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Research Article

Assessing energy policy effectiveness in Vietnam using multi-criteria decision making

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Abstract. Vietnam's energy transition is strong, and therefore, Vietnam needs a policy framework appropriate to the current context to promote this sustainable transition. This study assesses energy policy alternatives in Vietnam in order to identify the best policy strategies for sustainable energy transition by using a hybrid Multi-Criteria Decision Making (MCDM) approach. The research basically applies a DEMATEL-VIKOR framework to discuss five policy alternatives: Renewable Energy Promotion (RP), Energy Efficiency and Demand-Side Management (EE&DSM), Grid Modernization (GM), Fossil Fuel Transition (FFT), and Institutional, Regulatory and Market Reform (IR). Seven criteria, from Economic Efficiency (EE) to Policy Consistency (PC), were used for evaluation. The analysis by DEMATEL points to the Institutional and Regulatory Effectiveness (IE) as being the most crucial causal driver with the highest prominence score of 3.84 and a net causality value of 0.53. These results give direct information to the VIKOR analysis, where IR (A5) is the best compromise solution with a perfect Q-index value of 0.00 and the lowest individual regret (R-index) value of 0.08. In comparison, Fossil Fuel Transition (FFT) ranked the worst with a Q-index of 1.00. Sensitivity analysis to prove the robustness of IR as the dominant policy for all decision-making parameters (v). The results have illustrated that the energy policy of Vietnam should place more emphasis on institutional strengthening and grid modernization (Q = 0.22) than stand-alone technological deployment to ensure a stable, efficient, and equitable energy transition.

Keywords: Vietnamese policy; Sustainable transition; Energy policy; VIKOR; DEMATEL; Multi-criteria decision making approach

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1. Introduction

Vietnam is experiencing a major restructuring of its energy industry. The government is trying to keep the economy growing fast while at the same time trying to deal with increasing energy demand, environmental destruction, and international climate obligations (Hoang *et al.* 2022; Derouez and Ifa 2025; Huyen 2025). Vietnam's system has changed over the last 20 years from a comparatively energy-rich system to one characterized by capacity limitations and increasing demand to decarbonize the mix of power generation. In response, the government has made several changes in its energy policies to promote the use of renewable energy, improve energy efficiency efforts, update the infrastructure to enable the use of power, and improve institutional and regulatory frameworks (Hoai Thuong *et al.* 2025; Sudirman *et al.* 2025; Carson *et al.* 2025). A clear policy orientation towards a more diversified, low-carbon, and resilient energy system is mirrored in recent strategic initiatives, including new national plans for power development, as well as targets for renewable energy (Nguyen *et al.* 2025a, b, e). Due to the differences in formulation of policies, implementation capabilities, and interaction of institutional, technical, economic, and environmental factors, the efficacy of different policy interventions varies enormously (Shem *et al.* 2019; Nguyen *et al.* 2024a). There are many methodological challenges in assessing the efficacy of energy policies in such a complicated and changing environment. The results of energy policy are by definition multifaceted, not just on the economic success, but also on the long-term institutional stability, social acceptability, sustainability, and energy security (Huong *et al.* 2021; ASEAN Energy Cooperation 2025). Furthermore, the impact of policies often takes place over long periods of time and is influenced by other unpredictable external factors such as the behaviour of stakeholders and the volatility of markets and technology. These difficulties are aggravated in developing and emerging nations such as Vietnam due to a lack of data, obscure regulations, and the existence of multiple, sometimes incompatible, government goals (Do *et al.* 2021; Hung 2023). Because of this, traditional approaches to evaluation, which are based on precise quantitative measures or deterministic assumptions, tend to fail in capturing the complex and unpredictable nature of energy policy-making (Phuong Nguyen and Nguyen 2025a; Thai Hung and Thanh Tu 2025).

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When studying energy policy, uncertainty plays a very important role. Many critical policy factors, such as long-term environmental benefits, societal acceptance, investment attractiveness, and regulatory effectiveness, are difficult to quantify directly and often are assessed with the aid of expert opinion rather than empirical facts (Le *et al.* 2024; Nguyen *et al.* 2024b). These assessments, which are limited to information and subjective perceptions, are generally worded. It is such imprecision that very difficult for traditional analytical methods to handle and, as a result, it leads to the simplistic representation of complicated reality, or the omission of important qualitative characteristics (Morelli and Mele 2020; Gverdtsiteli 2023). As a result, there is a growing recognition of the need for evaluation frameworks that can express ambiguity and uncertainty and that, at the same time, maintain the depth of expert knowledge. Even though the evaluation of the effectiveness of energy policies is multifaceted, many studies still use evaluation methods that are either single-criteria evaluation or have a limited definition (Nguyen and Poczta-Wajda 2024,Vo *et al.* 2024a). For instance, cost-benefit analysis remains very commonly used, despite having been demonstrated to be logically clear and neutral and often favors economic efficiency at the expense of institutional, social, and environmental factors. In a similar vein, indicator-based evaluations tend to aggregate different measures of performance into composite indices without proper attention to the relations between criteria, or the relative importance of different policy objectives (Vo *et al.* 2024b; Liu *et al.* 2024). These methods assume, in an implicit way, a stable policy context and independence between the aspects of evaluation that are rarely true in the real world. For policymakers who need to work in complicated and uncertain environments, these techniques may produce rankings or recommendations that are deceptive or insufficiently informative (Thi Mai *et al.* 2024; Thai Hung and Thanh Tu 2025). The natural complexity of energy policy evaluation has led to the development of multi-criteria decision-making (MCDM) techniques as a powerful substitute for the same. MCDM techniques offer a more comprehensive accounting of the performance of policies in the sense that they allow for the simultaneous analysis of multiple, and sometimes conflicting, criteria (Wang *et al.* 2022, 2025). They work especially well in situations where choices need to find a balance between social justice, environmental preservation, economic growth, and institutional viability. However, there are still several restrictions in the literature, including the MCDM literature, in which many applications produce underestimations of subjectivity and ambiguity in expert assessments by identifying stable preferences and precise numerical inputs in the MCDM method (Al-Atesh *et al.* 2021; Candra Sari *et al.* 2022; Dat *et al.* 2025). The causal relationships between policy variables, for example, whether institutional efficacy has an impact on technological feasibility or economic efficiency, are also frequently ignored by commonly applied ranking approaches, which rely on evaluation criteria being independent of each other.

