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Development of a sustainable corporate social responsibility index for performance evaluation of the energy industry: A hybrid decision-making methodology

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A R T I C L E I N F O

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A B S T R A C T

The ever-increasing pressure from stakeholders and policymakers on energy companies to achieve Sustainable Development Goals (SDGs) and Corporate Social Responsibility (CSR) mission requires them to reinvent their policies and practices. This study aims to examine the performance of alternative business models for the oil and gas industry by employing a hybrid business analytics methodology under a fuzzy environment resulting in a generalizable model named "Sustainable Development Goals-oriented CSR Index." The proposed methodology employs a hybrid framework that utilizes bipolar Q-rung Orthopair Fuzzy (q-ROF), Multi Stepwise Weight Assessment Ratio Analysis (M-SWARA), and Elimination and Choice Translating Reality (ELECTRE) methods. The findings show that (i) the proposed model is reliable and consistent throughout the similar fuzzy set value ranges, (ii) clean energy is the most important SDG-oriented CSR Index factor for the sustainable energy industry in emerging economies, (iii) drilling is the best alternative energy sourcing for the oil and gas industry, and (iv) clean energy projects have the highest priority for energy investors. The results also highlight that global warming can be managed with effective energy practices for long-term sustainability. Finally, the findings suggest that energy companies should have the essential technological infrastructure and capable workforce to increase investment efficiency.

1. Introduction

Increasing challenges in the political arena due to unequal treatment of people, economic sanctions, international conflicts, and rising commodity prices, raise concerns about global sustainable economic growth, financial stability, people's well-being, and agricultural and energy resources adequacy. To calibrate this environment, United Nations (UN) launched a roadmap in 2015 and adopted the 2030 Sustainable Development Agenda which comprised 17 Sustainable Development Goals (SDGs) to pave the way for global prosperity and peace for mankind and the planet (UN, 2015). The roadmap mainly aims to reduce inequality, improve health and education, maintain economic stability, and manage climate change.

Among all SDGs, energy efficiency and the use of renewable energy resources stands to be one of the most well-noted goals. The increasing interest of global wealth management companies and stakeholders in SDGs and Corporate Social Responsibility (CSR) matters push energy companies to provide more proof of their corporate financial and non-financial performance for showing their long-term commitment to the SDGs agenda, particularly SDG-7 which aims to ensure sustainable energy across the globe. In this context, companies concentrated on the oil and gas extraction challenge with intensifying pressure from stakeholders to reduce greenhouse gas (GHG) emissions. To cope with this challenge, UN SDGs developed a diversified and environmentally friendly framework for energy companies to help in implementing effective strategies (Wang et al., 2023; Dong et al., 2023). In a similar vein, CSR activities of energy companies, as a business model, play a vital role in meeting the expectations of stakeholders.

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Furthermore, respective oil and gas companies incorporated the energy transition, leveraging their experience in the oil and gas sector to pursue a sustainable and renewable energy development process. In this frame, they implement CSR activities and act more consciously in their operations by taking necessary actions i.e., waste management, renewable energy production and consumption, and innovative technological solutions, to reduce carbon emissions and protect the environment and society (Barauskaite and Streimikiene, 2021; Carroll, 2021; Luo et al., 2021; Su and Urban, 2021). These actions also help energy companies to improve their corporate reputation and gain competitive advantages (Tibiletti et al., 2021). Beyond these benefits, investors and other stakeholders closely monitor environmental, social, and governance (ESG) disclosures of energy companies to ensure that they care about the well-being of society (Islam et al., 2021). Therefore, energy companies should execute a hybrid outline to implement a strategic, well-balanced, and operative method for achieving excellence in CSR (Shayan et al., 2022).

The energy industry has paramount importance not only on social and environmental sides but also from an economic perspective, meeting the needs of individuals and enabling the production of goods and services to boost economic prosperity in society (Leisen et al., 2019). The lack of energy supply leads countries to experience social and economic problems (Meng et al., 2021a,b). In this sense, the sustainability of the energy supply is quite important to mitigate economic, social, and environmental problems (Wei et al., 2021). So, companies should implement forward-looking policies and good CSR practices to be compatible with SDGs to enhance corporate performance and meet long-term goals.

However, the fulfillment of the SDGs and CSR-based corporate performance increases the costs of energy companies. Therefore, it is quite challenging for them to take the right measures. They should make a priority analysis to manage all these matters. Using a hybrid analytics approach in a fuzzy environment, this study aims to assess the performance of energy business model alternatives in five categories for the oil and gas industry. The paper primarily seeks to answer the following questions: (i) which of the five energy business model alternatives is the best one for the oil and gas industry to enhance corporate performance?, (ii) how does the performance of energy companies operating under five categories change with respect to the criteria of SDG oriented CSR Index?, (iii) how do energy companies operating under five main categories enhance the performance of global energy industry, and finally (iv) which of the SDGs-oriented CSR Index dimensions are the most significant factors enhancing industry performance.

