contributions to the field of climate policy DM, particularly within the context of the EU. The main contributions are as follows:

i. The study proposes and implements a novel T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytic for selecting the most suitable CCP among alternatives for the EU.
ii. Eight policy alternatives are developed to reflect different dimensions of climate change governance, providing a comprehensive and structured basis for EU policy evaluation.
iii. Eleven CCP selection criteria are identified, reflecting the multi-dimensional aspects of effective climate policy, including sustainability, innovation, regional needs, and justice.
iv. The proposed hybrid method incorporates T2NN, allowing for precise modeling of expert judgment, especially under uncertainty and linguistic ambiguity, which is common in policy DM.
v. The SITDE method is, for the first time, extended using T2NN sets, enhancing its capability to handle vagueness in expert evaluations.
vi. The study is the first to integrate the Schweizer–Sklar-based T2NNSSWAM AO with the SITDE method, enabling advanced aggregation of expert opinions through complex *t*-norm and *t*-conorm structures.
vii. Based on the findings, the study provides actionable insights and policy implications for EU decision-makers involved in the design and implementation of climate change strategies.

This paper is structured into seven sections. Section 2 shows literature review on CCP of the EU. Section 3 introduces the T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics. In Section 4, an application is conducted focusing on the ranking of climate change policies for the EU. Section 5 provides the results, Section 6 shows the implications, and Section 7 presents the study with the main findings and concluding remarks.

2. Climate Change Policy of the European Union: A Literature Review

Since the late 20th century, the accelerating impacts of climate change have evolved into far-reaching crises in human history [19]. No longer confined to the realm of environmental concern, climate change has increasingly occupied a central position in global political discourse, influencing a wide array of economic, social, and security agendas [20]. This transformation has redefined climate change from a narrowly framed ecological issue into a multidimensional phenomenon that necessitates systemic policy responses across multiple sectors [21].

In confronting this multifaceted crisis, the EU has positioned as a leader in climate governance, aligning its institutional and policy frameworks with the evolving demands of climate action [22]. The EU's approach goes beyond addressing the environmental consequences of global warming and natural disasters; it encompasses a holistic strategy that also covers the implications of climate change for economic growth, social equity, and international security [23]. This comprehensive strategy is embodied in the European Green Deal (EGD), which serves as the cornerstone of the EU's climate agenda. The EGD integrates a wide array of targeted policies and instruments, including investments in green technologies [24], the implementation of carbon pricing mechanisms [25], the establishment of a just transition framework [26], the pursuit of energy independence and security [27], and alignment with Sustainable Development Goals [28].

Through this transformative agenda, the EU seeks not only to decarbonize its internal systems but also to recalibrate its external engagement, positioning itself as a normative model for climate action at the global level. By integrating climate objectives into both domestic and foreign policy, the EU aspires to lead by example, demonstrating how climate resilience, economic competitiveness, and social cohesion can be pursued simultaneously within a sustainable development framework.

Since the 1990s, the EU has assumed as a leader in climate governance by actively participating in major global agreements, such as the Kyoto Protocol [29]. Through concrete and measurable commitments to reducing gas emissions, the EU has consistently reinforced its position as a central actor in the global climate regime [30]. This leadership was further consolidated with the adoption of the 2015 Paris Agreement [31], under which the EU intensified its efforts by implementing more ambitious internal policies while fostering enhanced international cooperation in addressing climate change. Within this framework, the EGD has emerged as a pivotal initiative, articulating the EU's objective of achieving carbon neutrality by 2050 [32]. The EGD offers a comprehensive and forward-looking roadmap that redefines climate change not solely as an environmental concern, but as an issue deeply interconnected with economic transformation, social equity, and geopolitical stability [28]. By embedding climate objectives across a broad array of policy domains, the EGD signals a paradigm shift toward an integrated model of sustainable development [33].

Complementing this strategic vision, the 2021 policy document "Creating a Climate Resilient Europe: The EU's New Strategy on Climate Change Adaptation" represents a critical milestone in deepening the EU's climate policy framework. This document outlines an integrated adaptation strategy that enhances the Union's capacity to respond to climate risks while promoting sustainable development. It presents a multi-dimensional roadmap that aligns environmental resilience with economic durability and societal well-being. Importantly, the strategy underscores the necessity of viewing climate change not only as a global threat but also as a catalyst for systemic transformation. It promotes a science-based, cooperative approach that integrates long-term sustainability goals with shared responsibilities among Member States. In doing so, the EU positions climate adaptation as a strategic imperative (anchored in resilience, solidarity, and innovation) that reinforces its broader vision for a sustainable and climate-resilient future.

The EU's green transformation strategy illustrates a paradigm shift in which economic policies are not solely instruments for achieving environmental goals but are also reoriented to enhance global competitiveness [34]. This strategy seeks to position the EU as a leader in technological innovation and economic resilience by aligning economic systems with climate imperatives and fostering sustainability-driven advancements. The approach reflects a deliberate integration of ecological and economic objectives, promoting a harmonized model of development [35]. In specifically, the moving to a carbon-neutral economy is conceived not solely as an environmental initiative, but as a transformative process with far-reaching implications for energy systems, consumption behavior, labor markets, and regional development [34]. Accordingly, the EU's climate strategy embodies the potential to establish a strategic development model that not only secures long-term sustainability but also redefines the Union's role in global economic governance.

In this context, the EU's economic transformation strategy prioritizes a shift from fossil fuel–based production models toward an economy grounded in renewable energy. As outlined in the EGD, investments in renewable technologies are not only aimed at lowering carbon emissions but are also positioned as key drivers of sustainable economic growth [36]. The EU seeks to diversify its energy portfolio, enhance energy security, and reduce dependency on imports. This strategic orientation also fosters innovation, with developments such as offshore wind farms and high-efficiency solar panels strengthening the EU's capacity to lead global energy markets and export advanced technologies. The EU's climate policy thus serves as a catalyst for infrastructure modernization, green industry growth, and economic revitalization through significant public and private investment. Moreover, it enhances the EU's ability to act autonomously in shaping its energy and economic policies, while reinforcing resilience against global disruptions [28]. Ultimately, the EU's renewable energy strategy integrates environmental objectives with economic and geopolitical aims, reinforcing Europe's leadership in the global energy transition and positioning it as a normative power in the evolving international order [37].

Another critical aspect of the EU's economic transformation is the integration of circular economy principles, which offer an alternative to the traditional linear model of consumption. By promoting resource efficiency through policies such as advanced recycling technologies, optimized waste management, and extended product life cycles, the EU aims to reduce its dependency on raw material imports while enhancing industrial cost efficiency. This strategic shift supports the EU's broader climate policy objectives by fostering economic resilience and reducing vulnerabilities in global supply chains. Circular economic practices, particularly in key sectors such as electronics, not only contribute to lowering carbon emissions but also provide firms with a competitive edge in international markets [38]. Thus, the EU's climate policy framework should be understood not solely as an environmental initiative, but as a strategic economic policy that enhances sustainability, boosts competitiveness, and positions the role of EU.

Moreover, the transition toward a carbon-neutral economy is also reshaping the social dimensions of the EU's economic structure, particularly in terms of labor markets and regional development dynamics [34]. The expansion of green technologies and renewable energy sectors has created new professional fields (ranging from energy efficiency experts to renewable energy technicians) highlighting the evolving nature of employment in a sustainable economy. To address potential disruptions, initiatives such as the Just Transition Mechanism have been implemented to retrain and reskill workers affected by the decline of fossil fuel industries, facilitating their integration into emerging green sectors. At the regional level, renewable energy investments have played a critical role in revitalizing carbon-intensive areas, thereby reducing spatial inequalities and enhancing local economic resilience. In this context, the EU's green transformation strategy embodies a vision that merges sustainability with economic competitiveness and social equity [39]. Rather than offering a reactive response to immediate challenges, it seeks to proactively shape the future socio-economic order. Consequently, the EU has reframed climate change not merely as a threat but as a transformative force driving technological, economic, and social innovation, thereby reinforcing its global leadership and long-term strategic resilience.

Within the realm of social policy, the EU has positioned climate justice as a central pillar of its green transformation strategy, embedding the transition within a framework that is responsive to societal needs and vulnerabilities. The EU's approach reflects a deliberate effort to ensure that climate action both advances environmental objectives and promotes social equity and cohesion. Key initiatives, such as the Just Transition Fund, aim to support communities and workers in fossil fuel-dependent regions by safeguarding their socio-economic security and integrating them into a more sustainable future. These efforts go beyond financial assistance, encompassing education, training, and employment programs that facilitate workforce adaptation and mitigate the social costs of structural change. Furthermore, the EU has implemented targeted policies to combat energy poverty and promote inclusive access to the benefits of the green economy. By aligning climate policy with goals such as reducing income disparities and improving public health, the EU seeks to transform the green transition into a vehicle for broader social justice and human well-being, ensuring that no group is left behind on the path toward sustainability [40].

The EU’s strategy, which is to combat climate change, has emerged as a critical policy domain that reinforces its leadership aspirations within the global climate regime and strengthens its role as a recognized actor in international affairs [41]. Particularly following the United States' withdrawal from the Kyoto Protocol, the EU's proactive stance in climate diplomacy has drawn significant attention, enhanced its global influence, and consolidated its status as a key player on the international stage. In a global system traditionally dominated by sovereign states, the EU’s supranational nature demonstrates that non-state actors can exert meaningful influence in global governance [42]. The EU’s leadership in climate diplomacy is rooted in its effective utilization of normative and civilian power. Its prominent role in shaping international frameworks (most notably the Paris Agreement) reflects its diplomatic capabilities and capacity for norm-setting, elevating its position as a standard-bearer in climate governance. This leadership has enabled the EU not only to pursue environmental objectives but also to serve as a unifying and guiding force in the international system. Green transformation initiatives and carbon neutrality targets exemplify the EU’s ability to transform the collective ambitions of its member states into a coherent and strategic global vision, embodying the distinctive nature of its non-state identity [43]. Climate diplomacy functions as a means of a tool that enhances the EU's legitimacy, soft power, and influence in global governance. Consequently, the EU’s leadership in the fight against climate change illustrates how its non-state actor identity can serve as a strategic asset, enabling it to shape international norms.

Finally (and perhaps most significantly) the EU’s climate policy has functioned as a strategic catalyst for deepening European integration [44]. Initiatives such as the EGD have underscored the imperative for collective action, fostering unity among Member States through a shared vision for addressing climate change. This policy framework necessitates enhanced cooperation in key areas, including the harmonization of energy policies, the cross-border integration of renewable energy infrastructure, and the coordination of emission reduction targets. Such mechanisms have contributed to reinforcing institutional cohesion by aligning economic and environmental objectives across the EU [36]. For instance, the "Fit for 55" legislative package has brought national energy markets and industrial standards closer together through common regulatory frameworks and financial instruments [45]. This integration not only advances policy coordination but also fosters a stronger sense of European identity and solidarity that transcends national agendas. Furthermore, equity-oriented instruments such as the Just Transition Mechanism have facilitated the participation of less economically developed Member States, mitigated regional disparities, and embedded social solidarity into the Union’s transformation process. Accordingly, the EU’s climate strategy operates not merely as an environmental initiative, but as a strategic lever that enhances political and economic integration. By fostering interdependencies and common goals, climate policy contributes to the construction of a more cohesive and integrated European project.

In conclusion, the EU has adopted a proactive and multidimensional approach to climate change, one that places environmental sustainability at the heart of its broader strategic vision. By interlinking ecological objectives with economic transformation and social equity, EU climate policy seeks secure long-term competitive advantages and global leadership. These efforts have established the EU not only as a principal actor in climate governance but also as an essential stakeholder in shaping the future of international cooperation.

3. Methodology Framework

This study addresses the critical task of formulating climate change policies within the EU and selecting the most effective policy alternative based on a comprehensive set of evaluation criteria. To facilitate this complex DM process, the study proposes the use of the T2NN–Schweizer-Sklar–

SITDE–DEPART model as a robust multi-criteria decision analytics. This hybrid approach integrates multiple advanced computational techniques to handle the inherent uncertainties and complexities associated with expert evaluations in climate policy analysis.

Within the methodology section, the foundational theoretical components are introduced in detail. These include the T2NN sets, which allow for the modeling of linguistic assessments with a high degree of precision by capturing uncertainty and imprecision. The Schweizer–Sklar *t*-norm and *t*-conorm operations are explained as fundamental mathematical tools used for aggregating expert opinions under uncertainty. Additionally, the T2NNSSWAM AO is presented, highlighting its novel application in synthesizing diverse expert judgments into a coherent collective evaluation.

Following the introduction of these core components, the study systematically outlines the proposed hybrid method. Each phase of the method is described comprehensively, from the initial data collection and transformation of linguistic expert evaluations into T2NN sets, through to the weighting and aggregation of criteria using SITDE, and finally to the ranking of policy alternatives by applying DEPART. This multi-stage process is designed to ensure transparency, accuracy, and reliability in the DM framework.

As the T2NN–Schweizer-Sklar–SITDE–DEPART model functions as an DSS system, it incorporates several input components essential to the DM process. These components include experts $\left(\beta=\{\beta_1,\beta_2,\ldots,\beta_p,\ldots,\beta_P\}\;(p=1,2,\ldots,P)\right)$, CCP criteria $\left(\gamma=\{\gamma_1,\gamma_2,\ldots,\gamma_q,\ldots,\gamma_Q\}\;(q=1,2,\ldots,Q)\right)$, and alternative CCP options $(\xi=\{\xi_1,\xi_2,\ldots,\xi_b,\ldots,\xi_B\}\;(b=1,2,\ldots,B))$. The stages and sub-steps of the T2NN-Schweizer-Sklar-SITDE-DEPART hybrid method are outlined as follows:

- ***Stage 1** – Determining the influence levels of experts based on experience levels using the T2NN approach*.

Step 1-1: Table 1 shows the scale to the levels of expertise level. Based on this scale, experts are categorized depending on expertise levels, resulting in the construction of an expertise level matrix. This matrix is then revised using the T2NN approach for achieving the T2NN-based expertise level matrix $\left(\widetilde{\mathfrak{P}}=\left[\widetilde{\mathfrak{P}}_p\right]_P\right)$.

Table 1
The scale corresponds to the levels of expertise [46]

Scale for expertise levels	T2NNs
Very-poor (VP)	⟨ (0.20,0.20,0.10), (0.65,0.80,0.85), (0.45,0.80,0.70) ⟩
Poor (P)	⟨ (0.35,0.35,0.10), (0.50,0.75,0.80), (0.50,0.75,0.65) ⟩
Medium-poor (MP)	⟨ (0.40,0.30,0.35), (0.50,0.45,0.60), (0.45,0.40,0.60) ⟩
Medium (M)	⟨ (0.50,0.45,0.50), (0.40,0.35,0.50), (0.35,0.30,0.45) ⟩
Medium-good (MG)	⟨ (0.60,0.45,0.50), (0.20,0.15,0.25), (0.10,0.25,0.15) ⟩
Good (G)	⟨ (0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20) ⟩
Very-good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩

Step 1-2: T2NN-based expertise level matrix can be converted to numerical-based expertise level matrix $\left(\mathfrak{P}=\left[\mathfrak{P}_p\right]_P\right)$ by fuzzification $\left(\propto\left(\widetilde{\mathfrak{P}}_p\right)\right)$ (Score Function) which is presented in Eq. (1).

$$\mathfrak{P}_p=\propto\left(\widetilde{\mathfrak{P}}_p\right)=\frac{1}{12}\Bigg(8+\left(T_{T_{\widetilde{\mathfrak{P}}_p}}(l)+2\left(T_{I_{\widetilde{\mathfrak{P}}_p}}(l)\right)+T_{F_{\widetilde{\mathfrak{P}}_p}}(l)\right)-\left(I_{T_{\widetilde{\mathfrak{P}}_p}}(l)+2\left(I_{I_{\widetilde{\mathfrak{P}}_p}}(l)\right)+I_{F_{\widetilde{\mathfrak{P}}_p}}(l)\right)-\left(F_{T_{\widetilde{\mathfrak{P}}_p}}(l)+2\left(F_{I_{\widetilde{\mathfrak{P}}_p}}(l)\right)+F_{F_{\widetilde{\mathfrak{P}}_p}}(l)\right)\Bigg);(p=1,\ldots,P)\big|\left(\propto\left(\widetilde{\mathfrak{P}}_p\right)\in[0,1]\right). \tag{1}$$

Step 1-3: To compute the influence levels matrix $\left(\delta = \left[\delta_p\right]_P\right)$ for experts, linear normalization can be done by employing Eq. (2).

$$\delta_p = \frac{\mathfrak{P}_p}{\sum_{p=1}^{P} \mathfrak{P}_p}; (p = 1, \dots, P). \tag{2}$$

- ***Stage 2*** *– Prioritization of climate change policy selection criteria using the T2NN-SITDE method*.