This study uses a combination of the VIKOR approach, Decision-Making Trial and Evaluation Laboratory (DEMATEL), and Interval Type-2 Fuzzy Sets (IT2FS) as an integrated evaluation framework to overcome these restrictions. By permitting membership functions to be fuzzy, IT2FS is a versatile and reliable way to express uncertainty, which may be used to capture higher-order ambiguity in expert judgment. In the case of energy policy analysis, where experts may or may not agree or may not know enough, this capability is particularly useful. The driving and dependent factors in the energy policy system can be identified by modeling the causal structure between evaluation criteria using the DEMATEL approach. DEMATEL contributes to enabling more targeted policy actions and enabling good interpretability of findings from the exposure of cause and effect (Pairan *et al.* 2023). Since energy policy choices often do not lead to the most optimal result in terms of a single criterion, the VIKOR technique is then subsequently applied to the ranking of policy alternatives and finding those that represent a compromise solution between competing objectives. Compared to traditional methods of evaluation, such fusion of IT2FS-DEMATEL and VIKOR have a number of advantages. First, it reduces the likelihood of biased or unduly determined results because it makes explicit allowances for subjectivity and uncertainty in expert assessments. Second, capturing the interdependence between evaluation criteria yields a more complete understanding of the structural dynamics of the efficacy of energy policy. Third, it generates policy rankings that focus on stability and compromise to the exclusion of extreme optimality, which is especially suitable in the context of public policy settings where it is important to balance the minds of different stakeholders. These characteristics combined make the framework suggested ideal for energy policies assessment in Vietnam, which has complex institutions, fast technical development, and changing government objectives.

Thus, the primary objective of this research is to develop and implement a framework of integration of IT2FS-DEMATEL-VIKOR, towards the assessment of the success of major energy policy options of Vietnam in a systematic manner. The particular aims of the study are to: (i) identify and structure some of the important factors affecting the success of energy policy, (ii) study the causal relation between the factors under uncertainty, (iii) rank the competing energy policy alternatives using compromise-oriented evaluation, and (iv) study the robustness of the results by sensitivity analysis. The research is making a significant contribution to literature in several ways. From the methodological point of view, it enriches the assessment of energy policies, clustering the compromise-based ranking and the causal analysis in a fuzzy type-2 environment in combination with an interval type-2. From the empirical perspective, it identifies some major areas to develop policies and gives context-specific information on the energy policy landscape in Vietnam. Lastly, from a pragmatic point of view, the results provide useful guidance for the decision-makers who wish to develop and implement more robust, cohesive, and successful energy policies in support of Vietnam's long-term energy transition objectives.

2. Methodology: IT2FS-DEMATEL–VIKOR Framework

2.1 Identification of Evaluation Criteria and Policy Alternatives

The energy policy options involved in the energy landscape of Vietnam are selected to be evaluated in five major options as listed in Table 1. Such options are diverse policy directions, intervention approaches, and isolated instruments, which can be assessed more comprehensively. Finding the proper assessment criteria and policy choices is the first needed step to check the success of energy policies, especially in the complicated and dynamic energy system of Vietnam. It requires a general and policy-relevant list of conditions to account for the interdependence established by the many aspects of energy regulation (economic, environmental, technical, social, and institutional). This study has found 7 major criteria to assess the

Table 1
Energy Policy Alternatives Considered for Evaluation

Code	Energy Policy Alternative	Description	Abb.
A1	Renewable Energy Promotion Policies	Policies supporting the employment of renewable energy technologies like solar, wind, biomass, and hydropower, through feed-in tariffs, competitive auctions, fiscal incentives, and investment support mechanisms (Febrina *et al.* 2025; Phuong Nguyen and Nguyen 2025b)	RP
A2	Energy Efficiency and Demand-Side Management Policies	Policies aimed at reducing energy consumption through industrial energy efficiency measures, building energy codes, appliance efficiency standards, and demand-response programs (Gooneratne and Pokhrel 2010; Thuy and Limmeechokchai 2015)	EE&DSM
A3	Grid Modernization and Energy Infrastructure Policies	Policies focusing on transmission and distribution expansion, smart grid deployment, energy storage integration, and enhancement of grid flexibility to accommodate renewable energy sources (Son and Voropai 2015; PIECH and SOBCZYK 2025).	GM
A4	Fossil Fuel Transition and Emission Reduction Policies	Policies targeting the gradual reduction of coal dependency, improvement of fuel quality, and implementation of emission control technologies in thermal power generation (Droege 2011; Hoang *et al.* 2023).	FFT
A5	Institutional, Regulatory, and Market Reform Policies	Policies addressing governance quality, regulatory transparency, electricity market liberalization, private-sector participation, and institutional coordination within the energy sector (Huong To and Minh Tran 2025; Nguyen *et al.* 2025d).	IR