Based on a broad secondary data and in-depth interviews with subject matter experts in the energy industry, we developed a hybrid business analytics model under a fuzzy environment. A novel two-stage model is constructed for this purpose. The first stage of our model calculates the weights of SDG-oriented CSR Index dimensions using bipolar q-ROF M-SWARA, which composes of six dimensions, i.e., gender equity in the workforce (GWF), activities and organizations for good health (AOG), recycling and waste management (RSG), use of renewable energy sources (URW), lifelong learning of workers (LWR), investments of technological infrastructure (IHV). Then, the second stage evaluates the SDGs-oriented CSR Index performance of the global energy industry by assessing the performance of the energy business model alternatives in five categories, i.e., equipment and services (EQS), refining and marketing (RGM), midstream (MST), drilling (DLG), and exploration and production (EDT) for the oil and gas industry. In this context, we employed bipolar q-ROF ELECTRE. The calculations are also run with Pythagorean Fuzzy Set (PFS) and Intuitionistic Fuzzy Sets (IFSs).

The main contributions of this study are listed and briefly explained below:

(i) Owing to the strategies to be developed in this study, the points that the enterprises should pay attention to enter the CSR index will be determined. This will allow businesses to use their budgets more effectively. Otherwise, making too many improvements for different criteria at the same time will cause the costs to increase too much. This will cause businesses to experience financial problems. In summary, thanks to the priority analysis made in this study, it will be possible for businesses to take action with more reasonable costs in order to enter the CSR index.

(ii) An original model has been proposed based on bipolar q-ROFSs, golden cut, M-SWARA, and ELECTRE. One of the most important barriers in decision-making models is uncertainty in the process. Uncertainty increases as problems become more and more complex. Therefore, the decision-making model to be created should be in the scope of solving this complexity.

(iii) A new technique, M-SWARA, is created by improving the classical SWARA to identify the interrelationships between the items. These improvements increase the effectiveness of the proposed model. While the importance weights of the criteria can be determined in the classical SWARA technique, the causal relationship between these factors cannot be analyzed. On the other hand, the criteria that are important for businesses to enter the CSR index may have effects on each other. For example, investing in the development of technological infrastructure also contributes to the increase of renewable energy projects. In this context, the developed M-SWARA technique is more suitable than the classical SWARA method in determining the most effective criteria for businesses to enter the CSR index.

(iv) It is shown that considering the golden cut in the calculation process of the degrees helps minimize uncertainties. Finally, calculating with PFSs and IFSs in addition to q-ROFSs allows us to properly validate the results.

The rest of the study is structured as follows. The following section highlights the conceptual background and empirical review of the relevant literature. Sections 3 and 4 explain the research methodology, the proposed model of the study, and the analysis. Finally, this paper concludes with implications and conclusions.

2. Conceptual background and literature review

Following the detrimental effects of the 2008 global financial crisis, regulatory authorities in many countries have required companies to make ESG and CSR disclosures to share their environmental and social policies and practices (Vardon et al., 2023; Zachariadis et al., 2023). The rising concerns of wealth management companies and stakeholders also suppress companies to follow up on CSR and ESG-conscious policies and disclose them in their financial and non-financial statements (Aksoy et al., 2020; Braam et al., 2016; Hacioglu and Dincer, 2017; Yilmaz et al., 2021).

ESG and CSR have been highly recognized by the energy industry. Energy companies should pay attention to managing waste not to harm the environment and negatively affect corporate reputation (Ławińska et al., 2022; Onubi et al., 2022). Therefore, they should focus on the risks of waste and implement policies to dispose of them (Fernando et al., 2022; Singhal et al., 2022; Vyas et al., 2022). Mahyari et al. (2022) studied optimal economic planning for waste management and identified that with the help of an effective waste management system, companies may increase customer satisfaction. CSR activities of energy companies may also lower the costs for consumers and encourage renewable energy and energy-saving technologies (Mukoro et al., 2022; Singh and Ru, 2022; Yang et al., 2022). In this matter, CSR is positively related to sustainable energy development (Tiep et al., 2021). For instance, green energy projects within renewable energy alternatives could produce cleaner energy (Effatpanah et al., 2022; Lee et al., 2023). These initiatives elevate the non-financial performance of companies such as carbon footprint mitigation and lead to better CSR performance (Meng et al., 2021a,b). Academic studies provide evidence to support these approaches. Mukhtarov et al. (2022), Mussagy et al. (2023) and

Dinçer et al. (2022) studied green energy investments and indicated that clean energy projects improve corporate image and reputation. Yuan et al. (2021) and Yüksel and Dinçer (2022) identified that green nuclear energy projects minimize the waste problem.