Step 2-1: Each CCP(ξ_b) is assessed by experts $\left(\beta_p\right)$ based on the CCP selection criteria $\left(\gamma_q\right)$ using Table 2. These assessments are then transformed into T2NN form as based-CCP evaluation matrices $\left(\widetilde{\widetilde{\mathfrak{K}}}^{(\beta_p)} = \left[\widetilde{\widetilde{\mathfrak{K}}}_{bq}^{(\beta_p)}\right]_{BQ}\right)$ where $\widetilde{\widetilde{\mathfrak{K}}}_{bq}^{(\beta_p)}$; $(b = 1,2, \dots, B;\ q = 1,2, \dots, Q;\ p = 1,2, \dots, P)$.

Table 2
Scale for assessing the climate change policies [46]

Linguistic variable	T2NNs
Very low (VL)	(0.20, 0.20, 0.10), (0.65, 0.80, 0.85), (0.45, 0.80, 0.70)
Low (L)	(0.35, 0.35, 0.10), (0.50, 0.75, 0.80), (0.50, 0.75, 0.65)
Medium low (ML)	(0.40, 0.30, 0.35), (0.50, 0.45, 0.60), (0.45, 0.40, 0.60)
Medium (M)	(0.50, 0.45, 0.50), (0.40, 0.35, 0.50), (0.35, 0.30, 0.45)
Medium high (MH)	(0.60, 0.45, 0.50), (0.20, 0.15, 0.25), (0.10, 0.25, 0.15)
High (H)	(0.70, 0.75, 0.80), (0.15, 0.20, 0.25), (0.10, 0.15, 0.20)
Very high (VH)	(0.95, 0.90, 0.95), (0.10, 0.10, 0.05), (0.05, 0.05, 0.05)

Step 2-2: To aggregate assessments, the T2NNSSWAM AO (Eq. (3)), which is based on the Schweizer–Sklar operations, is employed. As a result, the T2NN-based aggregated CCP evaluation matrix $\left(\widetilde{\widetilde{\mathfrak{K}}} = \left[\widetilde{\widetilde{\mathfrak{K}}}_{bq}\right]_{BQ}\right)$ is obtained.

$$T2NNSSWAM\left(\widetilde{\widetilde{\mathfrak{K}}}^{(\beta_1)}, \widetilde{\widetilde{\mathfrak{K}}}^{(\beta_2)}, \dots, \widetilde{\widetilde{\mathfrak{K}}}^{(\beta_p)}, \dots, \widetilde{\widetilde{\mathfrak{K}}}^{(\beta_P)}\right) = \bigoplus_{p=1}^{P} \delta_p \widetilde{\widetilde{\mathfrak{K}}}^{(\beta_p)}. \tag{3}$$

The experts' influence levels vector $\delta_p = \left(\delta_1, \delta_2, \dots, \delta_p, \dots, \delta_G\right)$ has interrelation with $\widetilde{\widetilde{\mathfrak{K}}}^{(\beta_p)}(p = 1,2, \dots, P)$. Also, $\delta_p > 0, \sum_{p=1}^{P} \delta_p = 1$, and $\eta < 0$.

Step 2-3: T2NN-based aggregated CCP evaluation matrix can be converted to numerical-based aggregated CCP evaluation matrix $\left(\mathfrak{K} = \left[\mathfrak{K}_{bq}\right]_{BQ}\right)$ by employing the score function $\left(\propto \left(\widetilde{\widetilde{\mathfrak{K}}}_{bq}\right)\right)$ which is presented in Eq. (4).

$$\mathfrak{K}_{bq} = \propto \left(\widetilde{\widetilde{\mathfrak{K}}}_{bq}\right) = \frac{1}{12}\left(8 + \left(T_{T_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l) + 2\left(T_{I_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right) + T_{F_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right) - \left(I_{T_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l) + 2\left(I_{I_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right) + I_{F_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right) - \left(F_{T_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l) + 2\left(F_{I_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right) + F_{F_{\widetilde{\widetilde{\mathfrak{K}}}_{bq}}}(l)\right)\right); \left(\propto \left(\widetilde{\widetilde{\mathfrak{K}}}_{bq}\right) \in [0,1]\right). \tag{4}$$

Step 2-4: The numerical-based CCP evaluation matrix is attained as the initial decision matrix $\left(\mathfrak{K} = \left[\mathfrak{K}_{bq}\right]_{BQ}\right)$ for using in SITDE method. Using Eq. (5), the normalized CCP evaluation matrix $\left(\mathfrak{O} = \left[\mathfrak{O}_{bq}\right]_{BQ}\right)$ is calculated.

$$\mathfrak{D}_{bq} = \begin{cases} \dfrac{\min\limits_{1\leq\cdots<q<\cdots\leq Q}(\mathfrak{K}_{bq})}{\mathfrak{K}_{bq}} \, for\ q \in \gamma^{+} \\ \dfrac{\mathfrak{K}_{bq}}{\max\limits_{1\leq\cdots<q<\cdots\leq Q}(\mathfrak{K}_{bq})} for\ q \in \gamma^{-} \end{cases} ; (b = 1, \ldots, B; q = 1, \ldots, Q). \tag{5}$$

Step 2-5: By performing Eq. (6), the skewness matrix $\left(\mathfrak{L} = \left[\mathfrak{L}_q\right]_Q\right)$ is obtained.

$$\mathfrak{L}_q = \frac{B}{(B-1)(B-2)} \sum_{b=1}^{B} \left(\frac{\mathfrak{D}_{bq} - \bar{\mathfrak{D}}_q}{\sigma_q}\right)^3 ; (q = 1, \ldots, Q), \tag{6}$$

herein σ_q refers to the standard deviation and $\bar{\mathfrak{D}}_q$ shows mean value for each criterion.

Step 2-6: By using Eq. (7), the normalized skewness matrix $\left(\mathfrak{N} = \left[\mathfrak{N}_q\right]_Q\right)$ is obtained.

$$\mathfrak{N}_q = log \left| \left(\left(\mathfrak{L}_q + 1\right) + \left(\left| \min_{1\leq\cdots<q<\cdots\leq Q} \left(\mathfrak{L}_q\right) \right| + 1 \right) \right) \right| ; (q = 1, \ldots, Q). \tag{7}$$

Step 2-7: To obtain the weights of the CCP criteria $\left(\delta = \left[\delta_p\right]_P\right)$, linear normalization can be done by employing Eq. (8).

$$\zeta_q = \frac{\mathfrak{N}_q}{\sum_{q=1}^{Q} \mathfrak{N}_q} ; (q = 1, \ldots, Q), \tag{8}$$

herein $\zeta_q = \left(\zeta_1, \zeta_2, \ldots, \zeta_q, \ldots, \zeta_Q\right)$ for $\zeta_q \in [0,1]$ with the constrain as $\sum_{q=1}^{Q} \zeta_q = 1$.

- ***<u>Stage 3</u>*** *– <u>Prioritization of climate change policies using the DEPART method</u>*.

Step 3-1: The crisp-based aggregated CCP matrix is considered as the initial decision matrix $\left(\mathfrak{K} = \left[\mathfrak{K}_{bq}\right]_{BQ}\right)$ (*Step 2-4*) for DEPART. Using Eq. (9), the normalized CCP evaluation matrix $\left(\mathfrak{M} = \left[\mathfrak{M}_{bq}\right]_{BQ}\right)$ is calculated.

$$\mathfrak{M}_{bq} = \frac{\mathfrak{K}_{bq}}{\sqrt{\sum_{b=1}^{B} \left(\mathfrak{K}_{bq}\right)^2}} ; (b = 1, \ldots, B; q = 1, \ldots, Q). \tag{9}$$

Step 3-2: The best values $\left(\mathfrak{A} = \left[\mathfrak{A}_q\right]_Q\right)$ and the worst values $\left(\mathfrak{B} = \left[\mathfrak{B}_q\right]_Q\right)$ can be obtained by performing Eq. (10) and Eq. (11), respectively.

$$\mathfrak{A}_q = \begin{cases} \max\limits_{1\leq\cdots<b<\cdots\leq B} \left(\mathfrak{M}_{bq}\right) \text{ for } q \in \gamma^{+} \\ \min\limits_{1\leq\cdots<b<\cdots\leq B} \left(\mathfrak{M}_{bq}\right) \text{ for } q \in \gamma^{-} \end{cases} ; (q = 1,2, \ldots, Q), \tag{10}$$

$$\mathfrak{B}_q = \begin{cases} \min\limits_{1\leq\cdots<b<\cdots\leq B} \left(\mathfrak{M}_{bq}\right) \text{ for } q \in \gamma^{+} \\ \max\limits_{1\leq\cdots<b<\cdots\leq B} \left(\mathfrak{M}_{bq}\right) \text{ for } q \in \gamma^{+} \end{cases} ; (q = 1,2, \ldots, Q). \tag{11}$$

Step 3-3: The positive-based deviations matrix $\left(\mathfrak{C} = \left[\mathfrak{C}_{bq}\right]_{BQ}\right)$ and the negative-based deviations matrix $\left(\mathfrak{D} = \left[\mathfrak{D}_{bq}\right]_{BQ}\right)$ are computed by Eq. (12) and Eq. (13), respectively.

$$\mathfrak{C}_{bq} = \left|\mathfrak{M}_{bq} - \mathfrak{A}_q\right|; (b = 1,2,\dots,B; q = 1,2,\dots,Q), \tag{12}$$

$$\mathfrak{D}_{bq} = \left|\mathfrak{M}_{bq} - \mathfrak{B}_q\right|; (b = 1,2,\dots,B; q = 1,2,\dots,Q). \tag{13}$$

Step 3-4: The positive pairwise matrix $(\mathfrak{Z} = [\mathfrak{Z}_{bb'}]_{BB})$ and the negative pairwise matrix $(\mathfrak{Y} = [\mathfrak{Y}_{bb'}]_{BB})$ are computed by employing Eq. (14) and Eq. (15), respectively.

$$\mathfrak{Z}_{bb'} = \sum_{q=1}^{Q}\left(\zeta_q\left(\frac{\mathfrak{C}_{bq}+max(\mathfrak{C}_{bq})}{\mathfrak{C}_{b'q}+max(\mathfrak{C}_{bq})}\right)\right); (b, b' = 1,2,\dots,B)|b \neq b', \tag{14}$$

$$\mathfrak{Y}_{bb'} = \sum_{q=1}^{Q}\left(\zeta_q\left(\frac{\mathfrak{D}_{b'q}+min(\mathfrak{D}_{bq})}{\mathfrak{D}_{bq}+min(\mathfrak{D}_{bq})}\right)\right); (b, b' = 1,2,\dots,B)|b \neq b', \tag{15}$$

herein $max(\mathfrak{C}_{bq})$ indicates the maximum values $\left(\mathfrak{C} = \left[\mathfrak{C}_{bq}\right]_{BQ}\right)$ (for positive deviation), $min(\mathfrak{D}_{bq})$ is the minimum values $\left(\mathfrak{D} = \left[\mathfrak{D}_{bq}\right]_{BQ}\right)$ (for negative deviation). Also, if $b = b'$, then $\mathfrak{Z}_{bb'} = \mathfrak{Y}_{bb'} = 1$. In addition, ζ_q refers the weight values of CCP criteria.

Step 3-5: The aggregated pairwise values $(\mathfrak{X} = [\mathfrak{X}_{bb'}]_{BB})$ is computed by using Eq. (16) $(\theta \in [0,1])$.

$$\mathfrak{X}_{bb'} = \theta\mathfrak{Z}_{bb'} + (1-\theta)\mathfrak{Y}_{bb'}; (b, b' = 1,2,\dots,B). \tag{16}$$

herein, θ parameter refers to the significant level of the aggregated pairwise values.

Step 3-6*:* The sum pairwise deviation ratio matrix $(\mathfrak{T} = [\mathfrak{T}_b]_B)$ is computed by using Eq. (17).

$$\mathfrak{T}_b = \sum_{b=1}^{B}\mathfrak{X}_{bb'}; (b, b' = 1,2,\dots,B). \tag{17}$$

Step 3-7: The ranking matrix $(\mu = [\mu_b]_B)$ of the climate change policies is calculated by using Eq. (18).

$$\mu_b = \frac{1}{B}\sum_{b=1}^{B}\frac{\mathfrak{X}_{bb'}}{\mathfrak{T}_b}; (b, b' = 1,2,\dots,B). \tag{18}$$

The T2NN–Schweizer-Sklar–SITDE–DEPART is shown in Figure 1.

4. Case Study: Ranking of Climate Change Policies for the European Union

4.1 Decision Model for Climate Change Policies Selection

4.1.1 Expert group for assessing climate change policies

An expert panel consisting of ten specialists was established to evaluate the climate change policies designed based on the identified CCP selection criteria. These experts possess extensive research backgrounds and academic expertise in EU affairs and climate policy. The detailed profiles of the expert group, including their affiliations, areas of specialization, and relevant publications, are presented in Table 3.

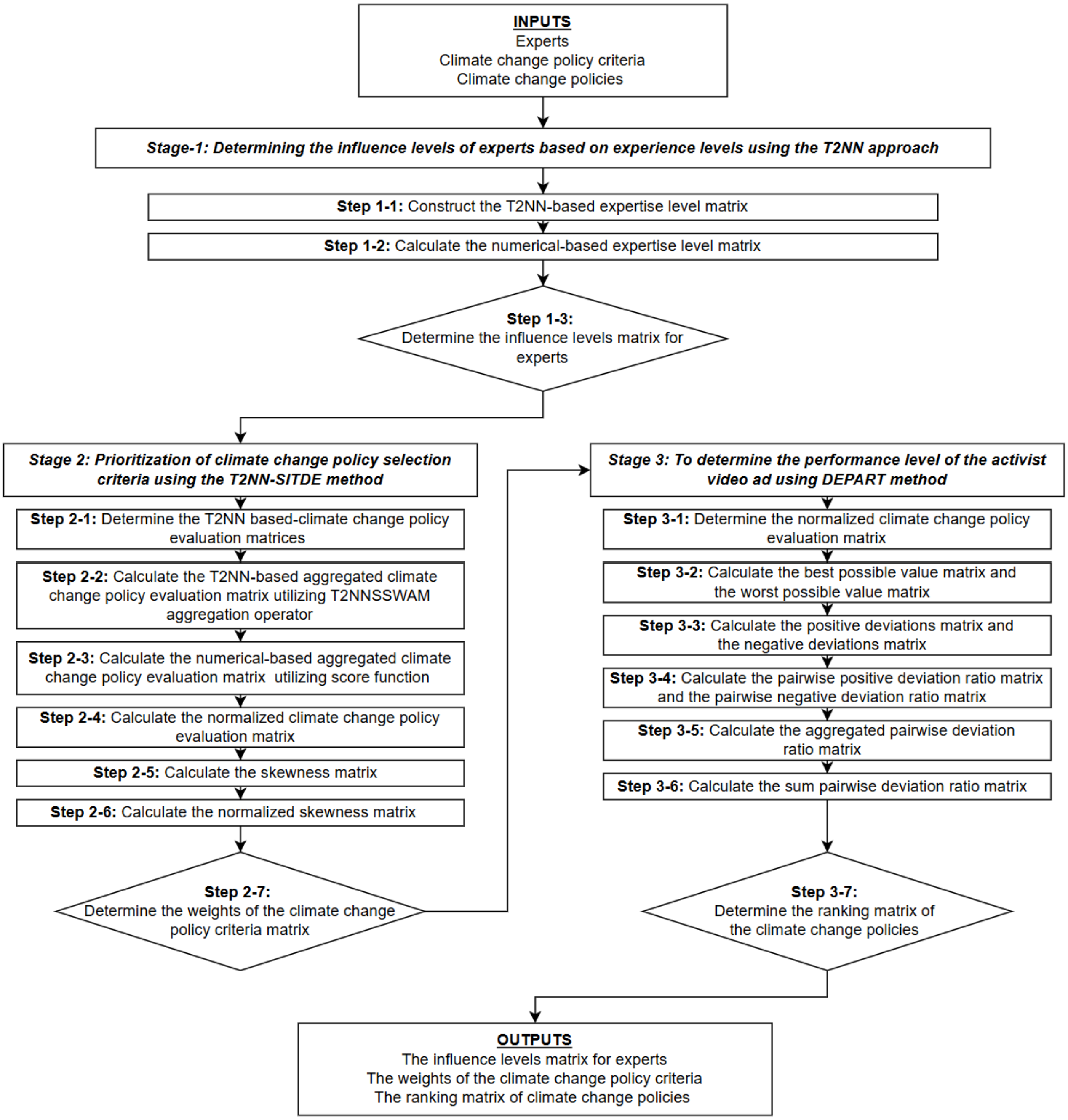

Fig. 1. Diagram of the T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics

Through structured consultations and interviews, the expert panel systematically assessed each proposed CCP against the predetermined criteria. Their evaluations were gathered using linguistic assessments, which were subsequently converted into initial decision matrices. These matrices served as the input for the application of the T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics. This rigorous expert-driven approach ensured that the DM process incorporated diverse perspectives and domain knowledge, thereby improving the robustness of the policy ranking outcomes.