Table 2
Evaluation Criteria for Assessing Energy Policy Effectiveness

Code	Criterion	Description	Abb.
C1	Economic Efficiency	Extent to which the policy minimizes system costs, enhances investment attractiveness, and ensures long-term financial sustainability of the energy sector (Pham *et al.* 2023).	EE
C2	Environmental Impact Mitigation	Ability of the policy to reduce greenhouse gas emissions, air pollutants, and other adverse environmental impacts (Nguyen *et al.* 2025d).	EI
C3	Energy Security Enhancement	Contribution of the policy to improving supply reliability, diversification of energy sources, and resilience of the national energy system (Selvakkumaran and Limmeechokchai 2013; Nasir *et al.* 2022).	ES
C4	Technical Feasibility	Practical implementation ability of the policy, considering technological maturity, infrastructure readiness, and operational constraints (Karagiannidis *et al.* 2009; Gadaleta *et al.* 2023; Truong *et al.* 2024)	TF
C5	Social Acceptance and Equity	The degree to which the policy is socially acceptable, affordable, and equitably benefits various stakeholder groups, including vulnerable populations (Thi *et a*l. 2025; Nguyen *et al.* 2025c).	SA
C6	Institutional and Regulatory Effectiveness	Effectiveness of policy design, regulatory enforcement, administrative capacity, and coordination among relevant institutions (Rehman *et al.* 2017; Ridho and Paksi 2025).	IE
C7	Policy Consistency and Long-Term Alignment	Alignment of the policy with national development objectives, climate commitments, and long-term energy transition strategies (Ullah *et al.* 2022; KÜÇÜK and Mohammad 2025).	PC

effectiveness of energy policies, as shown in Table 2. They are based on the thorough examination of national energy policies, new plans on the development of power resources, renewable energy strategies, and consultations with specialists. Collectively, the criteria suggest the energy transformation aim and constraints of Vietnam.

Causal relationship among the selected criteria is revealed using the Interval Type 2 Fuzzy DEMATEL methodology, which captures the inherent interdependence of these criteria, especially in terms of institutional efficacy, economic performance, and technical feasibility. Balance solutions that trade-off competing policy objectives are then determined and ranked using the VIKOR method. This combined approach is still methodologically effective and practically relevant to the context of the energy policy in Vietnam.

2.2 Expert Panel and Data Collection

In order to meet the complex and unpredictable nature of energy policy performance in Vietnam, particularly in aspects where quantitative data is low or not representative, the evaluation approach proposed in this research relies on expert knowledge. A purposive expert panel was thus assembled, consisting of people with significant professional involvement and experience in the energy industry. Twenty professionals employed in the sectors of planning, implementation, and energy policy were first asked to participate in the study. Sixteen of these experts agreed to participate, and twelve of them were able, ultimately, to provide comprehensive and practical answers that incorporated the data to do the analysis. The final expert panel was comprised of academic researchers with expertise in energy systems, sustainability, and policy analysis; industry practitioners with practical experience in power generation, grid operation, and renewable energy deployment; and policymakers involved in energy planning and regulatory oversight. Every expert who participated had at least 10 years of relevant work experience and demonstrated an understanding of the changing energy policy environment in Vietnam, including both new regulatory changes and the country's growth priorities. The credibility of the elicited judgments was enhanced by the diversity of the expert backgrounds, which ensured that a fair representation of strategic, analytical, and operational perspectives was obtained.

Being an inherently ambiguous and subjective question, data collection through a structured questionnaire was conducted, which was designed to elicit expert assessments in terms of language and not exact numbers. Different degrees of influence and performance were modelled by a predetermined language scale, which was then mapped to interval type-2 fuzzy sets to explicitly model the uncertainty. A more detailed picture of expert opinions is given by this representation, which includes both the membership grades, and their uncertainty bounds in the study. To construct the input matrices required for IT2FS-DEMATEL and VIKOR analyses, individual expert opinions were aggregated by the appropriate fuzzy operators, which ensures consistency, robustness, and analytical rigor during the evaluation process.

2.3 IT2FS-DEMATEL for Causal Analysis

- *Construction of the initial direct-relation matrix (Kou et al. 2021, Dincer and Yuksel 2019, Hosseini and Tarokh 2013)*

Let $C = \{c_1, \dots, c_n\}$ be the set of criteria and $D^{(k)} = [\tilde{z}_{ij}^{(k)}]$, the interval type-2 fuzzy direct-relation matrix of the expert k, where each $\tilde{z}_{ij}^{(k)}$ is an IT2 fuzzy number representing the influence of c_i on c_j.