To enhance CSR performance, energy companies should invest in new and innovative technologies. Although clean energy projects have high costs compared to fossil energy sources there are many benefits generated by the improvement of the technology in the production and efficiency performance of solar PV panels and cells (Chowdhury et al., 2021; Huang et al., 2021). Rapid development in renewable energy technology also reduces production costs and leads many energy companies to enter in clean energy business more than ever (Obileke et al., 2021). On the other hand, by the carbon capture and sequestration technology, energy companies become able to evaluate fossil fuels more harmlessly and increase their CSR performance (Dhirasasna and Sahin, 2021).

In recent studies, Kassouri et al. (2021) and Husin and Zaki (2021) evaluated the performance of the energy industry and concluded that energy companies should give priority to technological improvement to improve their performance. Energy companies should also periodically adjust their CSR strategies to decrease the pressure from stakeholders. This agenda should also compose of policies to encourage the use of renewable energy sources while gradually decreasing the use of fossil fuels, and installing waste and pollution control systems to minimize the impact on the ecosystem (Stjepcevic and Siksnelyte, 2017). From this perspective, CSR can bring benefits to companies by reducing the costs of accessing new capital and other financial resources.

Besides the preceding issues, qualified human resources increase the CSR performance of energy companies. In this frame, companies should employ workers with the right technical competence and analytical skills (Fang et al., 2021). Further, energy companies should provide necessary training to increase the technical capacities of the employees and to quickly solve technical problems that may occur in the processes (Armani et al., 2021; Liu et al., 2021). Finally, gender equity affects the CSR performance of companies. The fact that energy companies predominantly employ male workers may negatively influence the corporate image (Vangchuay and Niklaus, 2021). In this sense, energy companies may employ more women in the workplace (Lane et al., 2021; Owusu-Manu et al., 2021).

The aforesaid results in the prior studies indicate that there are many different factors that affect the SDG and CSR-oriented performance of energy companies, and each factor has its own cost and benefits. Whereas various energy companies have already been undertaking CSR activities, its rising popularity will continue to attract many of the remaining companies in the coming years. Thus, energy companies should make a priority analysis for each factor and take measures to sequentially implement them to improve SDG-oriented CSR performance. This study aims to support energy companies to harness the benefits of the SDGs and CSR and evaluates the performance of the energy industry by constructing a new model by creating an SDGs-oriented CSR Index.

3. Research methodology

Multi-criteria decision-making (MCDM) techniques in solving complex decision-making problems are very popular tools among decision-makers. The effect of the decision-making process starts with the decision makers' ability to draw a clearer framework for a problem, its dimensions, and contradictions with the decision maker's approach. Then, the process continues with the identification of the set of decision criteria, alternatives, and the execution of the correct analysis method. Finally, the findings should be tested to validate the initial results, and decision-makers should rank the best possible alternative solution based on the cost and benefit criteria. However, the quantitative and qualitative analysis may lack quality if decision-making units either skip more suitable methods or eliminate some of the data. Therefore, blending quantitative and quantitative techniques with experience and knowledge of decision-making units will be a perfect asset in solving complex decision-making problems from the energy to the aviation industries.

This study translates the quantitative and qualitative data into meaningful information by employing a sophisticated technique blending expertise and empirical data after conducting an extensive literature review and interviews with the subject matter experts in the field. In the study, we selected three experienced experts from the energy industry, each holding a Ph.D. degree and working experience of over 15 years. After holding meetings with the industry experts, we decided to construct a proposed index for SDGs-oriented CSR and determined the dimensions as a set of criteria, and finally, the five energy business models set as alternatives.

Our model relies on two stages. The first stage calculates the weights of the SDGs-oriented CSR Index dimensions by using bipolar q-ROF M-SWARA, which is composed of six dimensions, i.e., gender equity in the workforce (GWF), activities and organizations for good health (AOG), recycling and waste management (RSG), use of renewable energy sources (URW), lifelong learning of workers (LWR), investments of technological infrastructure (IHV). Then, the second stage evaluates the SDGs-oriented CSR Index performance of the global energy industry by assessing the performance of energy business model alternatives in five categories for the oil and gas industry, i.e., equipment and services (EQS), refining and marketing (RGM), midstream (MST), drilling (DLG), and exploration and production (EDT). In this context, we employ bipolar q-ROF ELECTRE. We also run the calculations with PFSs and IFSs.