Table 3
Expert group

Experts	Levels	Professions
β_1	Good	Postdoctoral researcher in climate action science
β_2	Very good	Retired professor of EU politics and environmental politics
β_3	Medium poor	Associate professor of European politics and climate change politics
β_4	Good	Senior associate researcher on EU institutions at the European Commission
β_5	Good	Professor of environmental policy and law at the Centre for Climate Change
β_6	Good	Associate professor of environmental climate change and European Union
β_7	Very good	Professor of sustainable development, specializing in sustainability governance
β_8	Very good	Professor of European Union politics and climate change policies
β_9	Very good	Professor of European Union politics
β_{10}	Very good	Retired professor of international relations and European politics

4.1.2 Criteria for climate change policies selection

To establish CCP, the EU considers criteria according to various priorities. The definition of the criteria is based on various strategic and geopolitical factors. The framework of these criteria is drawn based on literature, regional and global policies, and EU practices. Moreover, the criteria are derived from Europe-specific challenges. In shaping CCP, the EU has relied both on global influential regulations and regional instruments. For this, the EU considers regulatory instruments such as the European Climate Law, the European Green Deal, the Paris Agreement, and the Climate Change Adaptation Strategy to be guiding.

In setting the CCP criteria, the EU believes that it can demonstrate an important leadership position and that regional harmonization can have an impact on the global level. In this understanding, it can be said that the EU focuses on policymaking in three main stages. These are the formulation of the main objectives, the establishment of instruments or mechanisms for the implementation of the objectives, and finally the determination of the coverage and impact capacity of the objectives.

When determining the CCP criteria, firstly, in the target setting phase, it values basic criteria such as green economy and sustainability. Secondly, at the stage of determining the instruments, important criteria such as EU regulations (regulations), energy efficiency, scientific approach, and financing mechanisms. In the third stage, where the impact capacity is determined, it values criteria such as fair transition, labor harmonization, international cooperation, environmental justice, and social inclusion (Figure 2):

i. *Greenhouse gas emissions reduction capacity* (γ_1) – A central criterion for evaluating the effectiveness of climate change policies within the EU is their capacity to reduce greenhouse gas emissions in alignment with the Union's long-term climate neutrality targets [47]. The EU aims to reduce greenhouse gas emissions by 55% by 2030 and achieve net-zero emissions by 2050 [48], as part of its overarching vision of a "climate-neutral Europe." To achieve this target, the EU uses both regulatory and market-based tools, including the Emissions Trading System [49], carbon pricing mechanisms, carbon taxation, and the Carbon Border Adjustment Mechanism [50]. This policy approach reflects a hybrid model that integrates environmental governance with market-driven tools, consistent with neoliberal economic principles. Nevertheless, while these instruments are technically effective in curbing emissions, the criterion also demands that reduction strategies be implemented within a broader socio-economic context. Therefore, policies should not only be evaluated based on their technical capacity to reduce emissions but also on their ability to integrate social equity considerations and support a just transition, ensuring inclusiveness and public legitimacy.

ii. *Promotion of renewable energy sources* (γ_2) – The prioritization of renewable energy deployment (particularly wind, solar, hydroelectric, and sustainably sourced biomass) constitutes a fundamental criterion in the formulation of effective climate change policies [51,52]. Shifting from fossil fuels to low-carbon energy systems is a key part of the EU's climate strategy. The widespread use of renewable energy sources helps reduce greenhouse gas emissions and improves energy security by reducing dependence on external energy suppliers. Consequently, the promotion of renewables serves dual strategic purposes: advancing environmental sustainability and reinforcing the EU's energy sovereignty and strategic autonomy. As such, the development and implementation of policies that accelerate the renewable energy transition are key indicators of commitment to both climate mitigation and long-term geopolitical resilience.

iii. *Legal and institutional enforceability* (γ_3) – A strong legal and institutional framework is essential for evaluating the effectiveness and sustainability of climate change policies [53]. The EU has established a comprehensive governance structure that ensures the binding implementation of its environmental objectives. Through legally enforceable instruments (such as directives, regulations, and strategic frameworks) the EU translates climate commitments into actionable mandates. Notably, the European Climate Law legally commits Member States to achieving climate neutrality by 2050, thereby reinforcing accountability and ensuring transparent monitoring mechanisms. However, while this legal rigor strengthens policy credibility and continuity, it may also introduce implementation challenges. Overregulation and stringent administrative requirements are often criticized for elevating compliance costs and potentially diminishing global economic competitiveness. Therefore, the degree to which a climate policy balances legal enforceability with practical implementation ability should be considered a key selection criterion in assessing its overall viability and strategic value for the EU.

iv. *Sustainability integration* (γ_4) – A fundamental criterion for assessing EU climate change policies is their adherence to the principle of sustainability, which encompasses environmental, economic, and social dimensions. The EU's climate policies aim to support the sustainable use of natural resources while protecting ecosystems and meeting the needs of present and future generations [54]. This multi-dimensional approach views sustainability both as environmental protection, and as a key part of a broader development strategy [55]. Key initiatives, such as the EGD, exemplify this criterion by prioritizing the advancement of a circular economy model. However, an important evaluative consideration is the policy's ability to reconcile potential conflicts between economic interests and sustainability goals. Policies that marginalize social or environmental objectives in favor of short-term economic gains undermine the holistic vision of sustainability and present a significant barrier to achieving the EU's climate neutrality target by 2050. Thus, the best climate policies are those that effectively integrate sustainability principles across all sectors and scales, balancing economic development with ecological preservation and social equity.

v. *Energy efficiency* (γ_5) – Energy efficiency constitutes a critical criterion for evaluating EU climate change policies, as it directly supports both energy security and greenhouse gas emission reduction objectives [56]. Policies that promote higher efficiency in energy production and consumption enable the delivery of greater benefits while reducing environmental harm. Enhancing efficiency reduces reliance on fossil fuels, thereby diminishing the ecological footprint of energy use [57]. In addition, energy efficiency measures in industrial and residential sectors provide competitive advantages in the EU market by improving performance and reducing costs. Therefore, energy efficiency is important not only for environmental sustainability but also for economic viability. Furthermore, social engagement and behavioral compliance are indispensable components of effective energy efficiency strategies; sustainable gains require widespread public awareness and adherence. Therefore, the most effective climate policies are those that integrate technological improvements with mechanisms fostering societal participation to secure long-term and systemic energy efficiency improvements.

vi. *Technological infrastructure and innovation* (γ_6) – A key criterion for selecting the EU's climate policies is their promotion of technological infrastructure and innovation [58]. The EU's green economy emphasizes low-carbon production supported by advanced technologies, recognized globally as essential to combating climate change. Effective policies must ensure not only the development but also the equitable distribution of critical infrastructures (such as energy grids, digital networks, and green transport) across member states. This approach aligns with the EU's science-based policymaking, relying on data and scientific evidence from sources like the IPCC and environmental research. Grounding climate policies in empirical knowledge ensures rational, legitimate, and effective strategies beyond political debate.

vii. *Financial viability and equity* (γ_7) – Effective and sustainable climate policies require robust financial support [59]. The EGD funding mechanisms, combined with mobilizing private investments, form the economic foundation for the EU's climate transition. Given the economic disparities among member states, harmonizing financial contributions is challenging. Instruments such as the Just Transition Mechanism address these imbalances by providing targeted financial aid, thereby fostering social cohesion and political stability. Consequently, climate finance is essential not only as an implementation tool but also to ensure the EU's climate policies are equitable, inclusive, and sustainable.

viii. *Just transition and labor market inclusivity* (γ_8) – A successful climate policy must ensure a just transition that mitigates the negative impacts of the green transformation on the labor market [60]. This involves integrating workers from fossil fuel sectors into the emerging low-carbon economy, ensuring fair distribution of economic and social costs to maintain social cohesion and political stability. The EU's Just Transition Fund is a key instrument addressing financial and social disparities between member states during this process [28]. Labor market inclusion enhances the legitimacy and social acceptance of climate policies by reducing inequalities linked to structural change. Reskilling and upskilling are essential to prepare the workforce for new opportunities in sectors like battery production, wind, and solar energy. Adequate training infrastructure and dedicated funding are necessary to support these efforts. Complementary initiatives such as regional development programs and the European Skills Agenda provide strategic frameworks to facilitate workforce adaptation. Overall, just transition policies promote social inclusivity and economic feasibility, strengthening the resilience and sustainability of the EU's climate change strategy.

ix. *Multilateral cooperation and flexible integration* (γ_9) – Effective climate policy within the EU must be grounded in robust multilateral cooperation that reflects the global nature of climate change [61]. A participatory governance structure engaging regional and global actors is essential to ensure coordinated action for the common good. Equitable burden-sharing, where states assume responsibilities commensurate with their capacities, is a critical principle guiding such cooperation. However, implementing common climate policies is challenging because EU member states have different economic structures and varying levels of dependence on energy. Resistance from regions that depend heavily on carbon-intensive industries shows how difficult it is to align and harmonize climate commitments. In this context, the EU's climate diplomacy serves as a vital instrument to foster internal cohesion and assert global leadership, as exemplified by its role in the Paris Agreement. To address internal disparities and facilitate effective policy execution, strategies such as differentiated integration and flexible adaptation are necessary. These approaches enable the EU to accommodate heterogeneity among member states while maintaining collective progress toward climate objectives. Thus, the capacity to balance multilateral cooperation with adaptive, flexible mechanisms is a key criterion in evaluating the effectiveness of the EU's climate change policies [10].

x. *Commitment to environmental justice and social inclusion* (γ_{10}) – A comprehensive climate policy should include environmental justice by considering the social impacts of the green transition [20]. The EU's approach emphasizes equitable responsibility for environmental harm and the fair distribution of benefits arising from climate action [62]. Policies should ensure protection and support for workers adversely impacted by the phase-out of fossil fuel sectors, as well as vulnerable populations, including low-income groups potentially affected by energy transitions. Prioritizing social inclusion and fairness in DM processes is essential to enhance the legitimacy, acceptance, and sustainability of climate policies. Consequently, the degree to which a climate strategy promotes just, and inclusive transformation constitutes a vital criterion for evaluating the effectiveness and equity of the EU's climate change policies.

xi. *Promotion of inclusive societal participation and public awareness* (γ_{11}) – An effective climate policy must recognize society not merely as a passive recipient but as an active agent in implementing climate action [89]. The EU's approach emphasizes the essential role of broad-based participation across all social sectors to enhance the legitimacy, durability, and impact of climate change policies. Fostering a grassroots sense of responsibility and engagement is vital for achieving sustained outcomes and reinforcing the policy's foundation. Moreover, transparent collaboration between EU institutions, environmental organizations, and an informed public accelerates policy implementation and effectiveness. Thus, the extent to which a climate policy facilitates inclusive societal involvement and prioritizes public awareness through education and outreach constitutes a key criterion for evaluating the success of the EU's climate change strategy [63].

4.1.3 Climate change policies as alternatives

The EU has played a major and long-standing role in global efforts to combat climate change. Its goal of becoming climate neutral by 2050 is supported by policies like the European Green Deal, the Climate Law, and "Fit for 55", which focus on clean energy, cutting emissions, and adapting to climate change [28]. However, despite all these efforts, the continued increase in global emissions, the limited impact of EU policies, and the existence of low-binding commitments at the international level point to the inadequacies of the current approach.

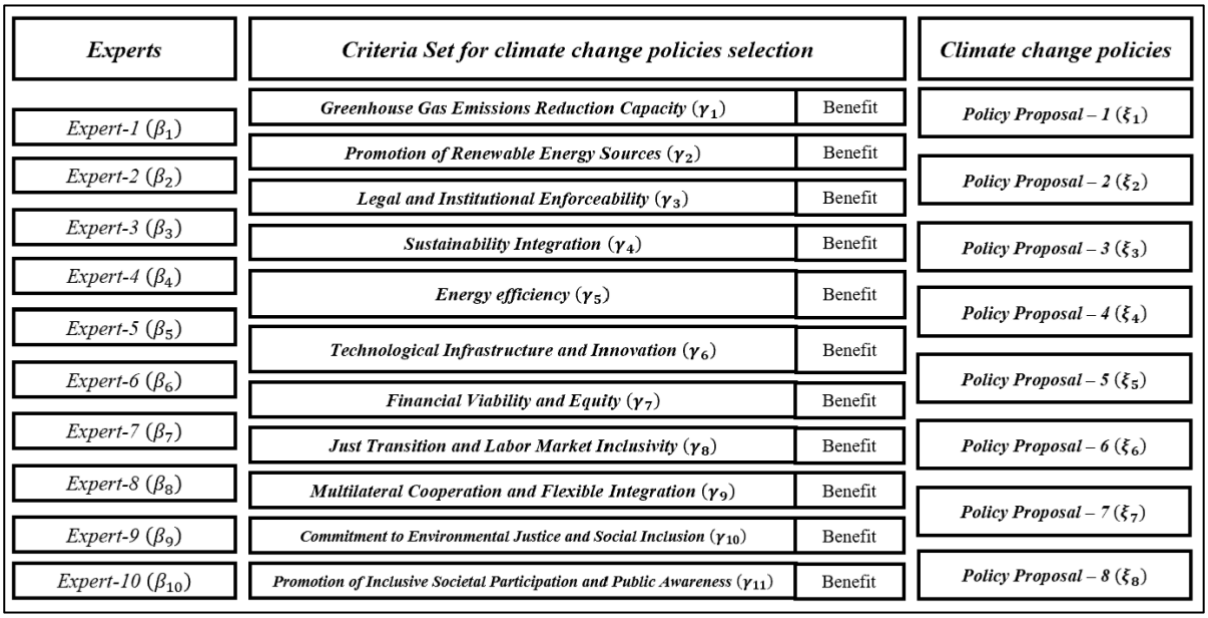

Fig. 2. Decision model for selecting climate change policy

Although the EU produces about 7% of global greenhouse gas emissions, its impact is limited globally due to increasing emissions from major economies like China, the United States, and India [64]. In addition, the voluntary structure of the Paris Agreement reduces accountability, and stronger and more inclusive actions are needed to meet the 1.5°C goal. At this point, the EU needs to go beyond its current strategy and evaluate alternative policy approaches.

This study presents a comprehensive list of alternative policies for the EU on climate change. To ensure the consistency and necessity of the alternative policies, successful and unsuccessful policies from the past were analyzed, revisions appropriate to the current situation were evaluated, and the international relations environment was considered. For this purpose, a literature review was conducted, including academic sources, strategy documents, international agreement texts, and other regulatory practices. Each alternative policy presents an independent proposal and implementation framework, and while some proposals may be compatible with each other, others may have different orientations. This diversity is important for the EU to develop flexibility and a multidimensional strategic mindset in achieving its climate goals. The main aim of the study is to identify weaknesses in current policies and suggest more effective, inclusive, and realistic climate policy options:

i. *Policy proposal – 1 (flexible cooperation policy with global powers)* (ξ_1) – Although the EU seeks to lead global climate action, the limits of acting alone are becoming more evident [65]. The EU's have only around 7 percent greenhouse gas emissions. However, emissions continue to increase in major economies such as China, the US, and India [64]. This picture shows that the EU needs more strategic and flexible co-operation with global powers to achieve its climate goals. Although the Paris Agreement has an inclusive structure, it remains weak in terms of bindingness and accountability as it is based on voluntary national contribution declarations (NDCs). With current commitments, the world is on a warming path of approximately 3°C, well above the 1.5°C limit. This situation highlights the need for multilateral co-operation supported by more stringent monitoring mechanisms and more robust commitments. In particular, the effective and responsible engagement of the major powers responsible for the bulk of global emissions plays a critical role. Actively involving these actors in the process will increase both the inclusiveness and effectiveness of climate governance [66]. Following the Copenhagen Summit in 2009, the EU revised its climate diplomacy strategy, strengthened its relations with major global actors, and started to show more flexibility in its positions [67]. This approach was decisive for the success of the Paris Agreement, highlighting the EU's diplomatic capacity to prioritize global cooperation. As a result, a policy of flexible co-operation can contribute to both maintaining the EU's global leadership role and building a more inclusive and accountable climate governance. This approach can be considered as a strong alternative strategy that overcomes the limitations of existing policies and puts international cohesion at the center.