The group IT2FS direct-relation matrix $\tilde{Z} = [\tilde{z}_{ij}]$ is obtained by aggregating the p experts' matrices through an IT2FS weighted averaging operator, such as

$$\tilde{z}_{ij} = \text{IT2-LWA}(\tilde{z}_{ij}^{(1)}, \dots, \tilde{z}_{ij}^{(p)}), i, j = 1, \dots, n. \quad (1)$$

- *IT2FS aggregation and normalization*

Each IT2 fuzzy element $\tilde{z}_{ij}$ is first converted to a representative crisp value using a graded mean integration representation (GMIR) operator:

$$d_{ij} = \text{GMIR}(\tilde{z}_{ij}), i, j = 1, \dots, n. \quad (2)$$

The normalized direct-relation matrix $X = [x_{ij}]$ is then obtained as

$$s = \max_i \sum_{j=1}^{n} d_{ij}, x_{ij} = \frac{d_{ij}}{s}, i, j = 1, \dots, n, \quad (3)$$

which ensures that $\max_i \sum_j x_{ij} < 1$ for the convergence of subsequent DEMATEL computations.

- *Total relation matrix*

Let I denote the $n \times n$ identity matrix, the total relation matrix $T = [t_{ij}]$ is computed as

$$T = X(I - X)^{-1}, \quad (4)$$

which captures both direct and indirect influences among criteria in a single matrix. The row and column sums are then obtained as

$$D_i = \sum_{j=1}^{n} t_{ij}, R_j = \sum_{i=1}^{n} t_{ij}, i, j = 1, \dots, n. \quad (5)$$

- *Cause–and–effect classification of criteria*

For each criterion $\boldsymbol{c_i}$, the prominence and relation indices are defined as:

$$P_i = D_i + R_i, E_i = D_i - R_i, i = 1, \dots, n. \quad (6)$$

Criteria with $E_i > 0$ are classified as cause factors (net influencers), while those with $E_i < 0$ are classified as effect factors (net receivers), and the magnitude $|E_i|$ indicates the strength of net causal impact.

2.4 VIKOR for Policy Effectiveness Ranking

Assume m energy policy alternatives A_j $(j = 1, \dots, m)$ and n criteria c_i with weights w_i such that

$$\sum_{i=1}^{n} w_i = 1. \quad (7)$$

- *Determination of best and worst values*

Let f_{ij} denote the performance of the policy A_j on criterion c_i.

For benefit-type criteria, the best and worst values are

$$f_i^* = \max_j f_{ij}, f_i^- = \min_j f_{ij}, i = 1, \dots, n, \quad (8)$$

While for cost-type criteria, the definitions are reversed.

- *Computation of S, R, and Q indices*

The group utility S_j and individual regret R_j for policy A_j are computed as

$$S_j = \sum_{i=1}^{n} w_i \frac{f_i^* - f_{ij}}{f_i^* - f_i^-}, R_j = \max_i \left\{ w_i \frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right\}, j = 1, \dots, m. \quad (9)$$

Let $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, and $R^- = \max_j R_j$; the VIKOR index Q_j is then given by

$$Q_j = v \frac{S_j - S^*}{S^- - S^*} + (1 - v) \frac{R_j - R^*}{R^- - R^*}, 0 \le v \le 1, \quad (10)$$

where v reflects the decision strategy between majority utility and individual rate. All policies are ranked in ascending order of Q_j, yielding a compromise ranking $A_{(1)}, A_{(2)}, \dots, A_{(m)}$ with $A_{(1)}$ as the most effective policy. Subject to the acceptable advantage and acceptable stability conditions on the best alternative, $A_{(1)}$ is selected as the compromise solution or supplemented by a set of top-ranked policies when these conditions are not fully satisfied (Opricovic and Tzeng 2007, Opricovic and Tzeng 2004, Rani *et al.* 2020).

2.5 Sensitivity Analysis

By systematically changing the decision strategy parameter over its entire range, from 0 to 1, sensitivity analysis measures the resilience of VIKOR ranks. This value is a compromise between maximum individual regret (worst-case performance on one of the different criteria) and group utility (average performance on all of the different criteria). The VIKOR index $\boldsymbol{Q_j}$ is then recalculated for each discrete v value (typically evaluated at increments of 0.1) for all energy policy options, which results in a series of compromise rankings. The stability of the top-ranked policy and overall preference order, more specifically in the sphere of the decision-maker's realistic options (for instance, $\boldsymbol{v} \in [\mathbf{0.3}, \mathbf{0.7}]$), is next evaluated with the intent of ranking stability. This stability is measured quantitatively using Spearman's rank correlation coefficient between the baseline ranking (sometimes at v=0.5) and the various v-specific rankings; values close to one indicate robust ordering that is not affected by strategy adjustments. In addition to $\boldsymbol{v}$ variation, some other perturbations of the criteria weights and performance scores are also included in the final robustness validation (Wasilewski *et al.* 2024, Wei 2025). Results are considered to be trustworthy for policy implementation if the leading policy is still superior with combined adjustments; however, if not, model improvement or other types of MCDM techniques are recommended.

3. Results and discussion

3.1 Results of IT2FS-DEMATEL

The heatmap provided in Figure 1 shows the DEMATEL direct relation matrix quantifying the causal relations between the seven evaluation criteria (C1-C7) to assess the effectiveness of energy policy. Each numerical value expresses the degree of influence that one criterion has over another, with higher values (shades of red) indicating greater influential power. Based on the data, Institutional and Regulatory Effectiveness (IE) becomes the most dominant driver in the system. It has the highest influence scores across the board, especially in the areas of Policy Consistency (PC) (0.63) or Economic Efficiency (EE) (0.61). This logic seems to imply that the success of technical or environmental goals is fundamentally reliant on the underlying governance and regulatory framework. Conversely, Social Acceptance and Equity (SA) seem to be more of a "receiver" or "resultant" factor, being relatively lower in its ability to influence pillars such as Economic Efficiency (EE) (0.26). In addition, there appears to be a strong two-way relationship between Economic Efficiency (EE) and Institutional Effectiveness (IE), reflecting the fact that financial sustainability and market reform are often combined. By analyzing these interdependencies, policymakers can identify that improving IE will yield the highest systemic "multiplier effect" across all other criteria, including Environmental Impact (EI) and Energy Security (ES).