IFSs were generated by Atanassov (1999) through membership and non-membership (MSH and NSH) degrees (μ_I, n_I) as in Equation (1) in the appendix. The requirement is given in Equation (2). PFSs were introduced by Yager (2013) with degrees (μ_p, n_p) as in Equation (3). The condition is shown in Equation (4). Furthermore, q-ROFSs were developed by Yager (2016) as in Equation (5). Equation (6) indicates the requirement. BFSs were created by Zhang (1994) to handle uncertainties in Equation (7). In this equation, ${\mu_B}^+$ defines the satisfaction degree, whereas ${\mu_B}^-$ shows the satisfaction of the same element. Equations 8–13 include the adoption of BFSs. Equations 14–17 identify the operational process. Defuzzification is made with Equations 18–20. Golden cut (φ) is used in the analysis process with the aim of calculating the degrees. In this process, a and b define large and small quantities (Khesin and Wang, 2022). The details are shown in Equations 21–23. Integration of golden cut to bipolar q-ROFSs are detailed in Equations 24–26.

SWARA was introduced by Keršuliene et al. (2010) to compute the weights of the items. The main benefit is to make a few pairwise comparisons. Equation (27) shows the relation matrix. Also, k_j (coefficient), q_j (recalculated weight), s_j (comparative importance rate), and w_j (weights) are calculated in Equations 28–30. A stable matrix is created in the final stage by limiting and transposing the relation matrix with the power of 2t+1.

ELECTRE was first proposed by Benayoun et al. (1966) for the ranking of the alternatives with binary superiority comparisons. In this study, this approach is integrated with the bipolar q-ROFSs. The resultant decision matrix is shown in Equation (31). Normalization of the matrix is performed using Equation (32). Equation (33) is used for weighting the values. Concordance and discordance (*C* and *D)* interval matrixes are created via Equations 34–39. Concordance *E*, *F*, and aggregated *G* index matrices are identified in Equations 40–47. The sets of E, F, and G are given with e_{ab}, f_{ab}, g_{ab}. Additionally, critical values are indicated by $\bar{c}$ and $\bar{d}$. Equations 48–50 are taken into consideration to compute net superior c_a, inferior d_a, and overall o_a values.

4. Analysis

In this study, we create a new model for evaluating the performance of the energy industry based on the selection of reliable energy business model alternatives by using the Sustainable Development Goals-oriented CSR Index, as depicted in Fig. 1.

In the proposed methodology, the first stage includes weighting the criteria of the SDGs-oriented CSR Index. Table 1 provides the list and references of the main factors.

With respect to CSR, gender equity in the workforce plays a critical role. We consider the activities and organizations for good health. Recycling and waste management indicate important issues for being environmental-friendly. Clean energy projects are also important in improving CSR performance. Lifelong learning of workers demonstrates that training may improve the productivity and quality of the employees. Finally, investments in technological infrastructure play an essential role in the high value-added outcomes. Table 2 shows the degrees and scales used in the evaluation process where positive and negative degrees refer to the PGR and NGR.

Table 3 explains the evaluations of the factors.

Table 4 shows the average values of the factors.

Table 5 shows the score functions for the bipolar q-ROF Multi-SWARA with equation (20). As an example, the criterion of AOG in the second line can be calculated as $((0.55)^3 - (0.34)^3) - ((-0.48)^3 - (-0.30^3)) = 0.213$.

Table 1
Criteria for the sustainable development goals-oriented CSR index.

Factors	Symbols	Study
Gender equity in the workforce	GWF	Vyas et al. (2022)
Activities and organizations for good health	AOG	Fernando et al. (2022)
Recycling and waste management	RSG	Onubi et al. (2022)
Use of renewable energy sources	URW	Singhal et al. (2022)
Lifelong learning of workers	LWR	Yang et al. (2022)
Investments in technological infrastructure	IHV	Mukoro et al. (2022)

Table 6 gives the values for the relationship degrees of each criterion with equations 28–30. Wj values of the criteria for GWF are computed as