ii. *Policy proposal – 2 (international cooperation-based policy under the EU's global leadership)* (ξ_2) – The EU should adopt the strategy of 'global climate leadership and co-operation' as an alternative policy approach within the scope of climate diplomacy. The necessity of this approach stems from the fact that the problem of climate change is global in nature. It will not be enough for the EU to reduce its emissions alone. However, it is imperative to reduce emissions and mainstream climate action worldwide. The EU therefore endeavors to assume leadership at the international level by utilizing its normative power and green diplomacy tools. With its ambitious climate policies and values-based approach, the EU is often described as a "green normative power" in global climate governance [68]. This position offers the EU the opportunity to be a steering force in global climate negotiations. For instance, in recent years, the EU has assumed the role of a 'leader-mediator', building bridges with developing countries against changing geopolitical balances and strengthening the ground for consensus in negotiations [22]. Based on the axis of climate justice, international development co-operation, and inclusiveness, this policy aims to reinforce the EU's global leadership in the climate field while leaving no one behind. Developing more inclusive co-operation in reducing carbon emissions, disseminating green technologies and increasing climate finance is imperative to limit global warming as envisaged by the Paris Agreement. The EU and its member states provide the largest share of public climate finance in the world, contributing around one-third of total global climate funding. In addition, the EU emphasizes technical assistance, technology transfer, and financing by establishing equitable partnerships with developing countries. Thus, the resilience of vulnerable societies disproportionately affected by climate change is supported and contribution is made to reduce global inequalities. This alternative policy approach to be adopted by the EU can contribute to the realization of its goal of leading a fairer and more effective climate struggle on a global scale by observing the principle of climate justice through green diplomacy and development cooperation instruments.

iii. *Policy proposal – 3 (harmonization-oriented policy based on regional interest for EU needs)* (ξ_3) – The alternative climate policy proposed under the EU Regional Adaptation Policy fills an important gap in terms of regional justice and resilience gaps in the EU. Different regions in the EU are affected by climate change in different ways and have unequal capacities to adapt. As emphasized by the European Environment Agency, differences in vulnerability and exposure to climate change persist and current adaptation efforts are insufficient for disadvantaged groups and regions. This situation is contrary to the principle of climate justice and necessitates a regional adaptation-oriented policy. Research results show that many regions with high climate risks lack the experience, capacity, and resources to adapt [69]. Failure to support these regions will deepen the existing resilience gap and create regional injustice within the EU. Therefore, a cohesion policy that considers different levels of vulnerability and empowers fragile regions is essential for the sustainability of the EU. Such a policy favors leadership-based governance, with leading members taking on a 'locomotive' role. It is recognized that some member states are much further ahead in climate policies than others, such as Germany [70]. These examples could accelerate the achievement of EU-wide climate targets by disseminating good practices and mobilizing lagging regions. Moreover, binding rules backed by tough sanctioned regional governance mechanisms would prevent non-compliance and ensure that all members fulfil their commitments. An assessment of EU climate law reveals that the success of GHG reduction targets depends on strict implementation and enforcement mechanisms [71]. This alternative policy, which considers regional differences, offers a fair and effective way to reduce emissions as well as build sustainability and climate resilience in every region. It will also contribute to securing the achievement of the EU's climate goals based on regional justice and resilience.

iv. *Policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)* (ξ_4) – The EU is developing an alternative policy approach by reframing climate diplomacy in terms of 'values-based governance'. This approach combines the EU's soft power with global climate leadership. The EU aims to be effective through values and persuasion rather than military or economic coercion [72]. Climate change is not just a technical issue; it is a global problem connected to human rights, nature, and climate justice. Therefore, by centering human dignity, the intrinsic value of the environment, and the principle of just transition in its climate policies, the EU positions itself as a 'normative power', i.e. an actor seeking to spread universal norms and values [73]. The 2023 Council conclusions also emphasized that the EU should pursue climate action based on human rights, social justice, equity, and inclusiveness. This value-oriented stance lends legitimacy to the EU's climate leadership and reinforces its normative influence at the global level. Another pillar of this policy is the international dissemination of EU values through public diplomacy. The EU tries to convince other countries to take more ambitious climate actions through diplomatic initiatives and communication strategies in multilateral platforms. This soft power strategy enables the EU to become a 'model power' in global climate governance, while at the same time aiming to shape the global climate regime with democratic values. In this way, it will be able to present itself as a role model through such climate policies. The EU's value-based climate leadership is seen as an alternative and balancing power, especially in the face of the risk of actors such as China filling the vacuum in an authoritarian manner after the periodic withdrawals of the US [72]. In this way, the EU can bring the concerns of both the developed North and the developing South on a common ground by playing the role of mediator and catalyst in climate negotiations. Value-based climate diplomacy should not only rely on normative discourses but should be supported by concrete policies. The EU has made the 2050 net-zero target legally binding with the European Climate Act and established strict mechanisms such as the Emissions Trading System [28]. This is a symbol of determination to protect environmental values. Similarly, in the international arena, the pursuit of binding commitments to accelerate the implementation of the Paris Agreement is seen as a complement to value-oriented diplomacy. In short, the EU can demonstrate effective and legitimate leadership in the fight against climate change by combining both soft power elements (e.g. norm dissemination, persuasion, reputation) and hard law, i.e. binding regulations and sanctions. This alternative policy approach is essential for the EU's global role as it addresses the climate crisis as a matter of moral leadership and offers a model for sustainable global climate governance in the long term.

v. *Policy proposal – 5 (integration of the green transition into the European labor market and just transition priority policy)* (ξ_5) – Policies towards climate targets carry the risk of deepening existing social inequalities if the social justice dimension is not taken into consideration. Steps to reduce fossil fuel use can create economic 'winners' and 'losers'. This may lead to new injustices for disadvantaged groups [74]. In fact, the European Green Deal recognized this risk and, in 2019, adopted the principle of "leaving no one behind. The international scientific community also highlights that a just transition is very important in climate policies. The green transition cuts jobs in coal and oil, but creates new jobs in renewable energy and energy efficiency. Without adequate social protection for affected workers and regions, this structural change can risk severe unemployment and economic decline. Therefore, strengthening social protection networks for fossil fuel-dependent sector employees, creating new employment areas in low-carbon sectors, and providing new skills to the labor force through comprehensive vocational training programs should be the main tools of this policy [74]. For the success of climate policies, governance processes should be inclusive. Workers, local communities, and other stakeholders should be included in the DM and implementation stages, thus ensuring distributional justice and participation. Otherwise, disproportionate sharing of the costs and benefits of transformation may create social reaction and resistance in vulnerable groups. A just transition approach can also advance climate action through social consensus and aim for a transformation that is fully in line with the social sustainability principles of the European Green Deal.

vi. *Policy proposal – 6 (geopolitical approach based on regional differentiation)* (ξ_6) – There is a need for an adaptation strategy that considers regional differences in EU climate policies. Climate change impacts are not the same across all regions in the EU. Especially Southern Europe is much more vulnerable than Northern Europe due to extreme heat waves, droughts, water scarcity, and forest fires. The report shows that climate change affects European regions differently, increasing inequalities. Southern regions are usually more negatively affected, while northern regions may even experience some benefits. Analyses by the EU Commission's Joint Research Centre show a clear north–south divide in the impacts of climate change, with welfare losses in Southern Europe being much higher than in Northern Europe. There are also criticisms that current EU adaptation policies do not adequately address the most vulnerable regions and groups [75]. Under these circumstances, it is imperative to adopt an adaptation model that considers regional vulnerability differences instead of a homogenous climate policy. Such a "North-South Climate Adaptation Strategy" will focus on taking adaptation measures according to the needs of different regions by realizing the principle of climate justice. This approach aims to increase the capacity of regional resilience by transferring more financial and technical resources to southern countries. Experts warn that if equality is not observed in adaptation policies, existing vulnerabilities may be reinforced, or new injustices may arise. Therefore, fair use of resources will help make sure no region is left behind in climate change. A fair adaptation strategy that considers regional differences will reinforce political cohesion by strengthening intra-EU solidarity against the climate crisis. Therefore, the alternative policy titled "EU North-South Climate Adaptation Strategy" is considered a necessary approach for the EU in the contexts of climate justice, regional resilience gaps, resource justice, and union solidarity.

vii. *Policy proposal – 7 (climate migration and inclusivity for intergenerational justice)* (ξ_7) – Extreme weather and environmental damage caused by climate change increase forced migration around the world. For example, the World Bank says up to 70 million people in sub-Saharan Africa may need to move because of climate change by 2050. This situation can be considered as the 'threat multiplier' of climate change. It jeopardizes climate security by creating new humanitarian crises with its impact. Current EU policies, on the other hand, largely focus on ensuring border security and deterring migration flows and fall short of finding lasting solutions to climate-induced migration. From an intergenerational climate justice perspective, this approach based solely on protecting borders carries the risk of transferring the burden of the climate crisis to the younger generations of the future and to vulnerable communities that are not responsible for the crisis. For these reasons, as an alternative policy for the EU, a strategy centered on the climate-migration nexus to increase adaptive capacity in source regions is proposed. This approach includes establishing early warning systems in regions vulnerable to climate change (e.g. Africa and the Middle East), strengthening resilience to disasters, supporting community-based development programs, and pursuing a climate-focused, inclusive foreign policy. The aim is to ensure that people can live a safe life where they are and reduce the pressure of forced displacement caused by climate change. Such a proactive adaptation and resilience strategy will mobilize the EU's foreign policy instruments to increase stability in source countries and contribute to preventing future uncontrolled migration movements. This policy option, based on climate security and climate justice, supports the EU's long-term goals and also promotes fairness between generations.

viii. *Policy proposal – 8 (promoting technological innovation in climate change)* (ξ_8) – It has an accelerating and complementary function to the ongoing efforts as an alternative policy that encourages technological innovation in the process of achieving the current climate targets of the EU. Innovative approaches such as artificial intelligence-supported energy systems, green entrepreneurship, science diplomacy, and localized climate solutions make it possible to reduce emissions. Indeed, environmentalist technological breakthroughs through green entrepreneurship play a critical role in reducing harmful emissions on a global scale and trigger social transformation [76]. In addition to environmental benefits, these technological innovations also strengthen the competitiveness of the EU economy. Although the EU is a global leader in developing climate-neutral technologies, more efforts are needed to bring these innovations to market and spread them widely. Innovation-driven climate governance is therefore indispensable for both accelerating sustainable development and maintaining the EU's industrial leadership. Additionally, policy that fosters technological innovation contributes to the EU's influence in the international arena through science diplomacy and technology transfer. Science and technology facilitate the realization of global climate agreements by providing strategic support to diplomatic efforts, and the Paris Climate Agreement is an important example. Through this policy, the EU will be able to support and drive climate action around the world through research collaborations and green technology sharing, thus strengthening its strategic position both by having a voice in global climate governance and by disseminating its values.

4.2 Selection of the Best Climate Change Policy using T2NN–Schweizer-Sklar–SITDE–DEPART

The steps of the T2NN–Schweizer-Sklar–SITDE–DEPART are presented for selection the most appropriate CCP alternative for the EU.

- ***Stage 1*** *– Determining the impact levels of experts based on experience levels using the T2NN approach.*

Step 1-1: In the expert consultations conducted for the selection of climate change policies for the EU, the experts' levels of expertise in EU affairs and climate change policies were determined based on the scale presented in Table 1. Then, the T2NN-based expertise level matrix $\left(\widetilde{\mathfrak{P}} = \left[\widetilde{\mathfrak{P}}_p\right]_P\right)$ was obtained (Table A1 in Appendix).

Step 1-2: The crisp-based expertise level matrix $\left(\mathfrak{P} = \left[\mathfrak{P}_p\right]_P\right)$ was obtained (Table A1) using the score function $\left(\propto \left(\widetilde{\mathfrak{P}}_p\right)\right)$ (Eq. (1)).

Step 1-3: The matrix $\left(\delta = \left[\delta_p\right]_P\right)$ representing the weights of experts was computed by linear normalization (Eq. (2)) (Table 4).

Table 4
Influence levels of experts' matrix

Experts	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
δ_p	0.0921	0.1070	0.0816	0.0921	0.0921	0.1070	0.1070	0.1070	0.1070	0.1070

- ***Stage 2*** *– Prioritization of climate change policy selection criteria using the T2NN-SITDE method.*

Step 2-1: Based on individual interviews with each expert, the climate change policies were assessed by the experts according to the CCP selection criteria using the evaluation scale provided in Table 2 (Shown in Table A2). Then, the T2NN-based CCP evaluation matrices $\left(\widetilde{\mathfrak{K}}^{(\beta_p)} = \left[\widetilde{\mathfrak{K}}_{bq}^{(\beta_p)}\right]_{BQ}\right)$ are constructed (Table A3).

Step 2-2: Using the T2NNSSWAM AO (Eq. (3)) $(\eta = -1)$, T2NN-based aggregated CCP evaluation matrix $\left(\widetilde{\mathfrak{K}} = \left[\widetilde{\mathfrak{K}}_{bq}\right]_{BQ}\right)$ (Table A4) was obtained.

Step 2-3: The crisp-aggregated CCP evaluation matrix $\left(\mathfrak{K} = \left[\mathfrak{K}_{bq}\right]_{BQ}\right)$ (Table A5) was computed by performing the Eq. (4).

Step 2-4: The normalized CCP evaluation matrix $\left(\mathfrak{O} = \left[\mathfrak{O}_{bq}\right]_{BQ}\right)$ (Table A6) was calculated (Eq. (5)).

Step 2-5: The skewness matrix $\left(\mathfrak{L} = \left[\mathfrak{L}_q\right]_Q\right)$ (Table A6) was calculated (Eq. (6)).

Step 2-6: The normalized skewness matrix $\left(\mathfrak{N} = \left[\mathfrak{N}_q\right]_Q\right)$ was calculated (Table A6) (Eq. (7)).

Step 2-7: The weights of the CCP criteria matrix $\left(\delta = \left[\delta_p\right]_P\right)$ was calculated (Eq. (8)) (Table 5).

Table 5
Weights of the climate change policy criteria matrix

Criteria	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
δ_p	0.1011	0.1080	0.0957	0.1087	0.1079	0.0959	0.0980	0.0868	0.0880	0.0468	0.0631
Rank	4th	2nd	7th	1st	3rd	6th	5th	9th	8th	11th	10th

- ***Stage 3** – Prioritization of climate change policies using the DEPART method*.

Step 3-1: The normalized CCP evaluation matrix $\left(\mathfrak{M} = \left[\mathfrak{M}_{bq}\right]_{BQ}\right)$ (Table A7) for DEPART was calculated (Eq. (9)).

Step 3-2: The best possible value matrix $\left(\mathfrak{A} = \left[\mathfrak{A}_{q}\right]_{Q}\right)$ and the worst possible value matrix $\left(\mathfrak{B} = \left[\mathfrak{B}_{q}\right]_{Q}\right)$ were calculated (Eq. (10) and Eq. (11)) (Table A7).

Step 3-3: The positive-based deviations matrix $\left(\mathfrak{C} = \left[\mathfrak{C}_{bq}\right]_{BQ}\right)$ (Table A8) and the negative-based deviations matrix $\left(\mathfrak{D} = \left[\mathfrak{D}_{bq}\right]_{BQ}\right)$ (Table A9) were determined (Eq. (12) and Eq. (13)).

Step 3-4: The positive pairwise values $(\mathfrak{Z} = [\mathfrak{Z}_{bb'}]_{BB})$ (Table A10) and the negative pairwise values $(\mathfrak{Y} = [\mathfrak{Y}_{bb'}]_{BB})$ (Table A11) were determined (Eq. (14) and Eq. (15)).

Step 3-5: The aggregated pairwise values $(\mathfrak{X} = [\mathfrak{X}_{bb'}]_{BB})$ (Table A12) were calculated under $\theta = 0.5$ (Eq. (16)).

Step 3-6: The sum pairwise values $(\mathfrak{T} = [\mathfrak{T}_{b}]_{B})$ (Table A12) were calculated (Eq. (17)).

Step 3-7: The ranking matrix $(\mu = [\mu_b]_B)$ of the climate change policies was calculated (Eq. (17)) (Table 6).

Table 6
Ranks of the climate change policy matrix

Climate change policies	$\boldsymbol{\gamma_1}$	$\boldsymbol{\gamma_2}$	$\boldsymbol{\gamma_3}$	$\boldsymbol{\gamma_4}$	$\boldsymbol{\gamma_5}$	$\boldsymbol{\gamma_6}$	$\boldsymbol{\gamma_7}$	$\boldsymbol{\gamma_8}$
μ_b	0.1229	0.1391	0.1210	0.1519	0.1215	0.1072	0.0952	0.1413
Rank	4th	3rd	6th	1st	5th	7th	8th	2nd

4.3 Checking Robustness
4.3.1 Robustness checks

In the study conducted to support CCP selection in the EU, the T2NN–Schweizer-Sklar–SITDE–DEPART was proposed and implemented. During the application process, alternative CCP options were generated for the EU, and the selection of the most appropriate policy was carried out based on expert evaluations. As a result of the application, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" was identified as the most suitable policy. To assess the robustness of the proposed model as well as validate the reliability of the obtained result, robust tests were conducted. Then, three sensitivity analysis scenarios were developed.