Figure 2 shows the criteria prominence, which is defined as the sum of dispatched and received influences (D+R) for the seven evaluation criteria defined in Table 2. This metric is a measure of the total importance or centrality of a criterion in the energy policy evaluation system. It is evident from the bar chart that Institutional and Regulatory Effectiveness (IE) is the most prominent factor with a value of 3.84. This logical high point suggests that IE is the main driver and central link inside the network and has a strong impact on other factors such as Economic Efficiency (EE) and Policy Consistency (PC).

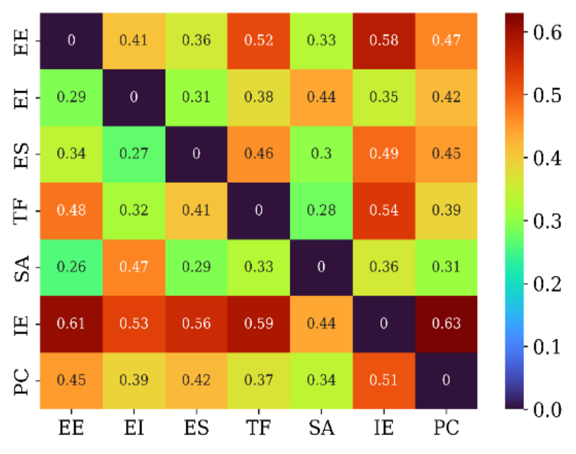

Fig. 1 DEMATEL direct relation matrix

	EE	EI	ES	TF	SA	IE	PC
EE	0	0.41	0.36	0.52	0.33	0.58	0.47
EI	0.29	0	0.31	0.38	0.44	0.35	0.42
ES	0.34	0.27	0	0.46	0.3	0.49	0.45
TF	0.48	0.32	0.41	0	0.28	0.54	0.39
SA	0.26	0.47	0.29	0.33	0	0.36	0.31
IE	0.61	0.53	0.56	0.59	0.44	0	0.63
PC	0.45	0.39	0.42	0.37	0.34	0.51	0

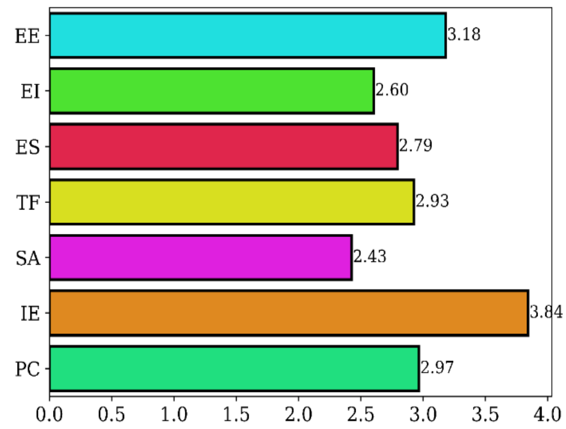

Fig. 2 Criteria prominence (D+R)

Economic Efficiency (EE) is the second most prominent criterion at 3.18, which highlights its critical importance in terms of long-term financial sustainability of energy alternatives. Conversely, Social Acceptance and Equity (SA) have the lowest prominence at 2.43, indicating that it is more of an isolated result than focalized. Overall, the prominent values indicate a hierarchy in which governance and economic viability are the backbone of good energy policy implementation.

Figure 3 describes the net causality of the evaluation criteria, as the difference between dispatched and received influence (D-R). In the DEMATEL methodology, criteria with positive values are classified as causal factors (drivers), and those with negative values are classified as effect factors (receivers). Institutional and Regulatory Effectiveness (IE), in particular, is the biggest causal factor with the highest positive value of 0.53. This suggests that improvements in governance, regulatory enforcement, and administrative capacity are at the core of triggering improvements in the rest of the energy system. Economic Efficiency (EE) also acts as a causal factor at 0.26, showing that the financial sustainability and cost-minimization of a policy directly impact on its overall success. In contrast, Environmental Impact Mitigation (EI) is the most significant effect factor with a value of -0.24, followed by Technical Feasibility (TF) and Policy Consistency (PC) with a value of -0.20 and -0.19, respectively. This logic suggests that environmental achievements or technical readiness are, to a large degree, a result of the basic regulatory and economic structures in place. By focusing on the causal pillars of IE and EE, policymakers can better control the resultant environmental

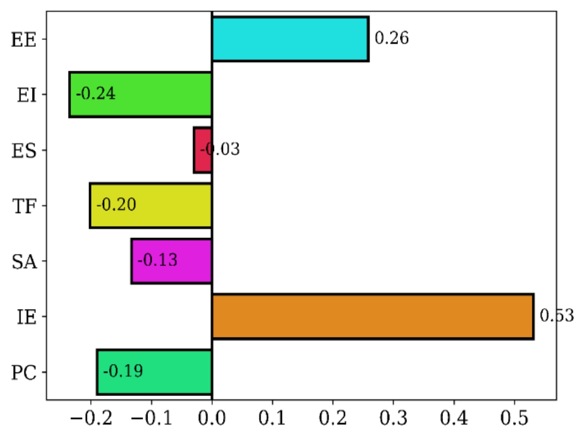

Fig. 3 Cause and effect (D-R)