$$w_{URW} = \frac{1}{(1 + 0.805 + 0.657 + 0.550 + 0.468)} = 0.287,$$

$$w_{IHV} = \frac{0.805}{(1 + 0.805 + 0.657 + 0.550 + 0.468)} = 0.231,$$

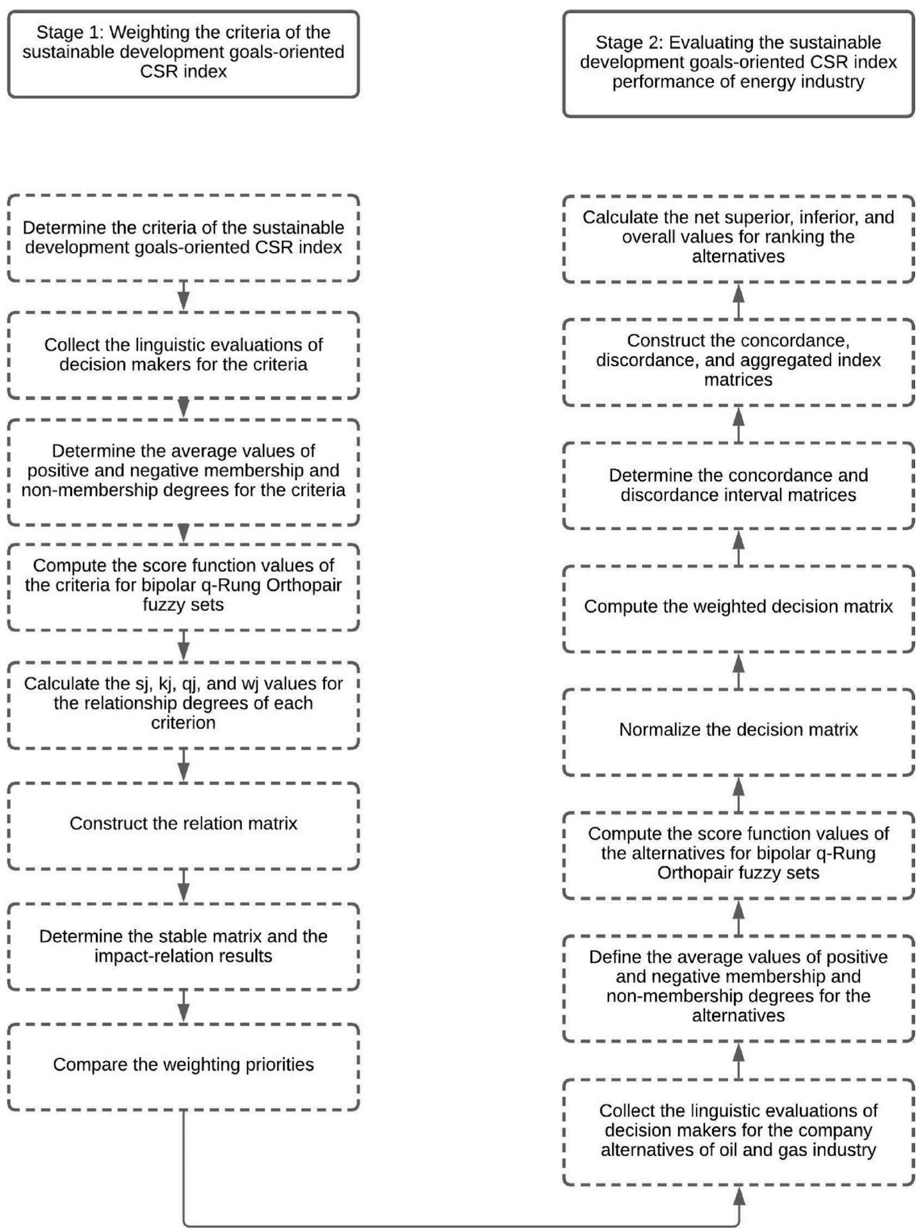

Fig. 1. Proposed methodology.

Table 2
Degrees and scales.

Scales		PGR		NGR	
Factors	**Alternatives**	**MSH**	**NSH**	**MSH**	**NSH**
No (n)	Weakest (w)	.40	.25	−.60	−.37
Some (s)	Poor (p)	.45	.28	−.55	−.34
Medium (m)	Fair (f)	.50	.31	−.50	−.31
High (h)	Good (g)	.55	.34	−.45	−.28
Very high (vh)	Best (b)	.60	.37	−.40	−.25

$$w_{AOG}=\frac{0.657}{(1+0.805+0.657+0.550+0.468)}=0.189,$$

$$w_{LWR}=\frac{0.550}{(1+0.805+0.657+0.550+0.468)}=0.158,$$

$$w_{RSG}=\frac{0.468}{(1+0.805+0.657+0.550+0.468)}=0.135$$

The relation matrix is given in Table 7. The wj values of the criteria are stated in the relation matrix properly.

Table 8 exhibits the stable matrix. The stabilized values of the criteria are provided for the bipolar q-ROFSs by transposing and limiting the matrix to the power of 7.

Fig. 2 shows the impact-relation map for the factors.

The weights of the factors are detailed in Table 9.

These results are also illustrated in Fig. 3.

The clean energy project is the most important factor in the SDGs-oriented CSR Index for the energy industry. Activities and organizations for good health and well-being and gender equity in the workforce are also other significant factors. In the second stage, we evaluate the SDGs-oriented CSR Index performance of the energy industry. Table 10 focuses on the energy business model alternatives for energy companies in the oil and gas industry.

Equipment and services include the supply of materials used in energy production. The refinery shows where crude oil is refined and processed into products. Midstream deals with transportation in the energy industry. Drilling refers to the energy obtained from the use of underground resources. Exploration and production explain extensive exploration activities for energy resources and the availability of energy. Table 11 provides evaluations of alternatives.

Table 12 explains the average values for the alternatives.