In Scenario 1, the θ parameter used in DEPART, which serves as the alternative ranking component of the hybrid model, varied within the [0,1] interval. This helped us see how different weights for positive and negative deviations change the final ranking of climate policies when forming the combined pairwise matrix. Figure 3 shows the ranking of EU climate change policies under Scenario 1. As the weight of the positive deviation values, a rise in the scores of the fourth, seventh, and eighth policies were observed, whereas minor decreases occurred in the scores of the remaining policies. However, no change occurred in the final policy rankings, demonstrating that T2NN–Schweizer-Sklar–SITDE–DEPART is robust under Scenario 1.

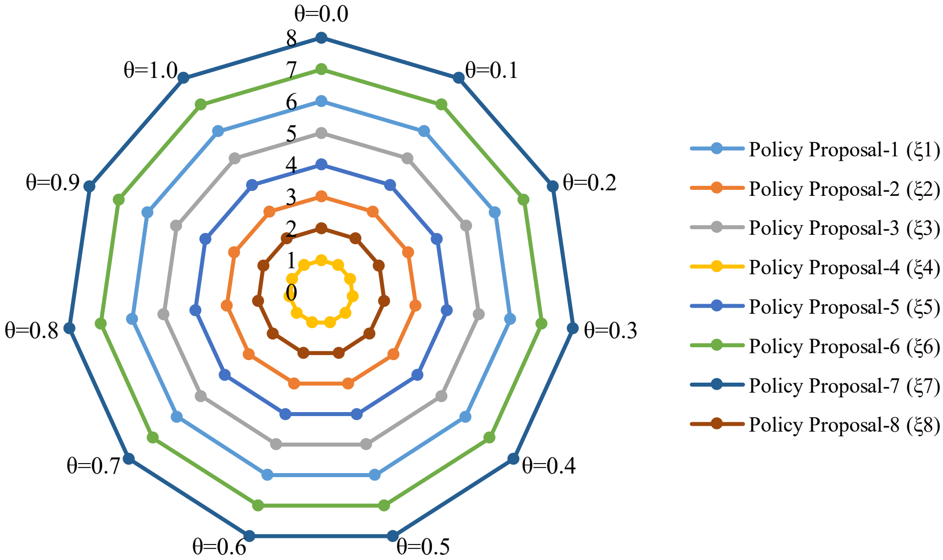

Fig. 3. Ranking of the climate changing policy according to the first sensitivity analysis

In Scenario 2, the η parameter of the T2NNSSWAM AO, which represents the strength of the hybrid method in aggregating expert assessments, was varied with negative values in the range of -1 to -100. As shown in Figure 4, the final scores of the climate change policies remain nearly identical across different values of the η parameter. Consistently, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" was identified as the top-ranked policy across all aggregation processes. These findings further confirm the robustness of the hybrid method under Scenario 2.

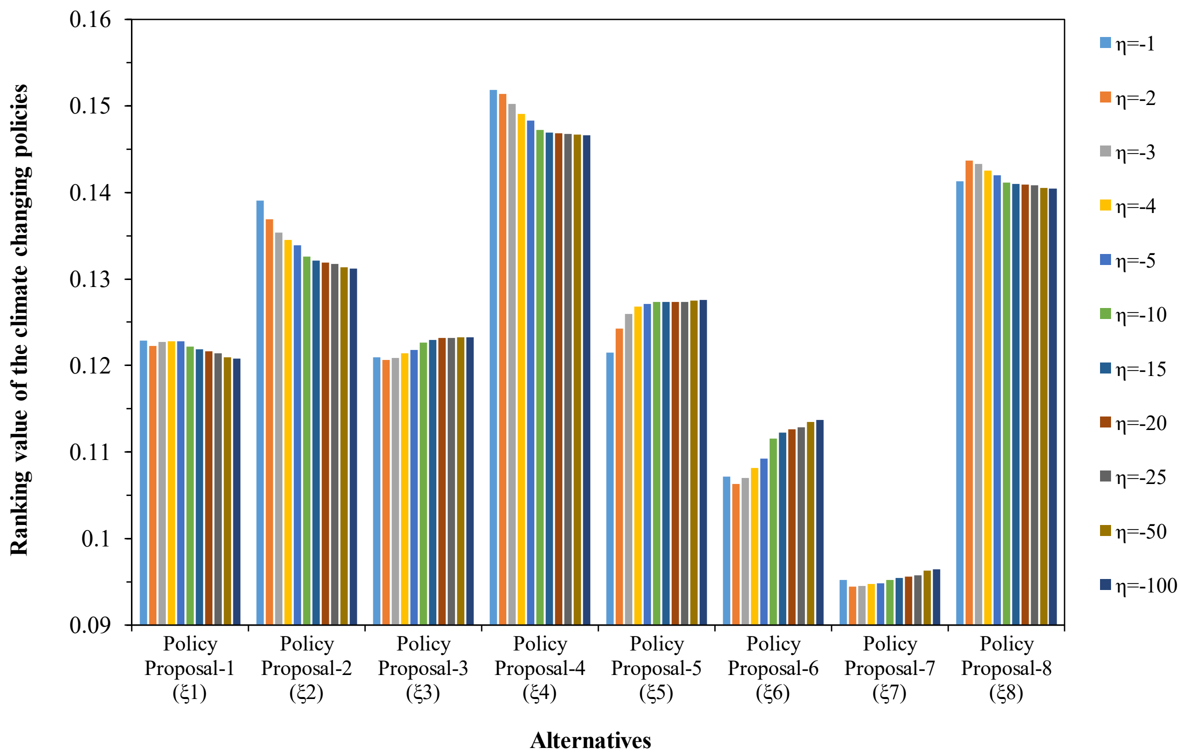

Fig. 4. Result of the second sensitivity analysis

In Scenario 3, a stepwise elimination was applied. Initially, Policy 7 was removed from the decision model, followed sequentially by Policies 6, 5, 3, 1, and 2. After each removal, the proposed hybrid method was re-applied. Across all iterations, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" remained the top-ranked option, consistent with the main analysis findings. As illustrated in Figure 5, the ranking score of Policy 4 progressively increased.

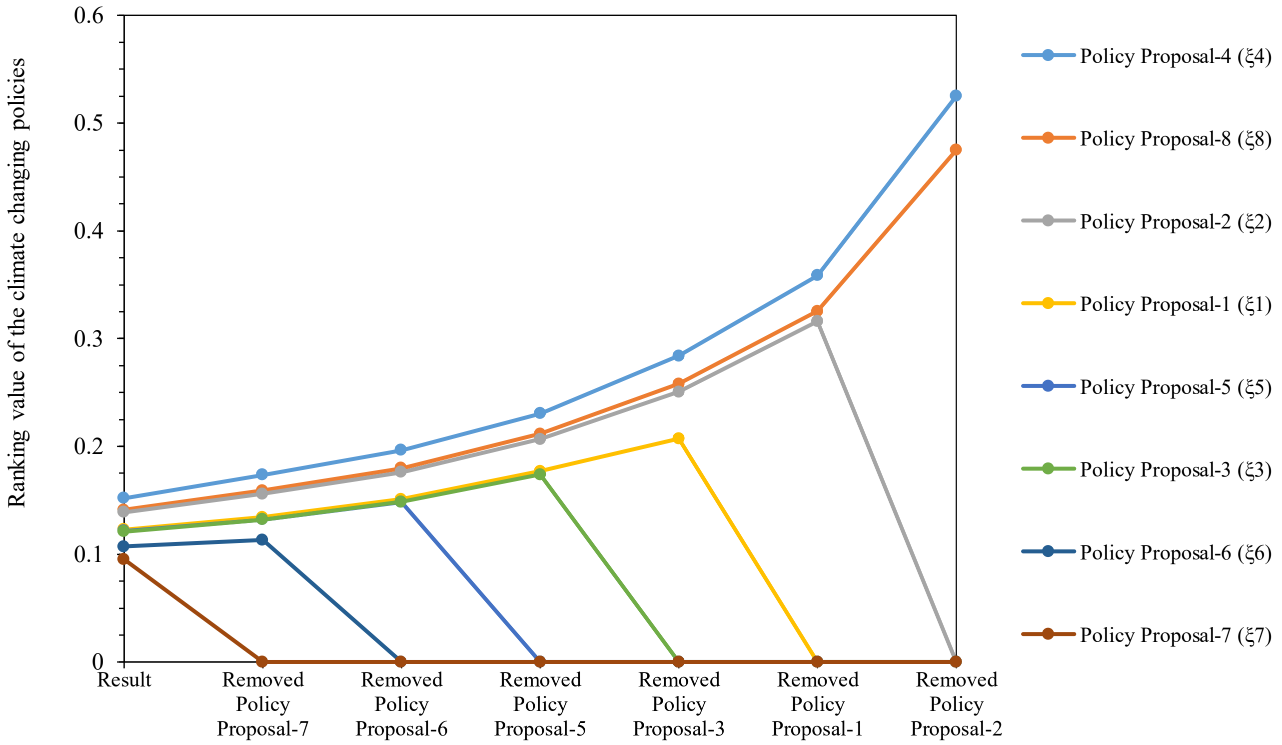

Fig. 5. Result of the third sensitivity analysis

Table 7 presents the updated policy rankings at each stage of the scenario.

Table 7
Ranking of the climate changing policy according to third sensitivity analysis

Scenarios	Ranking of the policies	Best policy
Result	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
Removed pol. proposal-7	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6$"	Pol. prop. – 4
Removed pol. proposal-6	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_3 \succ \xi_5$"	Pol. prop. – 4
Removed pol. proposal-5	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_3$"	Pol. prop. – 4
Removed pol. proposal-3	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1$"	Pol. prop. – 4
Removed pol. proposal-1	"$\xi_4 \succ \xi_8 \succ \xi_2$"	Pol. prop. – 4
Removed pol. proposal-2	"$\xi_4 \succ \xi_8$"	Pol. prop. – 4

In conclusion, the findings from all three sensitivity analysis scenarios confirm the robustness and stability of the T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics, reinforcing its reliability in the selection of EU climate change policies.

4.3.2 Comparative checks

To analyze the consistency of the results of T2NN–Schweizer-Sklar–SITDE–DEPART, various alternative ranking methods were used to generate independent rankings of CCP alternatives. These results were then compared with the findings of the main study. The alternative ranking methods used for the comparison analysis include: ARTASI, MABAC [77], MARCOS [78], RAM [79], SAW, TOPSIS [80], AROMAN [81], WASPAS [82], ARLON [83], WEDBA [84], CoCoSo [85], RATGOS [86], RAWEC [87], and CORASO.

As shown in Figure 6, the ranking scores obtained through each method were normalized using the max–min normalization to ensure standardization.

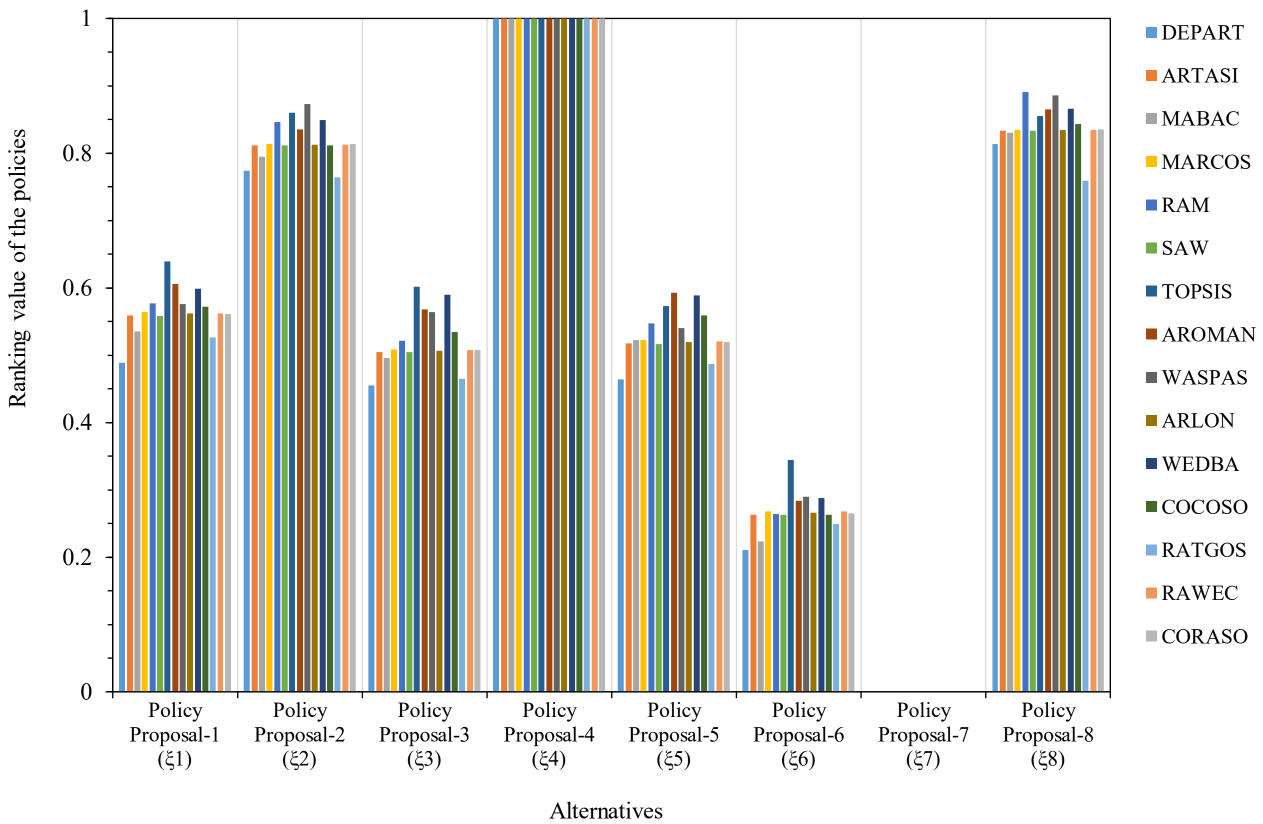

Fig. 6. Ranking values for the comparative analysis

Table 8 presents the resulting CCP rankings for each method. It was observed that in all methods, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" was ranked as the top-performing alternative, fully aligned with the primary research result.

Furthermore, when evaluating the overall rankings, it was found that (except for TOPSIS, WASPAS, WEDBA, and RATGOS) all remaining methods produced identical policy orderings to those obtained using the proposed hybrid method. In the TOPSIS results, the second and eighth policies as well as the third and fifth policies swapped positions. In WASPAS and WEDBA, only the third and fifth policies exchanged places. In RATGOS, the second and eighth policies were switched.

Table 9 provides a correlation analysis between T2NN–Schweizer-Sklar–SITDE–DEPART and the other ranking methods. The findings show a very high level of correlation, indicating strong consistency between the DEPART-based results and those of the alternative ranking approaches.

Table 8
Rankings according to the comparative analysis

Methods	Ranking of the climate changing policies	Best policy
This study	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	*Pol. prop. – 4*
ARTASI	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
MABAC	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
MARCOS	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
RAM	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
SAW	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
TOPSIS	"$\xi_4 \succ \boldsymbol{\xi_2} \succ \boldsymbol{\xi_8} \succ \xi_1 \succ \boldsymbol{\xi_3} \succ \boldsymbol{\xi_5} \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
AROMAN	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
WASPAS	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \boldsymbol{\xi_3} \succ \boldsymbol{\xi_5} \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
ARLON	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
WEDBA	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \boldsymbol{\xi_3} \succ \boldsymbol{\xi_5} \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
CoCoSo	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_3 \succ \xi_1 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
RATGOS	"$\xi_4 \succ \boldsymbol{\xi_2} \succ \boldsymbol{\xi_8} \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
RAWEC	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4
CORASO	"$\xi_4 \succ \xi_8 \succ \xi_2 \succ \xi_1 \succ \xi_5 \succ \xi_3 \succ \xi_6 \succ \xi_7$"	Pol. prop. – 4

Table 9
Correlation analysis

Methods	This study	ARTASI	MABAC	MARCOS	RAM	SAW	TOPSIS	AROMAN	WASPAS	ARLON	WEDBA	COCOSO	RATGOS	RAWEC	CORASO
This study	*1.0*	*0.997*	*0.998*	*0.996*	*0.994*	*0.997*	*0.982*	*0.988*	*0.992*	*0.997*	*0.987*	*0.994*	*0.997*	*0.997*	*0.997*
ARTASI		1.0	0.999	1.0	0.999	1.0	0.993	0.996	0.997	1.0	0.996	0.999	0.997	1.0	1.0
MABAC			1.0	0.999	0.998	0.999	0.989	0.996	0.996	0.999	0.995	0.999	0.997	0.999	0.999
MARCOS				1.0	0.999	1.0	0.994	0.997	0.998	1.0	0.996	0.999	0.997	1.0	1.0
RAM					1.0	0.999	0.993	0.997	0.998	0.999	0.996	0.998	0.992	0.999	0.999
SAW						1.0	0.993	0.996	0.997	1.0	0.996	0.999	0.997	1.0	1.0
TOPSIS							1.0	0.997	0.995	0.994	0.997	0.995	0.988	0.994	0.994
AROMAN								1.0	0.997	0.997	1.0	0.999	0.991	0.997	0.997
WASPAS									1.0	0.998	0.997	0.997	0.991	0.998	0.998
ARLON										1.0	0.996	0.999	0.997	1.0	1.0
WEDBA											1.0	0.998	0.989	0.996	0.996
COCOSO												1.0	0.995	0.999	0.999
RATGOS													1.0	0.997	0.997
RAWEC														1.0	1.0
CORASO															1.0

5. Results

In this study, the EU's CCP-making process was taken as a model to improve the mechanisms for policy selection. Eight different climate policy options were developed to find the most effective way to address climate change in the EU. These policy proposals addressed various strategic dimensions: policy proposal 1 focused on flexible cooperation, policy proposal 2 emphasized international collaboration, policy proposal 3 targeted regional needs, policy proposal 4 was grounded in cultural and normative power through climate diplomacy, policy proposal 5 highlighted the integration of green transition efforts, policy proposal 6 promoted regional differentiation, policy proposal 7 centered on intergenerational justice, and policy proposal 8 prioritized technological innovation. To rank these policy alternatives, a comprehensive evaluation framework was developed based on expert assessments. In this context, T2NN–Schweizer-Sklar–SITDE–DEPART was proposed and implemented. The application of this multi-criteria decision analytics produced three key outcomes.