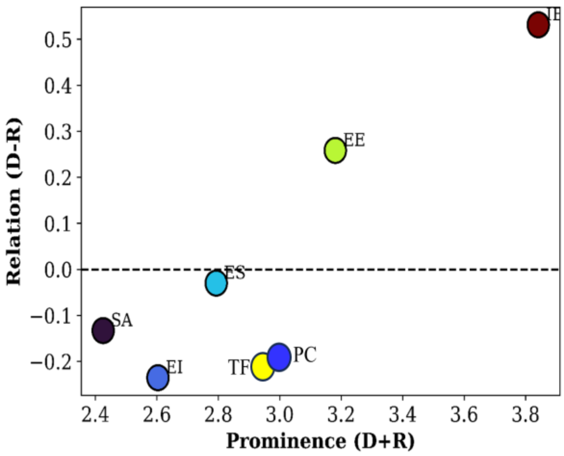

Fig. 4 DEMATEL causal network

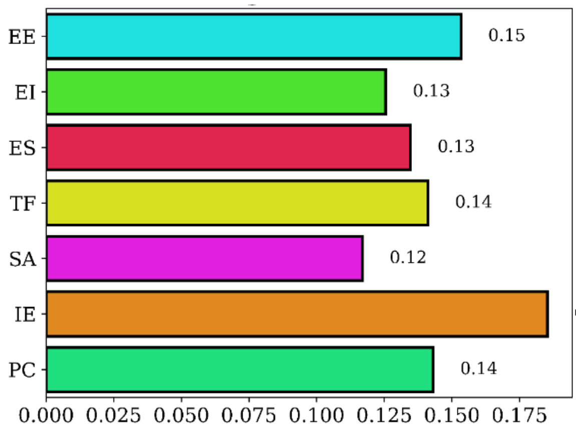

Fig. 5 Criteria weights (from DEMATEL)

and social outcomes.

Figure 4 shows the DEMATEL causal network that can be used to synthesize the results obtained in the previous analyses through the mapping of evaluation criteria on a Cartesian coordinate system. The horizontal axis is Prominence (D+R), a measure of the sum of the influence and importance of a criterion, and the vertical axis is Relation (D-R), showing whether a criterion is a net cause or effect. Institutional and Regulatory Effectiveness (IE) is located in the upper-right quadrant, making it the most important causal factor with the highest prominence (3.84) and net relation (0.53). This validates that governance is the underlying peg of the whole policy system. Economic Efficiency (EE) also lies in the causal zone with high importance in driving other factors. On the contrary, bottom-left and bottom-center include the effect factors, including Environmental Impact Mitigation (EI), Technical Feasibility (TF), Policy Consistency (PC), and Social Acceptance (SA). These factors have negative (D-R) values, which means that they are the beneficiaries of improvements made to IE and EE. Energy Security (ES) lies close to the zero line and is a transition element. The visual evidence indicates that effective optimization of the energy sector should strategically prioritize high-prominence causal drivers, particularly IE, as they exert the strongest systemic influence.

3.2 VIKOR analysis

Figure 5 shows the final criteria weights obtained by the DEMATEL analysis, which are critical inputs to the subsequent VIKOR multi-criteria decision-making process. These weights measure the relative importance of each of the evaluation criteria (C1-C7) according to their systemic influence. Institutional and Regulatory Effectiveness (IE) is the most influential factor at 0.19, signaling further its role as the most important driver for successful energy policy. Economic Efficiency (EE) comes next with a weight of 0.15, followed by Technical Feasibility (TF) and Policy Consistency (PC) with a weight of 0.14. Environmental Impact Mitigation (EI) and Energy Security (ES) have the same weight of 0.13, and the lowest weight belongs to Social Acceptance (SA), which is 0.12. In the context of VIKOR analysis, these weights will be used for aggregating the performance of policy alternatives (A1-A5) and calculating the compromise ranking of policy alternatives. By taking the IE and EE into account first, the VIKOR model will naturally give a preference to alternatives that have shown good governance and financial sustainability.

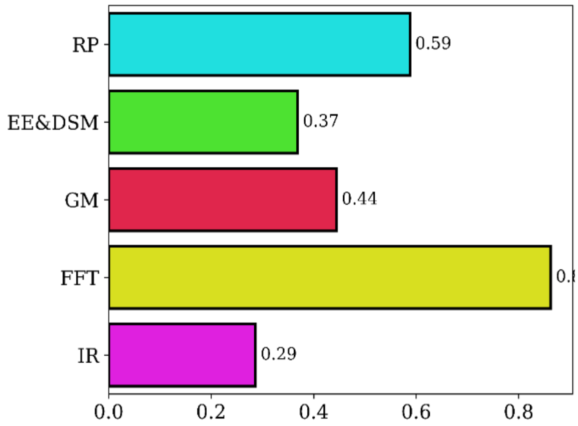

Fig. 6 Vikor S index

Figure 6 presents the results obtained for the values of the S index, the measure of the group utility in the VIKOR approach, for the five energy policy alternatives. However, in this context, the smaller the S value, the closer an alternative is to the ideal solution by maximizing the total utility according to all the criteria weighed. Institutional, Regulatory, and Market Reform Policies (IR) have the best performance with the lowest score of 0.29. This suggests that institutional frameworks are the most important things to prioritize in order to get the greatest benefit to the energy system overall. Following IR is Energy Efficiency and Demand-Side Management (EE&DSM), which has a value of 0.37, and Grid Modernization (GM) has a value of 0.44. Renewable Energy Promotion (RP) comes next at 0.59, then Fossil Fuel Transition (FFT) has the worst distance from the ideal utility at 0.86. The logic of these results suggests that there is higher collective utility in governance-based and efficiency-focused strategies than in technology-specific or transition-heavy policies when one is to be assessed against the set criteria.