The score function values of the alternatives are detailed in Table 13. Similarly, the score functions are computed for the bipolar q-ROF Multi-SWARA with equation (20). As an example, the score function of EQS with respect to GWF can be calculated as $((0.60)^3-(0.37)^3)-((-0.53)^3-(-0.33^3))=0.281$.

The normalization of this matrix is given in Table 14. The normalized value of EQS in terms of GWF is presented as $0.640=\frac{0.281}{\sqrt{(0.281^2+0.175^2+0.165^2+0.186^2+0.147^2)}}$ with formula (32).

This matrix is weighted in Table 15. The weighted value of EQS in terms of GWF is determined as $0.107=0.640\times0.167$ with formula (33).

Concordance and discordance interval matrices are given in Table 16. The concordance and discordance interval matrix values for the RGM in the row and the EQS in the column are given as $0.676=0.175+0.158+0.178+0.166$ and $1.000=\frac{\max(0.0403;0.00827)}{\max(0.0403;0.02744;0.00858;0.02661;0.00827;0.0205)}$ respectively.

Concordance, discordance, and aggregated index matrices are constructed in Table 17. The index matrices are defined by using formulas (43) and (47).

The causal relations of the alternatives are shown in Fig. 4.

It is noted that drilling is the most influential alternative. Net superior, inferior, and overall values for ranking the alternatives are computed and shown in Table 18. The values are computed by using equations 48–50. As an example, the net superior, net inferior, and overall values of EQS are calculated respectively as $-0.424=1.788-2.212$, $-0.436=3.180-3.616$, and $0.013=-0.424-(-0.436)$.

Table 3
Evaluations of factors.

Decision Maker 1												
	GWF		AOG		RSG		URW		LWR		IHV	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
GWF			S	N	H	H	S	N	M	M	H	N
AOG	VH	S			S	VH	S	H	M	N	VH	H
RSG	S	S	H	S			M	M	M	M	S	M
URW	M	M	S	H	H	N			S	M	M	H
LWR	M	H	M	N	H	H	M	N			M	VH
IHV	VH	S	H	M	M	H	VH	VH	VH	VH		
Decision Maker 2												
	GWF		**AOG**		**RSG**		**URW**		**LWR**		**IHV**	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
GWF			M	N	H	H	S	N	M	H	H	N
AOG	VH	H			VH	VH	S	H	M	M	VH	H
RSG	S	M	H	S			M	VH	M	VH	S	M
URW	S	H	S	N	M	S			M	M	VH	N
LWR	S	M	H	H	VH	H	M	N			S	H
IHV	H	S	H	M	M	H	VH	VH	VH	VH		
Decision Maker 3												
	GWF		**AOG**		**RSG**		**URW**		**LWR**		**IHV**	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
GWF			M	M	S	H	H	N	VH	H	H	VH
AOG	S	H			S	VH	M	H	H	N	VH	H
RSG	H	M	H	H			M	M	H	H	VH	VH
URW	M	M	M	M	S	N			S	M	M	H
LWR	S	N	M	H	H	H	M	N			M	VH
IHV	H	H	M	VH	VH	H	M	VH	S	VH		

Table 4
Average values of the factors.

	GWF				AOG			
	PGR		NGR		PGR		NGR	
	μ	n	μ	n	μ	N	μ	n
GWF					.48	.30	−.57	−.35
AOG	.55	.34	−.48	−.30				
RSG	.48	.30	−.52	−.32	.55	.34	−.52	−.32
URW	.48	.30	−.48	−.30	.47	.29	−.52	−.32
LWR	.47	.29	−.52	−.32	.52	.32	−.50	−.31
IHV	.57	.35	−.52	−.32	.53	.33	−.47	−.29
	RSG				**URW**			
	PGR		**NGR**		**PGR**		**NGR**	
	μ	**n**	**M**	**N**	**μ**	**n**	**M**	**N**
GWF	.52	.32	−.45	−.28	.48	.30	−.60	−.37
AOG	.50	.31	−.40	−.25	.47	.29	−.45	−.28
RSG					.50	.31	−.47	−.29
URW	.50	.31	−.58	−.36				
LWR	.57	.35	−.45	−.28	.50	.31	−.60	−.37
IHV	.53	.33	−.45	−.28	.57	.35	−.40	−.25
	LWR				**IHV**			
	PGR		**NGR**		**PGR**		**NGR**	
	μ	**n**	**μ**	**n**	**μ**	**n**	**μ**	**n**
GWF	.53	.33	−.47	−.29	.55	.34	−.53	−.33
AOG	.52	.32	−.57	−.35	.60	.37	−.45	−.28
RSG	.52	.32	−.45	−.28	.50	.31	−.47	−.29
URW	.47	.29	−.50	−.31	.53	.33	−.50	−.31
LWR					.48	.30	−.42	−.26
IHV	.55	.34	−.40	−.25				

Table 5
Score functions.