The first outcome involved determining the impact of the participating experts by using T2NN sets. This stage linked the experts' DM impact to their levels of expertise. The result indicated a dominance of highly experienced experts in the process, as evidenced by the ranking "β_2 = β_6 = β_7 = β_8 = β_9 = β_{10} > β_1 = β_4 = β_5 > β_3", which shows that most contributions came from individuals with extensive subject-matter knowledge.

The second outcome addressed the prioritization of 11 evaluation criteria developed specifically for the EU context. These criteria were weighted using the T2NN–Schweizer-Sklar–SITDE method: "sustainability integration" (γ_4) **>** "promotion of renewable energy sources" (γ_2) > "energy efficiency" (γ_5) > "greenhouse gas emissions reduction capacity" (γ_1) > "financial viability and equity" (γ_7) > "technological infrastructure and innovation" (γ_6) > "legal and institutional enforceability" (γ_3) > "multilateral cooperation and flexible integration" (γ_9) > "just transition and labor market inclusivity" (γ_8) > "promotion of inclusive societal participation and public awareness" (γ_{11}) > "commitment to environmental justice and social inclusion" (γ_{10}). The most influential criterion was identified as "sustainability integration", underlining the strategic importance of long-term and systemic sustainability in EU climate policy. In contrast, the criterion with the least influence was "commitment to environmental justice and social inclusion". This relatively low ranking was attributed to the emphasis on strategic and structural priorities over socially inclusive elements at the macro-policy level.

The third outcome was the ranking of the CCP alternatives, determined using DEPART based on the previously established criteria weights: "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" (ξ_4) > "policy proposal – 8 (promoting technological innovation in climate change)" (ξ_8) > "policy proposal – 2 (international cooperation-based policy under the EU's global leadership)" (ξ_2) > "policy proposal – 1 (flexible cooperation policy with global powers)" (ξ_1) > "policy proposal – 5 (integration of the green transition into the European labor market and just transition priority policy)" (ξ_5) > "policy proposal – 3 (harmonization-oriented policy based on regional interest for EU needs)" (ξ_3) > "policy proposal – 6 (geopolitical approach based on regional differentiation)" (ξ_6) > "policy proposal – 7 (climate migration and inclusivity for intergenerational justice)" (ξ_7). The analysis revealed that policy proposal 4, which emphasizes climate diplomacy and is rooted in cultural and normative power, was ranked as the most successful policy alternative. This result suggests that a holistic and values-based diplomatic strategy is perceived by experts as the most effective approach for the EU's leadership.

In addition to these results, three sensitivity scenarios were conducted to test the proposed hybrid method. In each scenario, the findings consistently supported the original rankings. The first scenario tested the impact of altering the θ parameter within DEPART, the second examined the variation of the η parameter within the T2NNSSWAM AO, and the third involved the systematic removal of policies from the decision model to observe the persistence of "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" as the top-ranked alternative.

Furthermore, to validate the consistency of the proposed T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics, it was compared against fourteen well-established MCDM methods. The results showed a high degree of alignment across all methods, with "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" consistently ranked as the best-performing alternative. Except for minor variations in ranking positions among a few policies in four of the comparison methods (TOPSIS, WASPAS, WEDBA, and RATGOS), the general order remained highly consistent. Correlation analysis further confirmed a strong agreement between T2NN–Schweizer-Sklar–SITDE–DEPART and the alternative ranking methods, indicating the robustness of the presented neutrosophic model.

In conclusion, the T2NN–Schweizer-Sklar–SITDE–DEPART is demonstrated to be a reliable, consistent, and applicable tool for determining the best climate change policies within the EU. Its capacity to integrate expert judgment, prioritize complex criteria, and evaluate multiple policy scenarios provides significant value for strategic climate governance and policy development.

6. Implications

The findings of this study are important for methods, practice, and policy-making. These implications provide valuable insights for all partners involved in climate policy formulation.

6.1 Methodological Implications

i. The study introduces the novel T2NN–Schweizer-Sklar–SITDE–DEPART, thus expanding the boundaries of DM models by integrating neutrosophic theory with advanced aggregation and ranking techniques.
ii. SITDE is extended for the first time using T2NNs, enhancing its ability to process linguistic and uncertain expert evaluations with greater precision.
iii. The Schweizer-Sklar-based T2NNSSWAM AO is applied in combination with SITDE, enabling complex and flexible modeling of decision-maker opinions through *t*-norm and *t*-conorm logic.
iv. DEPART is employed in combination with SITDE-derived weights, offering a robust alternative ranking approach based on positive and negative deviations. This dual-deviation mechanism strengthens the objectivity of prioritization processes.

6.2 Practical Implications

i. The study presents a replicable and transparent multi-criteria decision analytics for prioritizing climate change policies, which can be applied in other regional or international contexts beyond the EU.
ii. By systematically incorporating expert knowledge through T2NN linguistic evaluations, the methodology bridges the gap between theoretical modeling and practical DM needs.
iii. "Sustainability integration" emerged as the most influential policy selection criterion, indicating that long-term and system-wide integration of sustainability considerations should be central to any climate policy evaluation framework.

6.3 Implications for EU Policy Makers

i. The results offer a scientifically grounded prioritization of eight alternative climate policy proposals tailored to the EU's needs, guiding policymakers in selecting the most effective strategies.
ii. Among the proposed alternatives, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)" is identified as the most successful approach.

This suggests that climate strategies incorporating soft power and global engagement may yield the most effective results for the EU.

iii. The neutrosophic multi-criteria decision analytics enables EU institutions to manage uncertainty and linguistic ambiguity in policy assessment processes, enhancing the robustness and transparency of strategic decisions.

7. Conclusions

This study developed model for the selection of the best alternative policies tailored for the EU. In this context, eight alternative climate policy proposals were constructed, and 11 selection criteria were identified to guide the DM process. A novel T2NN–Schweizer-Sklar–SITDE–DEPART model was introduced, integrating neutrosophic logic and advanced MCDM techniques. The method effectively incorporates expert knowledge and linguistic assessments, enabling a nuanced evaluation of policy options in the presence of uncertainty and vagueness.

The integration of the T2NN framework allowed for a more sensitive representation of expert opinions, particularly in addressing the ambiguity and subjectivity inherent in linguistic evaluations. Prioritization of the selection criteria was achieved using the extended SITDE method, which was, for the first time, adapted to work with T2NN sets. Additionally, the aggregation process was significantly improved by employing the Schweizer–Sklar operation-based T2NNSSWAM operator, facilitating a robust synthesis of expert judgments through complex mathematical operations.

The DEPART method was employed to rank the policies based on the weighted criteria. Its integration with the T2NN–SITDE weighting mechanism represents a novel application in climate policy evaluation. DEPART's dual consideration of positive and negative deviations ensured a rigorous and balanced ranking of the proposed alternatives. The evaluation process identified "sustainability integration" as the best criterion in understanding policy effectiveness, emphasizing the importance of embedding sustainability principles across all stages of climate policymaking.

Among the eight proposed alternatives, "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)", which focuses on climate diplomacy and the normative power of the EU, was identified as the most effective strategy. This outcome underscores the potential of leveraging cultural and normative influence in global climate governance. Sensitivity analysis showed that the results are stable, and comparisons with 14 other ranking methods confirmed strong agreement, supporting the reliability of the findings.

7.1. Study Limitations

Although the study makes useful contributions to climate policy decision-making and methods, it also has some limitations that should be noted. These limitations offer direction for ongoing research and contextualize the findings within the scope of the current investigation:

i. The proposed DM framework relies heavily on linguistic evaluations provided by a panel of experts. Although the use of T2NN helps capture uncertainty and subjectivity in these assessments, the inherent bias and variability in expert opinions may still influence the final outcomes.

ii. The eight alternative climate change policies were designed specifically for the EU context. As a result, the findings may not be directly generalizable to other geopolitical regions with differing socio-economic, cultural, or environmental conditions.

iii. The T2NN–Schweizer-Sklar–SITDE–DEPART multi-criteria decision analytics is computationally intensive and requires a high level of technical understanding to implement effectively. This complexity may pose challenges for policymakers or practitioners unfamiliar with advanced models.

7.2 Suggestions for Future Research

In this paper, several recommendations are proposed to guide future research, enhance DM processes, and inform EU climate policy development:

i. Policymakers and stakeholders are encouraged to adopt advanced hybrid MCDM approaches, such as the T2NN-Schweizer–Sklar-SITDE-DEPART method, to effectively evaluate and prioritize climate policy alternatives under uncertainty and vagueness.
ii. The identified 11 climate policy selection criteria should be periodically reviewed and updated in response to emerging scientific evidence, policy trends, and global climate commitments to maintain their relevance and accuracy.
iii. To facilitate adoption by non-technical users, simplified software interfaces or digital platforms based on the hybrid methodology should be developed to support real-time DM by policymakers and environmental agencies.
iv. Given the prominence of "policy proposal – 4 (climate diplomacy and policy based on cultural and normative power)", the EU is advised to further explore and invest in culturally-driven diplomatic strategies that reinforce climate leadership through normative influence.

Funding
This research was not funded by any grant.

Conflicts of Interest
The authors declare no conflicts of interest.

Appendix: Supplementary Tables

Table A1
Numerical-based expert participation level matrix

Experts	Expertise level	T2NN-based expertise level matrix $\left(\widetilde{\mathfrak{P}} = \left[\widetilde{\mathfrak{P}}_{\mathbf{p}}\right]_{\mathbf{p}}\right)$	$\mathfrak{P}_{\mathbf{p}}$
β_1	Good (G)	⟨ (0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20) ⟩	0.800
β_2	Very good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩	0.929
β_3	Medium poor (MP)	⟨ (0.40,0.30,0.35), (0.50,0.45,0.60), (0.45,0.40,0.60) ⟩	0.708
β_4	Good (G)	⟨ (0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20) ⟩	0.800
β_5	Good (G)	⟨ (0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20) ⟩	0.800
β_6	Good (G)	⟨ (0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20) ⟩	0.929
β_7	Very good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩	0.929
β_8	Very good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩	0.929
β_9	Very good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩	0.929
β_{10}	Very good (VG)	⟨ (0.95,0.90,0.95), (0.10,0.10,0.05), (0.05,0.05,0.05) ⟩	0.929

Table A2
Linguistic-based climate change policy evaluation matrices

	ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
β_1	ξ_1	MG	G	G	MG	G	G	MG	MG	MG	MG	MG
	ξ_2	G	G	G	MG	MG	G	G	MG	MG	MG	MG
	ξ_3	MG	G	G	MG	G	M	M	M	MG	M	MG
	ξ_4	MG	G	G	MG	G	G	MG	MG	G	G	MG
	ξ_5	MG	MG	MG	MG	MG	M	M	MG	G	MG	M
	ξ_6	MG	MG	MG	MP	M	MG	MP	M	MG	MG	MG
	ξ_7	M	MG	M	G	M	MG	M	MG	M	MG	M
	ξ_8	MG	MG	MG	MG	MG	MG	MG	M	MG	M	M
	ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
β_2	ξ_1	G	MG	G	M	MG	MG	MG	MG	G	M	MG
	ξ_2	G	G	G	G	MG	G	MG	G	G	MG	MG
	ξ_3	M	MG	G	MG	MG	MG	M	MG	MG	M	M
	ξ_4	G	G	G	G	G	G	G	G	G	VG	G
	ξ_5	G	MG	MG	MG	G	VG	MG	VG	MG	M	MG
	ξ_6	MG	M	MG	M	MG	M	M	M	MG	M	MG
	ξ_7	M	M	MG	M	M	M	M	MG	M	MG	MG
	ξ_8	G	G	MG	G	VG	VG	G	VG	MG	M	MG
$\vdots$						$\vdots$						
	ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
β_{10}	ξ_1	MG	MG	G	M	MG	M	MG	MG	G	MG	MG
	ξ_2	VG	G	VG	MG	MG	MG	MG	MG	MG	MG	M
	ξ_3	M	MG	VG	MG	MG	M	M	M	MG	MG	M
	ξ_4	G	G	VG	G	G	G	G	MG	G	G	MG
	ξ_5	MG	M	MG	MP	M	MP	M	MG	M	M	M
	ξ_6	MG	MP	MG	MP	MG	M	MP	M	MP	M	M
	ξ_7	M	MP	MG	M	MP	M	M	MP	M	MP	MP
	ξ_8	G	MG	M	M	M	M	MG	M	MG	M	M

Table A3
T2NN based-climate change policy evaluation matrices*

	ξ_b	γ_1								
		$T_{T_{\tilde{\aleph}(\beta_p)}}(l)$	$T_{I_{\tilde{\aleph}(\beta_p)}}(l)$	$T_{F_{\tilde{\aleph}(\beta_p)}}(l)$	$I_{T_{\tilde{\aleph}(\beta_p)}}(l)$	$I_{I_{\tilde{\aleph}(\beta_p)}}(l)$	$I_{F_{\tilde{\aleph}(\beta_p)}}(l)$	$F_{T_{\tilde{\aleph}(\beta_p)}}(l)$	$F_{I_{\tilde{\aleph}(\beta_p)}}(l)$	$F_{F_{\tilde{\aleph}(\beta_p)}}(l)$
β_1	ξ_1	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15
	ξ_2	0.70	0.75	0.80	0.15	0.20	0.25	0.10	0.15	0.20
	ξ_3	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15
	ξ_4	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15
	ξ_5	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15
	ξ_6	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15
	ξ_7	0.50	0.45	0.50	0.40	0.35	0.50	0.35	0.30	0.45
	ξ_8	0.60	0.45	0.50	0.20	0.15	0.25	0.10	0.25	0.15

* T2NN numbers are shown only for the first expert depending on the first criterion. The same transformation is applied to the other experts and criteria

Table A4
T2NN-based aggregated climate change policy evaluation matrix

ξ_b	γ_1								
	T_T	T_I	T_F	I_T	I_I	I_F	F_T	F_I	F_F
ξ_1	0.9222	0.9165	0.9269	0.0689	0.0712	0.0729	0.0524	0.0655	0.0662
ξ_2	0.9448	0.9298	0.9470	0.0630	0.0656	0.0537	0.0452	0.0503	0.0516
ξ_3	0.9028	0.8981	0.9000	0.0838	0.0767	0.0897	0.0669	0.0854	0.0783
ξ_4	0.9213	0.9175	0.9275	0.0683	0.0725	0.0742	0.0529	0.0651	0.0680
ξ_5	0.9091	0.9102	0.9153	0.0714	0.0732	0.0833	0.0556	0.0735	0.0732
ξ_6	0.9062	0.9022	0.9054	0.0751	0.0697	0.0833	0.0556	0.0800	0.0697
ξ_7	0.9003	0.8973	0.8991	0.0918	0.0870	0.0968	0.0823	0.0885	0.0909
ξ_8	0.9218	0.9190	0.9291	0.0675	0.0735	0.0742	0.0529	0.0639	0.0688
ξ_b	γ_2								
	T_T	T_I	T_F	I_T	I_I	I_F	F_T	F_I	F_F
ξ_1	0.9083	0.9080	0.9126	0.0725	0.0721	0.0833	0.0556	0.0753	0.0721
ξ_2	0.9311	0.9228	0.9362	0.0672	0.0726	0.0668	0.0520	0.0589	0.0637
ξ_3	0.9068	0.9041	0.9078	0.0743	0.0704	0.0833	0.0556	0.0784	0.0704
ξ_4	0.9201	0.9168	0.9264	0.0686	0.0727	0.0752	0.0531	0.0659	0.0686
ξ_5	0.9167	0.9083	0.9176	0.0792	0.0770	0.0795	0.0633	0.0737	0.0733
ξ_6	0.9026	0.8973	0.8990	0.0827	0.0751	0.0886	0.0642	0.0862	0.0762
ξ_7	0.8998	0.8969	0.8986	0.0928	0.0883	0.0976	0.0840	0.0893	0.0924
ξ_8	0.9297	0.9171	0.9307	0.0691	0.0673	0.0658	0.0500	0.0628	0.0593
⋮	⋮								
ξ_b	γ_{11}								
	T_T	T_I	T_F	I_T	I_I	I_F	F_T	F_I	F_F
ξ_1	0.9043	0.8981	0.9000	0.0785	0.0701	0.0848	0.0580	0.0838	0.0705
ξ_2	0.9058	0.9038	0.9074	0.0775	0.0746	0.0864	0.0607	0.0796	0.0753
ξ_3	0.9056	0.9059	0.9101	0.0797	0.0805	0.0897	0.0669	0.0787	0.0824
ξ_4	0.9342	0.9182	0.9338	0.0702	0.0668	0.0623	0.0503	0.0607	0.0570
ξ_5	0.9033	0.9022	0.9052	0.0852	0.0835	0.0931	0.0740	0.0828	0.0864
ξ_6	0.9039	0.9000	0.9024	0.0811	0.0751	0.0880	0.0637	0.0833	0.0763
ξ_7	0.9007	0.8970	0.8980	0.0887	0.0835	0.0944	0.0752	0.0894	0.0856
ξ_8	0.9026	0.9013	0.9043	0.0860	0.0845	0.0937	0.0747	0.0841	0.0873