Figure 7 illustrates the R index values, which are the maximum individual regret for energy policy alternatives in the VIKOR framework. In this context, the R index quantifies the worst performing criterion for each alternative, where the lower the score, the more balanced the performance is (no extreme deficiencies in any one of the areas). Institutional, Regulatory, and Market Reform Policies (IR) gets the best result with the lowest R index of 0.08, indicating that it has the lowest individual regret among the options. Grid Modernization (GM)

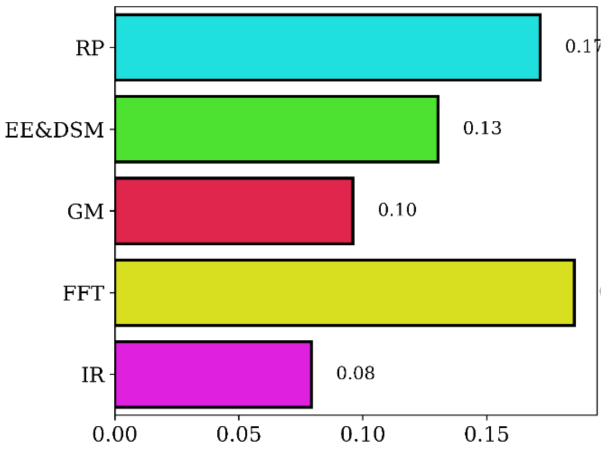

Fig. 7 Vikor R index

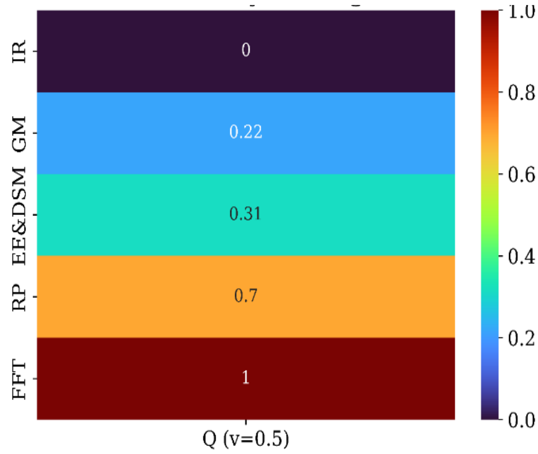

Fig. 9 Final policy ranking

has the next score of 0.10, and Energy Efficiency and Demand-Side Management (EE&DSM) has a score of 0.13. Renewable Energy Promotion (RP) and Fossil Fuel Transition (FFT) had higher levels of regret at 0.17 and 0.19, respectively. The logic of these findings seems to suggest that governance-based reforms (IR) are not only effective for group utility but also the most stable choice, as there is the least possible risk of significant failure in any particular evaluation category. Consequently, it can be seen that A5 is the most robust alternative when considering individual criterion constraints.

The final VIKOR ranking index (Q) of the five energy policy alternatives is shown in Figure 8 using the weight of the stability (v), which is set at 0.5. This index is the final compromise score between the group utility (S) and the individual regret (R). Within the VIKOR logic, when an alternative has the lowest Q value, it is regarded as the best alternative. Institutional, Regulatory, and Market Reform Policies (IR/A5) scores a perfect Q score of 0.00, conclusively making it the best-ranked policy alternative. This result is highly consistent with the previous results obtained by DEMATEL, which found governance and institutional effectiveness as the main causal drivers for the whole system. Grid Modernization (GM/A3) has the second-highest Q value of 0.22, closely followed by Energy Efficiency and Demand-Side Management (EE&DSM/A2), which has a Q value of 0.31. Renewable Energy Promotion (RP/A1) has a much higher index of 0.70, whereas Fossil Fuel Transition (FFT/A4) has the highest score of 1.00, which makes it a more favorable leasing option. These results show that

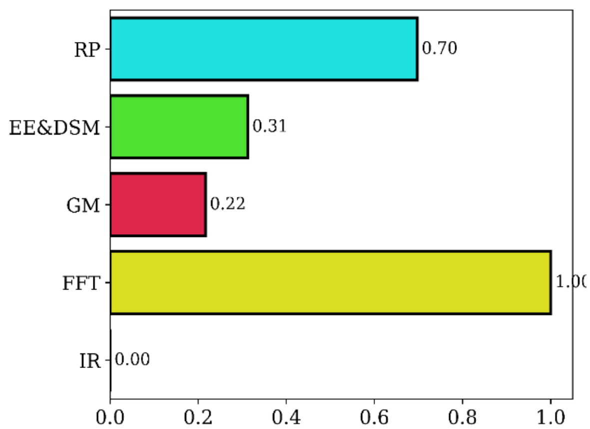

Fig. 8 Vikor Q index (v = 0.05)

institutional strengthening and infrastructure modernization should take precedence over isolated technology deployment or fossil fuel adjustments in a stable policy strategy to achieve the optimal overall balance on economic, environmental, and social criteria.