	GWF	AOG	RSG	URW	LWR	IHV
GWF	.000	.225	.175	.251	.194	.243
AOG	.213	.000	.144	.147	.244	.235
RSG	.192	.232	.000	.173	.175	.173
URW	.173	.183	.247	.000	.173	.211
LWR	.183	.201	.209	.260	.000	.142
IHV	.244	.194	.186	.188	.176	.000

The ranking results with the IFSs, PFSs, and q-ROFSs are shown in Table 19.

The results are also shown in Fig. 5.

Table 7
Relation matrix.

	GWF	AOG	RSG	URW	LWR	IHV
GWF		.189	.135	.287	.158	.231
AOG	.187		.143	.163	.280	.227
RSG	.223	.265		.161	.189	.161
URW	.160	.188	.269		.160	.222
LWR	.161	.191	.229	.277		.141
IHV	.274	.230	.163	.194	.139	

Table 8
Stable matrix.

	GWF	AOG	RSG	URW	LWR	IHV
GWF	.167	.167	.167	.167	.167	.167
AOG	.175	.175	.175	.175	.175	.175
RSG	.158	.158	.158	.158	.158	.158
URW	.178	.178	.178	.178	.178	.178
LWR	.157	.157	.157	.157	.157	.157
IHV	.166	.166	.166	.166	.166	.166

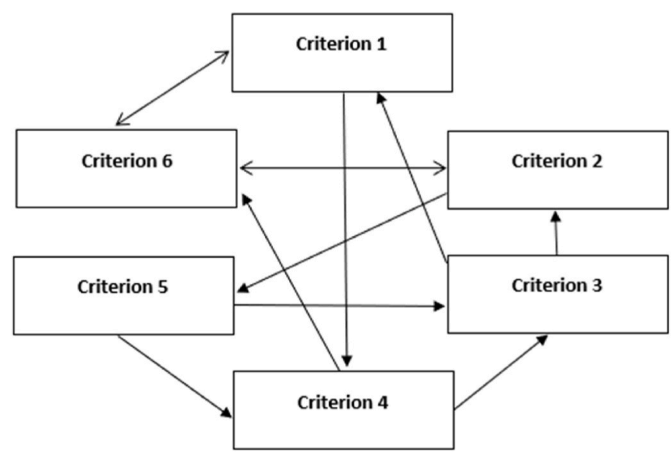

Fig. 2. Impact-relation map for the factors.

We identified drilling as the best alternative for the oil and gas industry. Refining and marketing can be another ideal alternative for the energy industry. Finally, supplying the materials used in energy production is ranked as the third alternative.

At the end of the analysis, the sensitivity analysis is also applied for understanding the methodological soundness of the proposed hybrid

Table 6
Sj, kj, qj, and wj values.

GWF	Sj	kj	qj	wj	AOG	Sj	kj	qj	Wj
URW	.251	1.000	1.000	.287	LWR	.244	1.000	1.000	.280
IHV	.243	1.243	.805	.231	IHV	.235	1.235	.810	.227
AOG	.225	1.225	.657	.189	GWF	.213	1.213	.668	.187
LWR	.194	1.194	.550	.158	URW	.147	1.147	.582	.163
RSG	.175	1.175	.468	.135	RSG	.144	1.144	.508	.143
RSG	**Sj**	**kj**	**qj**	**wj**	**URW**	**Sj**	**kj**	**qj**	**Wj**
AOG	.232	1.000	1.000	.265	RSG	.247	1.000	1.000	.269
GWF	.192	1.192	.839	.223	IHV	.211	1.211	.826	.222
LWR	.175	1.175	.714	.189	AOG	.183	1.183	.698	.188
URW	.173	1.173	.609	.161	GWF	.173	1.173	.595	.160
IHV	.173	1.173	.609	.161	LWR	.173	1.173	.595	.160
LWR	**Sj**	**kj**	**qj**	**wj**	**IHV**	**Sj**	**kj**	**qj**	**Wj**
URW	.260	1.000	1.000	.277	GWF	.244	1.000	1.000	.274
RSG	.209	1.209	.827	.229	AOG	.194	1.194	.838	.230
AOG	.201	1.201	.689	.191	URW	.188	1.188	.705	.194
GWF	.183	1.183	.582	.161	RSG	.186	1.186	.595	.163
IHV	.142	1.142	.510	.141	LWR	.176	1.176	.506	.139

Table 9
Comparative weighting priorities for the factors.