Table A5
Numerical-aggregated climate change policy evaluation matrix

ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
ξ_1	0.9290	0.9215	0.9240	0.9154	0.9210	0.9183	0.9208	0.9163	0.9283	0.9143	0.9167
ξ_2	0.9422	0.9333	0.9425	0.9211	0.9194	0.9210	0.9205	0.9208	0.9267	0.9200	0.9177
ξ_3	0.9130	0.9201	0.9385	0.9195	0.9328	0.9125	0.9131	0.9124	0.9191	0.9139	0.9159
ξ_4	0.9288	0.9281	0.9446	0.9229	0.9287	0.9299	0.9283	0.9197	0.9417	0.9376	0.9341
ξ_5	0.9223	0.9212	0.9202	0.9173	0.9185	0.9266	0.9139	0.9316	0.9167	0.9158	0.9118
ξ_6	0.9194	0.9135	0.9186	0.9098	0.9169	0.9151	0.9094	0.9111	0.9157	0.9130	0.9150
ξ_7	0.9068	0.9058	0.9137	0.9107	0.9032	0.9090	0.9077	0.9109	0.9074	0.9134	0.9086
ξ_8	0.9292	0.9325	0.9264	0.9185	0.9362	0.9354	0.9271	0.9349	0.9194	0.9133	0.9109

Table A6
Normalized climate change policy evaluation matrix, skewness matrix, and normalized skewness matrix

ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
ξ_1	0.9760	0.9830	0.9889	0.9938	0.9806	0.9898	0.9857	0.9942	0.9776	0.9986	0.9911
ξ_2	0.9624	0.9705	0.9695	0.9877	0.9823	0.9869	0.9861	0.9893	0.9792	0.9924	0.9900
ξ_3	0.9932	0.9845	0.9735	0.9894	0.9682	0.9961	0.9941	0.9984	0.9873	0.9990	0.9920
ξ_4	0.9763	0.9760	0.9672	0.9858	0.9725	0.9774	0.9778	0.9905	0.9637	0.9738	0.9727
ξ_5	0.9831	0.9834	0.9929	0.9918	0.9833	0.9809	0.9932	0.9778	0.9898	0.9970	0.9965
ξ_6	0.9862	0.9916	0.9946	1.0000	0.9850	0.9933	0.9981	0.9998	0.9910	1.0000	0.9930
ξ_7	1.0000	1.0000	1.0000	0.9990	1.0000	1.0000	1.0000	1.0000	1.0000	0.9996	1.0000
ξ_8	0.9758	0.9714	0.9863	0.9905	0.9647	0.9717	0.9790	0.9743	0.9870	0.9997	0.9975
$\mathfrak{L}_q$	0.0226	0.5075	-0.3184	0.5565	0.4936	-0.3102	-0.1745	-0.8277	-0.7631	-2.4445	-1.9005
$\mathfrak{N}_q$	0.6500	0.6948	0.6155	0.6991	0.6936	0.6164	0.6304	0.5583	0.5660	0.3010	0.4055

Table A7
Normalized climate change policy evaluation matrix, the best possible value matrix, and the worst possible value matrix

ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
ξ_1	0.3555	0.3534	0.3518	0.3530	0.3531	0.3525	0.3548	0.3522	0.3560	0.3523	0.3537
ξ_2	0.3605	0.3579	0.3588	0.3552	0.3525	0.3535	0.3547	0.3540	0.3554	0.3544	0.3541
ξ_3	0.3494	0.3528	0.3573	0.3546	0.3576	0.3503	0.3518	0.3507	0.3525	0.3521	0.3534
ξ_4	0.3554	0.3559	0.3597	0.3559	0.3561	0.3570	0.3576	0.3535	0.3611	0.3612	0.3604
ξ_5	0.3529	0.3532	0.3503	0.3537	0.3522	0.3557	0.3521	0.3581	0.3516	0.3528	0.3518
ξ_6	0.3518	0.3503	0.3497	0.3508	0.3515	0.3513	0.3504	0.3502	0.3512	0.3517	0.3530
ξ_7	0.3470	0.3473	0.3479	0.3512	0.3463	0.3489	0.3497	0.3502	0.3480	0.3519	0.3505
ξ_8	0.3556	0.3576	0.3527	0.3542	0.3590	0.3591	0.3572	0.3594	0.3526	0.3519	0.3514
$\mathfrak{A}_q$	0.3605	0.3579	0.3597	0.3559	0.3590	0.3591	0.3576	0.3594	0.3611	0.3612	0.3604
$\mathfrak{B}_q$	0.3470	0.3473	0.3479	0.3508	0.3463	0.3489	0.3497	0.3502	0.3480	0.3517	0.3505

Table A8
Positive deviations matrix

ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
ξ_1	0.0050	0.0045	0.0079	0.0029	0.0058	0.0066	0.0029	0.0072	0.0051	0.0090	0.0067
ξ_2	0.0000	0.0000	0.0008	0.0007	0.0065	0.0055	0.0030	0.0054	0.0057	0.0068	0.0063
ξ_3	0.0112	0.0051	0.0023	0.0013	0.0013	0.0088	0.0058	0.0087	0.0087	0.0091	0.0070
ξ_4	0.0051	0.0020	0.0000	0.0000	0.0029	0.0021	0.0000	0.0059	0.0000	0.0000	0.0000
ξ_5	0.0076	0.0047	0.0093	0.0021	0.0068	0.0034	0.0055	0.0013	0.0096	0.0084	0.0086
ξ_6	0.0087	0.0076	0.0099	0.0050	0.0074	0.0078	0.0072	0.0092	0.0100	0.0095	0.0074
ξ_7	0.0136	0.0105	0.0118	0.0047	0.0127	0.0102	0.0079	0.0092	0.0131	0.0093	0.0099
ξ_8	0.0049	0.0003	0.0070	0.0017	0.0000	0.0000	0.0004	0.0000	0.0085	0.0094	0.0090

Table A9
Negative deviations matrix

ξ_b	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	γ_{11}
ξ_1	0.0085	0.0060	0.0039	0.0022	0.0068	0.0036	0.0051	0.0021	0.0080	0.0005	0.0031
ξ_2	0.0136	0.0105	0.0110	0.0044	0.0062	0.0046	0.0049	0.0038	0.0074	0.0027	0.0035
ξ_3	0.0024	0.0055	0.0095	0.0037	0.0114	0.0014	0.0021	0.0006	0.0045	0.0003	0.0028
ξ_4	0.0084	0.0085	0.0118	0.0050	0.0098	0.0081	0.0079	0.0034	0.0131	0.0095	0.0099
ξ_5	0.0060	0.0059	0.0025	0.0029	0.0059	0.0068	0.0024	0.0080	0.0036	0.0011	0.0012
ξ_6	0.0048	0.0029	0.0019	0.0000	0.0053	0.0024	0.0007	0.0001	0.0032	0.0000	0.0025
ξ_7	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
ξ_8	0.0086	0.0102	0.0048	0.0034	0.0127	0.0102	0.0075	0.0092	0.0046	0.0001	0.0009

Table A10
Pairwise positive deviation ratio matrix

ξ_b	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7	ξ_8
ξ_1	1.0000	0.8887	1.0288	0.8072	1.0232	1.1369	1.2540	0.8780
ξ_2	1.1497	1.0000	1.1796	0.9293	1.1767	1.3069	1.4428	1.0124
ξ_3	1.0038	0.8891	1.0000	0.8014	1.0242	1.1338	1.2512	0.8753
ξ_4	1.2646	1.1241	1.2869	1.0000	1.2989	1.4324	1.5753	1.1248
ξ_5	0.9989	0.8878	1.0247	0.8104	1.0000	1.1292	1.2391	0.8591
ξ_6	0.8836	0.7853	0.9033	0.7107	0.8992	1.0000	1.1028	0.7730
ξ_7	0.8064	0.7165	0.8239	0.6469	0.8169	0.9124	1.0000	0.7059
ξ_8	1.1811	1.0542	1.2072	0.9636	1.1853	1.3371	1.4757	1.0000

Table A11
Pairwise negative deviation ratio matrix

ξ_b	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7	ξ_8
ξ_1	1.0000	0.9049	1.0506	0.8350	1.0296	1.1596	1.3508	0.9067
ξ_2	1.1195	1.0000	1.1710	0.9333	1.1506	1.2969	1.5093	1.0149
ξ_3	0.9815	0.8840	1.0000	0.8113	1.0086	1.1315	1.3165	0.8862
ξ_4	1.2157	1.0977	1.2638	1.0000	1.2533	1.4039	1.6279	1.1107
ξ_5	0.9929	0.8966	1.0412	0.8307	1.0000	1.1458	1.3241	0.8828
ξ_6	0.8667	0.7837	0.9054	0.7209	0.8882	1.0000	1.1656	0.7838
ξ_7	0.7536	0.6801	0.7852	0.6242	0.7666	0.8699	1.0000	0.6805
ξ_8	1.1333	1.0263	1.1864	0.9522	1.1456	1.3101	1.5232	1.0000

Table A12
Aggregated pairwise deviation ratio matrix and sum pairwise deviation ratio matrix

ξ_b	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7	ξ_8
ξ_1	1.0000	0.8968	1.0397	0.8211	1.0264	1.1482	1.3024	0.8924
ξ_2	1.1346	1.0000	1.1753	0.9313	1.1636	1.3019	1.4760	1.0137
ξ_3	0.9927	0.8865	1.0000	0.8063	1.0164	1.1326	1.2839	0.8807
ξ_4	1.2402	1.1109	1.2754	1.0000	1.2761	1.4181	1.6016	1.1178
ξ_5	0.9959	0.8922	1.0329	0.8205	1.0000	1.1375	1.2816	0.8710
ξ_6	0.8751	0.7845	0.9043	0.7158	0.8937	1.0000	1.1342	0.7784
ξ_7	0.7800	0.6983	0.8046	0.6356	0.7918	0.8911	1.0000	0.6932
ξ_8	1.1572	1.0402	1.1968	0.9579	1.1655	1.3236	1.4995	1.0000
$\mathfrak{T}_b$	8.1758	7.3094	8.4290	6.6886	8.3334	9.3531	10.5791	7.2471

References

[1] Clark, B., & York, R. (2005). Carbon metabolism: Global capitalism, climate change, and the biospheric rift. *Theory and Society*, *34*, 391-428. https://doi.org/10.1007/s11186-005-1993-4.

[2] Fankhauser, S., Smith, S. M., Allen, M., Axelsson, K., Hale, T., Hepburn, C., et al. (2022). The meaning of net zero and how to get it right. *Nature Climate Change*, *12*(1), 15-21. https://doi.org/10.1038/s41558-021-01245-w.

[3] Ostrom, E. (2012). Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales?. *Economic Theory*, *49*, 353-369. https://doi.org/10.1007/s00199-010-0558-6.

[4] Schneider, F., Kallis, G., & Martinez-Alier, J. (2010). Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. *Journal of Cleaner Production*, *18*(6), 511-518. https://doi.org/10.1016/j.jclepro.2010.01.014.

[5] Voulvoulis, N., Giakoumis, T., Hunt, C., Kioupi, V., Petrou, N., Souliotis, I., & Vaghela, C. J. G. E. C. (2022). Systems thinking as a paradigm shift for sustainability transformation. *Global Environmental Change*, *75*, 102544. https://doi.org/10.1016/j.gloenvcha.2022.102544.

[6] Domorenok, E., & Graziano, P. (2023). Understanding the European Green Deal: A narrative policy framework approach. *European Policy Analysis*, *9*(1), 9-29. https://doi.org/10.1002/epa2.1168.

[7] Cifuentes-Faura, J. (2022). European Union policies and their role in combating climate change over the years. *Air Quality, Atmosphere & Health*, *15*(8), 1333-1340. https://doi.org/10.1007/s11869-022-01156-5.

[8] Giuliani, A., & Baron, H. (2025). The CAP (Common Agricultural Policy): a short history of crises and major transformations of European agriculture. In *Forum for Social Economics*, 54(1), 68-94. Routledge. https://doi.org/10.1080/07360932.2023.2259618.

[9] Kulovesi, K., & Oberthür, S. (2020). Assessing the EU's 2030 Climate and Energy Policy Framework: Incremental change toward radical transformation?. *Review of European, Comparative & International Environmental Law*, *29*(2), 151-166. https://doi.org/10.1111/reel.12358.

[10] Biesbroek, G. R., Swart, R. J., Carter, T. R., Cowan, C., Henrichs, T., Mela, H., et al. (2010). Europe adapts to climate change: comparing national adaptation strategies. *Global Environmental Change*, *20*(3), 440-450. https://doi.org/10.1016/j.gloenvcha.2010.03.005.

[11] Hainsch, K., Löffler, K., Burandt, T., Auer, H., Del Granado, P. C., Pisciella, P., & Zwickl-Bernhard, S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal?. *Energy*, *239*, 122067. https://doi.org/10.1016/j.energy.2021.122067.

[12] Wolf, S., Teitge, J., Mielke, J., Schütze, F., & Jaeger, C. (2021). The European Green Deal—more than climate neutrality. *Intereconomics*, *56*, 99-107. https://doi.org/10.1007/s10272-021-0963-z.

[13] Dobrodolac, M., Bošković, S., Jovčić, S., & Lazarević, D. (2024). Sustainable Delivery Model Selection using AROMAN Approach. *Decision Making Advances, 2*(1), 73-82. https://doi.org/10.31181/dma21202429.

[14] Parker, C. F., & Karlsson, C. (2010). Climate change and the European Union's leadership moment: an inconvenient truth?. *JCMS: Journal of Common Market Studies*, *48*(4), 923-943. https://doi.org/10.1111/j.1468-5965.2010.02080.x.

[15] Gopisetty, Y. B., & Sama, H. R. (2024). Skewness impact through distributional evaluation (SITDE) method: a new method in multi-criteria decision making. *Journal of the Operational Research Society*. https://doi.org/10.1080/01605682.2024.2416910.

[16] Yalçın, G. C., Kara, K., Işık, G., Simic, V., & Pamucar, D. (2025). Development of a Decision Support System for Performance Measurement of Social Movements. *Cognitive Computation*, *17*(1), 1-27. https://doi.org/10.1007/s12559-024-10385-y.

[17] Kara, K., Yalçın, G. C., Simic, V., Polat, M., & Pamucar, D. (2024). An integrated neutrosophic Schweizer-Sklar-based model for evaluating economic activities in organized industrial zones. *Engineering Applications of Artificial Intelligence*, *130*, 107722. https://doi.org/10.1016/j.engappai.2023.107722.

[18] Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., & Antucheviciene, J. (2025). Simulation-Aided Analysis of a Deviation-Based Pairwise Assessment Ratio Technique (DEPART) for MCDM. *International Journal of Computers Communications & Control*, *20*(3). https://doi.org/10.15837/ijccc.2025.3.7038.

[19] Moser, S. C. (2010). Communicating climate change: history, challenges, process and future directions. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(1), 31-53. https://doi.org/10.1002/wcc.11.

[20] Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: climate change and the discourse of environmental justice. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 359-374. https://doi.org/10.1002/wcc.275.

[21] Dhar, T. K., & Khirfan, L. (2017). A multi-scale and multi-dimensional framework for enhancing the resilience of urban form to climate change. *Urban Climate*, *19*, 72-91. https://doi.org/10.1016/j.uclim.2016.12.004.