Figure 9 shows the VIKOR compromise ranking results at balanced decision strategy parameter (v=0.5) in which equal importance is given to group utility and individual regret. The normalized Q values provide a clear difference in the relative performance between the five energy policy alternatives and offer a stable reference point for prioritizing policies. Institutional and Regulatory Reform (IR) achieves the minimum Q value of 0, which means that it is the ideal compromise solution under circumstances of balanced decision. This outcome reflects IR's consistently good performance in economic, institutional, and long-term alignment criteria, with no critical weaknesses dominating the evaluation. Grid Modernization (GM) comes next with a low Q value of 0.22, indicating a favorable compromise position that is supported by its role in improving system reliability, flexibility, and renewables integration, despite moderate implementation challenges. Energy Efficiency and Demand-Side Management (EE&DSM) is ranked next with a Q value of 0.31, which is relatively good in terms of effectiveness, but with rather greater performance on different criteria such as institutional readiness or social acceptance. Renewable Energy Promotion (RP) has a much higher Q-value of 0.70, which means that although it has high environmental and long-term value, there are significant trade-offs in terms of cost-effectiveness, grid compatibility or short-term viability. Fossil Fuel Transition (FFT) is the worst with the highest Q value of 1.00, confirming its worst compromise position because of continuous environmental, economic, and policy constraints. Overall, Figure 10 reinforces the robustness of VIKOR results by clearly showing the most stable and balanced policy alternative of IR and shows the relative gaps that restrict the competitiveness of RP and FFT under a neutral decision-making perspective.

3.3 VIKOR sensitivity analysis

The VIKOR sensitivity analysis (Figure 10) explores the stability of the policy rankings by changing the value of the decision strategy parameter (v), which balances the group utility (majority satisfaction) and individual regret (opposition from the worst-performing criterion). As shown in the analysis, Fossil Fuel Transition policies (FFT) have a constant and maximum Q

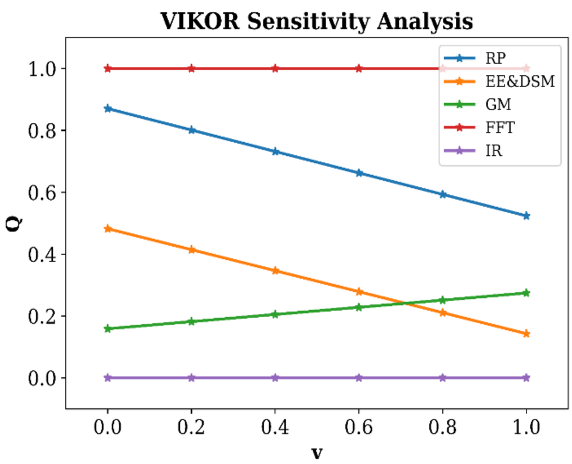

Fig. 10 VIKOR sensitivity analysis

value over the entire range of (v), i.e., consistently poor performance regardless of whether the decision emphasis is collective benefit or individual regret minimization. This invariance implies that FFT is the least favorite alternative under any compromise situation and can be seen as a result of structural weaknesses under many different evaluation criteria. Renewable Energy Promotion (RP) has a clear decreasing trend in Q values with increasing (v), implying that the relative performance of (RP) improves with increasing weight given to group utility. This behavior emphasizes RP's high aggregate benefits over the criteria of economic, environmental, and long-term alignment, making it more attractive in consensual decision contexts. On the other hand, Energy Efficiency and Demand-Side Management (EE&DSM) shows a reducing Q trajectory with the increasing (v), and at last it converges to Grid Modernization (GM). This suggests that EE&DSM works well in regret-sensitive settings but loses relative advantage in broader system-wide benefits settings.

4. Conclusion

The evaluation of energy policy effectiveness in Vietnam underlines the basic need for good governance and market reform in reaching a successful national energy transformation. Through the combination of DEMATEL and VIKOR method, this study is illustrated to show that Institutional, Regulatory, and Market Reform Policies offer the greatest group utility ($S = 0.29$), and the minimum regret ($R = 0.08$) for an individual. The near dominance of the IR alternative in different sensitivity scenarios confirms that in the absence of a strong regulatory framework, the effectiveness of technical policies or other environmental policies, e.g., Renewable Energy Promotion (Q = 0.70), is limited by systemic inefficiencies and higher trade-offs in cost-effectiveness. Furthermore, Grid Modernization was found to be a crucial secondary priority with a low Q value of 0.22, consistent with the necessity of enhancing system reliability and accommodating renewables despite the moderate implementation difficulty. The research comes to the conclusion that a balanced decision strategy prioritizes institutional readiness to minimize implementation risks and maximize economic efficiency. The future scope for this research is to extend the evaluation framework to also include emerging technologies such as green hydrogen and carbon capture under the Fossil Fuel Transition category, which currently registers the greatest distance from the ideal solution with a Q-index of 1. Additionally, the fuzzy-based MCDM models proposed in subsequent studies could be used for consideration of the inherent uncertainties and subjective judgments of the various stakeholders in the Vietnamese energy sector. Integrating sub-national data would also give more granular information on regional constraints of infrastructure and social acceptance levels in the country as well, especially for Energy Efficiency and Demand-Side Management, which ranked third with a Q value of 0.31. Ultimately, this multi-criteria approach offers a stable point of reference for prioritizing policies that are consistent with Vietnam's long-term development goals and climate commitments.

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