[22] Bäckstrand, K., & Elgström, O. (2013). The EU's role in climate change negotiations: from leader to 'leadiator'. *Journal of European Public Policy*, *20*(10), 1369-1386. https://doi.org/10.1080/13501763.2013.781781.
[23] Scheffran, J., & Battaglini, A. (2011). Climate and conflicts: the security risks of global warming. *Regional Environmental Change*, *11*, 27-39. https://doi.org/10.1007/s10113-010-0175-8.
[24] Stefanis, C., Stavropoulos, A., Stavropoulou, E., Tsigalou, C., Constantinidis, T. C., & Bezirtzoglou, E. (2024). A spotlight on environmental sustainability in view of the European Green Deal. *Sustainability*, *16*(11), 4654. https://doi.org/10.3390/su16114654.
[25] Elkerbout, M. (2020). The changing role of carbon pricing in the EU. *National Institute Economic Review*, *251*, R13-R24. https://doi.org/10.1017/nie.2020.3.
[26] Sabato, S., & Mandelli, M. (2024). Towards an EU framework for a just transition: welfare policies and politics for the socio-ecological transition. *European Political Science*, *23*(1), 14-26.
[27] Joița, D., Panait, M., Dobrotă, C. E., Diniță, A., Neacșa, A., & Naghi, L. E. (2023). The European dilemma—Energy security or green transition. *Energies*, *16*(9), 3849. https://doi.org/10.3390/en16093849.
[28] Filipović, S., Lior, N., & Radovanović, M. (2022). The green deal–just transition and sustainable development goals Nexus. *Renewable and Sustainable Energy Reviews*, *168*, 112759. https://doi.org/10.1016/j.rser.2022.112759.
[29] Kilian, B., & Elgström, O. (2010). Still a green leader? The European Union's role in international climate negotiations. *Cooperation and conflict*, *45*(3), 255-273. https://doi.org/10.1177/0010836710377392.
[30] Van Schaik, L., & Schunz, S. (2012). Explaining EU activism and impact in global climate politics: is the Union a norm-or interest-driven actor?. *JCMS: Journal of Common Market Studies*, *50*(1), 169-186. https://doi.org/10.1111/j.1468-5965.2011.02214.x.
[31] Oberthür, S., & Groen, L. (2017). The European Union and the Paris Agreement: leader, mediator, or bystander?. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(1), e445. https://doi.org/10.1002/wcc.445.
[32] Almeida, D. V., Kolinjivadi, V., Ferrando, T., Roy, B., Herrera, H., Gonçalves, M. V., & Van Hecken, G. (2023). The "greening" of empire: The European Green Deal as the EU first agenda. *Political Geography*, *105*, 102925. https://doi.org/10.1016/j.polgeo.2023.102925.
[33] Schunz, S. (2022). The 'European Green Deal'–a paradigm shift? Transformations in the European Union's sustainability meta-discourse. *Political Research Exchange*, *4*(1), 2085121. https://doi.org/10.1080/2474736X.2022.2085121.
[34] Barry, D., & Hoyne, S. (2021). Sustainable measurement indicators to assess impacts of climate change: Implications for the New Green Deal Era. *Current Opinion in Environmental Science & Health*, *22*, 100259. https://doi.org/10.1016/j.coesh.2021.100259.
[35] Pianta, M., & Lucchese, M. (2020). Rethinking the European Green Deal: An industrial policy for a just transition in Europe. *Review of Radical Political Economics*, *52*(4), 633-641. https://doi.org/10.1177/0486613420938207.
[36] Hereu-Morales, J., Segarra, A., & Valderrama, C. (2024). The European (Green?) Deal: A systematic analysis of environmental sustainability. *Sustainable Development*, *32*(1), 647-661. https://doi.org/10.1002/sd.2671.
[37] Veugelers, R., Tagliapietra, S., & Trasi, C. (2024). Green industrial policy in Europe: Past, present, and prospects. *Journal of Industry, Competition and Trade*, *24*(1), 4. https://doi.org/10.1007/s10842-024-00418-5.
[38] Fitch-Roy, O., & Bailey, I. (2023). Green growth and competitiveness in EU climate policy: paradigm shift or'plus de la même chose'?. In *Handbook on European Union Climate Change Policy and Politics* (pp. 173-186). Edward Elgar Publishing. https://doi.org/10.4337/9781789906981.00024.
[39] Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Łuniewska, M., Ruggieri, A., & Ioppolo, G. (2021). Enabling the Circular Economy transition: A sustainable lean manufacturing recipe for Industry 4.0. *Business Strategy and the Environment*, *30*(7), 3255-3272. https://doi.org/10.1002/bse.2801.
[40] Montfort, S., Fesenfeld, L., Stadelmann-Steffen, I., & Ingold, K. (2023). Policy sequencing can increase public support for ambitious climate policy. *Policy and Society*, *42*(4), 454-477. https://doi.org/10.1093/polsoc/puad030.
[41] Ruiz, A. Z., Martín, J. M. M., & Prados-Castillo, J. F. (2023). The European Union facing climate change: A window of opportunity for technological development and entrepreneurship. *Sustainable Technology and Entrepreneurship*, *2*(2), 100035. https://doi.org/10.1016/j.stae.2022.100035.
[42] Oberthür, S., & Dupont, C. (2021). The European Union's international climate leadership: towards a grand climate strategy?. *Journal of European Public Policy*, *28*(7), 1095-1114. https://doi.org/10.1080/13501763.2021.1918218.
[43] Evro, S., Oni, B. A., & Tomomewo, O. S. (2024). Global strategies for a low-carbon future: lessons from the US, China, and EU's pursuit of carbon neutrality. *Journal of Cleaner Production*, 142635. https://doi.org/10.1016/j.jclepro.2024.142635.
[44] Buzogány, A., Parks, L., & Torney, D. (2025). Democracy and the European Green Deal. *Journal of European Integration*, *47*(2), 135-154. https://doi.org/10.1080/07036337.2025.2459859.

[45] Oberthür, S., & Kulovesi, K. (2025). Accelerating the EU's climate transformation: The European Green Deal's Fit for 55 Package unpacked. *Review of European, Comparative & International Environmental Law*. https://doi.org/10.1111/reel.12596.

[46] Simic, V., Gokasar, I., Deveci, M., & Karakurt, A. (2022). An integrated CRITIC and MABAC based type-2 neutrosophic model for public transportation pricing system selection. *Socio-Economic Planning Sciences*, *80*, 101157. https://doi.org/10.1016/j.seps.2021.101157.

[47] Perissi, I., & Jones, A. (2022). Investigating European Union decarbonization strategies: Evaluating the pathway to carbon neutrality by 2050. *Sustainability*, *14*(8), 4728. https://doi.org/10.3390/su14084728.

[48] Gaeta, M., Nsangwe Businge, C., & Gelmini, A. (2021). Achieving net zero emissions in Italy by 2050: Challenges and opportunities. *Energies*, *15*(1), 46. https://doi.org/10.3390/en15010046.

[49] Teixidó, J., Verde, S. F., & Nicolli, F. (2019). The impact of the EU Emissions Trading System on low-carbon technological change: The empirical evidence. *Ecological Economics*, *164*, 106347. https://doi.org/10.1016/j.ecolecon.2019.06.002.

[50] Bellora, C., & Fontagné, L. (2023). EU in search of a Carbon Border Adjustment Mechanism. *Energy Economics*, *123*, 106673. https://doi.org/10.1016/j.eneco.2023.106673.

[51] Asante, D., Ampah, J. D., Afrane, S., Adjei-Darko, P., Asante, B., Fosu, E., et al. (2022). Prioritizing strategies to eliminate barriers to renewable energy adoption and development in Ghana: A CRITIC-fuzzy TOPSIS approach. *Renewable Energy*, *195*, 47-65. https://doi.org/10.1016/j.renene.2022.06.040.

[52] Qian, S., Qiu, Y., Bouraima, M. B., Badi, I., & Chusi, T. N. (2024). Assessing the Challenges to Leverage Carbon Markets for Renewable Energy in Developing Countries: A Multi-Criteria Decision-Making Approach. *Spectrum of Engineering and Management Sciences, 2*(1), 151-160. https://doi.org/10.31181/sems21202412s.

[53] Omri, A., & Jabeur, S. B. (2024). Climate policies and legislation for renewable energy transition: The roles of financial sector and political institutions. *Technological Forecasting and Social Change*, *203*, 123347. https://doi.org/10.1016/j.techfore.2024.123347.

[54] Tutak, M., Brodny, J., & Bindzár, P. (2021). Assessing the level of energy and climate sustainability in the European Union countries in the context of the European green deal strategy and agenda 2030. *Energies*, *14*(6), 1767. https://doi.org/10.3390/en14061767.

[55] Basuri, T., Gazi, K. H., Bhaduri, P., Das, S. G., & Mondal, S. P. (2025). Decision-analytics-based Sustainable Location Problem - Neutrosophic CRITIC-COPRAS Assessment Model. *Management Science Advances, 2*(1), 19-58. https://doi.org/10.31181/msa2120257.

[56] Chlechowitz, M., Reuter, M., & Eichhammer, W. (2022). How first comes energy efficiency? Assessing the energy efficiency first principle in the EU using a comprehensive indicator-based approach. *Energy Efficiency*, *15*(8), 59. https://doi.org/10.1007/s12053-022-10063-8.

[57] Li, R., Wang, X., & Wang, Q. (2022). Does renewable energy reduce ecological footprint at the expense of economic growth? An empirical analysis of 120 countries. *Journal of Cleaner Production*, *346*, 131207. https://doi.org/10.1016/j.jclepro.2022.131207.

[58] Jänicke, M. (2012). Dynamic governance of clean-energy markets: how technical innovation could accelerate climate policies. *Journal of Cleaner Production*, *22*(1), 50-59. https://doi.org/10.1016/j.jclepro.2011.09.006.

[59] Lamperti, F., Bosetti, V., Roventini, A., Tavoni, M., & Treibich, T. (2021). Three green financial policies to address climate risks. *Journal of Financial Stability*, *54*, 100875. https://doi.org/10.1016/j.jfs.2021.100875.

[60] Stevis, D., & Felli, R. (2015). Global labour unions and just transition to a green economy. *International Environmental Agreements: Politics, Law and Economics*, *15*, 29-43. https://doi.org/10.1007/s10784-014-9266-1.

[61] Bäckstrand, K., Kuyper, J. W., Linnér, B. O., & Lövbrand, E. (2017). Non-state actors in global climate governance: from Copenhagen to Paris and beyond. *Environmental Politics*, *26*(4), 561-579. https://doi.org/10.1080/09644016.2017.1327485.

[62] Paavola, J., & Adger, W. N. (2006). Fair adaptation to climate change. *Ecological Economics*, *56*(4), 594-609. https://doi.org/10.1016/j.ecolecon.2005.03.015.

[63] Corner, A., Markowitz, E., & Pidgeon, N. (2014). Public engagement with climate change: the role of human values. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 411-422. https://doi.org/10.1002/wcc.269.

[64] Mehmood, K., Tauseef Hassan, S., Qiu, X., & Ali, S. (2024). Comparative analysis of CO 2 emissions and economic performance in the United States and China: Navigating sustainable development in the climate change era. *Geoscience Frontiers*, *15*(5), 101843. https://doi.org/10.1016/j.gsf.2024.101843.

[65] Dennison, S., Loss, R. & Söderström, J. (2021). *Europe’s green moment: How to meet the climate challenge*.

[66] Bäckstrand, K., Kuyper, J., & Nasiritousi, N. (2021). From collaboration to contestation? Perceptions of legitimacy and effectiveness in post-Paris climate governance. *Earth System Governance*, *9*, 100115. https://doi.org/10.1016/j.esg.2021.100115.

[67] Belis, D., Schunz, S., Wang, T., & Jayaram, D. (2018). Climate diplomacy and the rise of 'multiple bilateralism'between China, India and the EU. *Carbon & Climate Law Review*, *12*(2), 85-97. https://www.jstor.org/stable/26489002.

[68] Von Lucke, F. (2021). Principled pragmatism in climate policy? The EU and changing practices of climate justice. *Political Geography*, *86*, 102355. https://doi.org/10.1016/j.polgeo.2021.102355.

[69] Aguiar, F. C., Bentz, J., Silva, J. M., Fonseca, A. L., Swart, R., Santos, F. D., & Penha-Lopes, G. (2018). Adaptation to climate change at local level in Europe: An overview. *Environmental Science & Policy*, *86*, 38-63. https://doi.org/10.1016/j.envsci.2018.04.010.

[70] McCauley, D., Pettigrew, K. A., Todd, I., & Milchram, C. (2023). Leaders and laggards in the pursuit of an EU just transition. *Ecological Economics*, *205*, 107699. https://doi.org/10.1016/j.ecolecon.2022.107699.

[71] Peeters, M., & Athanasiadou, N. (2020). The continued effort sharing approach in EU climate law: Binding targets, challenging enforcement?. *Review of European, Comparative & International Environmental Law*, *29*(2), 201-211. https://doi.org/10.1111/reel.12356.

[72] Barichella, A. (2017). How Europe can and should become the guardian of the Paris Agreement on climate change. *European Issues Fondation Robert Schuman*, (450), 1-10.

[73] Von Lucke, F., Diez, T., Aamodt, S., & Ahrens, B. (2021). *The EU and global climate justice: normative power caught in normative battles*. Routledge. https://doi.org/10.4324/9781003081517.

[74] Akgüç, M., Arabadjieva, K., & Galgóczi, B. (2022). Why the EU's patchy 'just transition'framework is not up to meeting its climate ambitions. *ETUI Research Paper-Policy Brief*. http://dx.doi.org/10.2139/ssrn.4220500.

[75] Remling, E. (2018). Depoliticizing adaptation: a critical analysis of EU climate adaptation policy. *Environmental Politics*, *27*(3), 477-497. https://doi.org/10.1080/09644016.2018.1429207.

[76] Potluri, S., & Phani, B. V. (2022). Green entrepreneurship: a disruptive mitigation strategy for climate change. In *Handbook of climate change mitigation and adaptation* (pp. 3787-3819). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-72579-2_165.

[77] Pamucar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). *Expert Systems with Applications*, *42*(6), 3016-3028. https://doi.org/10.1016/j.eswa.2014.11.057.

[78] Stević, Ž., Pamučar, D., Puška, A., & Chatterjee, P. (2020). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). *Computers & Industrial Engineering*, *140*, 106231. https://doi.org/10.1016/j.cie.2019.106231.

[79] Sotoudeh-Anvari, A. (2023). Root Assessment Method (RAM): A novel multi-criteria decision making method and its applications in sustainability challenges. *Journal of Cleaner Production*, *423*, 138695. https://doi.org/10.1016/j.jclepro.2023.138695.

[80] Lai, Y. J., Liu, T. Y., & Hwang, C. L. (1994). Topsis for MODM. *European Journal of Operational Research*, *76*(3), 486-500. https://doi.org/10.1016/0377-2217(94)90282-8.

[81] Bošković, S., Švadlenka, L., Jovčić, S., Dobrodolac, M., Simić, V., & Bacanin, N. (2023). An alternative ranking order method accounting for two-step normalization (AROMAN)—A case study of the electric vehicle selection problem. *IEEE Access*, *11*, 39496-39507. https://doi.org/10.1109/ACCESS.2023.3265818.

[82] Chakraborty, S., & Zavadskas, E. K. (2014). Applications of WASPAS method in manufacturing decision making. *Informatica*, *25*(1), 1-20. https://doi.org/10.15388/Informatica.2014.01.

[83] Kara, K., Yalçın, G. C., Simic, V., Baysal, Z., & Pamucar, D. (2024). The alternative ranking using two-step logarithmic normalization method for benchmarking the supply chain performance of countries. *Socio-Economic Planning Sciences*, *92*, 101822. https://doi.org/10.1016/j.seps.2024.101822.

[84] Rao, R. V., Singh, D., Bleicher, F., & Dorn, C. (2012). Weighted Euclidean distance-based approach as a multiple attribute decision making method for manufacturing situations. *International Journal of Multicriteria Decision Making*, *2*(3), 225-240. https://doi.org/10.1504/IJMCDM.2012.047845.

[85] Yazdani, M., Zarate, P., Kazimieras Zavadskas, E., & Turskis, Z. (2019). A combined compromise solution (CoCoSo) method for multi-criteria decision-making problems. *Management Decision*, *57*(9), 2501-2519. https://doi.org/10.1108/MD-05-2017-0458.

[86] Dinçer, H., Eti, S., Yüksel, S., Özdemir, S., Yílmaz, A. E., & Ergün, E. (2023). Integrating data mining and fuzzy decision-making techniques for analyzing the key minimizing factors of carbon emissions. *Journal of Intelligent & Fuzzy Systems*, *45*(5), 7317-7333. https://doi.org/10.3233/JIFS-232303.

[87] Puška, A., Štilić, A., Pamučar, D., Božanić, D., & Nedeljković, M. (2024). Introducing a Novel multi-criteria Ranking of Alternatives with Weights of Criterion (RAWEC) model. *MethodsX*, 102628. https://doi.org/10.1016/j.mex.2024.102628.