	Bipolar IFSs	Bipolar PFSs	Bipolar q-ROFSs
GWF	3	3	3
AOG	2	2	2
RSG	5	5	5
URW	1	1	1
LWR	6	6	6
IHV	4	4	4

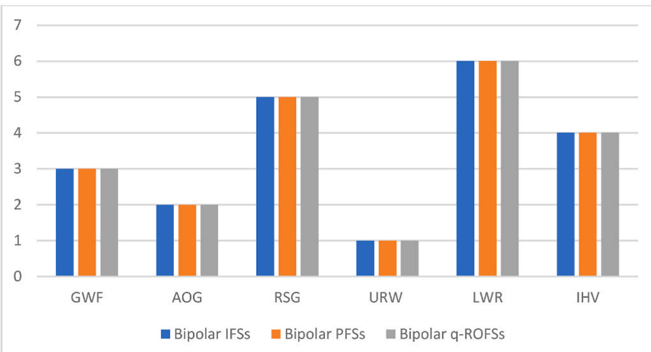

Fig. 3. Comparative weighting results.

Table 10
Selected energy business model alternatives for energy companies in the oil and gas industry.

Alternatives	Symbols	References
Equipment and services	EQS	Lane et al. (2021)
Refining and marketing	RGM	Dhirasasna and Sahin (2021)
Midstream	MST	Chowdhury et al. (2021)
Drilling	DLG	Husin and Zaki (2021)
Exploration and production	EDT	Carroll (2021)

model as seen in Table 20.

Table 20 shows the sensitivity analysis of the ranking results with 6 Cases. These cases are illustrated by changing the weights of the criteria consecutively in the relation set. The results demonstrate that the ranking results are almost the same in each case. This is clear evidence of the coherency of the hybrid methodology and is applicable for further studies of fuzzy-based decision-making models.

Table 12
Average values for the alternatives.

	GWF				AOG			
	PGR		NGR		PGR		NGR	
	μ	n	μ	n	μ	n	μ	N
EQS	.60	.37	−.53	−.33	.50	.31	−.45	−.28
RGM	.52	.32	−.45	−.28	.52	.32	−.55	−.34
MST	.50	.31	−.45	−.28	.50	.31	−.55	−.34
DLG	.45	.28	−.53	−.33	.52	.32	−.45	−.28
EDT	.45	.28	−.47	−.29	.50	.31	−.42	−.26
	RSG				**URW**			
	PGR		**NGR**		**PGR**		**NGR**	
	μ	**n**	**μ**	**n**	**M**	**N**	**M**	**N**
EQS	.60	.37	−.45	−.28	.45	.28	−.40	−.25
RGM	.60	.37	−.50	−.31	.53	.33	−.45	−.28
MST	.45	.28	−.48	−.30	.60	.37	−.45	−.28
DLG	.55	.34	−.47	−.29	.60	.37	−.48	−.30
EDT	.45	.28	−.55	−.34	.55	.34	−.42	−.26
	LWR				**IHV**			
	PGR		**NGR**		**PGR**		**NGR**	
	μ	**n**	**M**	**n**	**μ**	**N**	**μ**	**n**
EQS	.60	.37	−.45	−.28	.48	.30	−.40	−.25
RGM	.52	.32	−.52	−.32	.55	.34	−.43	−.27
MST	.45	.28	−.40	−.25	.60	.37	−.50	−.31
DLG	.60	.37	−.50	−.31	.55	.34	−.43	−.27
EDT	.52	.32	−.40	−.25	.48	.30	−.50	−.31

Table 11
Evaluations of alternatives.

Decision Maker 1												
	GWF		AOG		RSG		URW		LWR		IHV	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
EQS	B	F	P	G	B	G	P	B	B	G	P	B
RGM	F	G	G	W	B	F	P	G	G	W	B	G
MST	F	G	P	W	P	G	B	G	P	B	B	F
DLG	P	F	G	G	G	B	B	F	B	W	G	G
EDT	P	F	B	G	P	W	G	G	G	B	G	F
Decision Maker 2												
	GWF		**AOG**		**RSG**		**URW**		**LWR**		**IHV**	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
EQS	B	W	B	G	B	G	P	B	B	G	P	B
RGM	B	G	G	W	B	F	B	G	P	G	B	B
MST	P	G	B	W	P	W	B	G	P	B	B	F
DLG	P	W	P	G	G	W	B	G	B	B	G	G
EDT	P	G	P	B	P	G	G	B	P	B	P	F
Decision Maker 3												
	GWF		**AOG**		**RSG**		**URW**		**LWR**		**IHV**	
	PGR	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**	**PGR**	**NGR**
EQS	B	F	P	G	B	G	P	B	B	G	G	B
RGM	P	G	P	G	B	F	G	G	G	F	P	G
MST	G	G	P	G	P	B	B	G	P	B	B	F
DLG	P	F	G	G	G	B	B	F	B	F	G	B
EDT	P	G	P	B	P	W	G	B	G	B	P	F

Table 13
Score function values of the alternatives.

	GWF	AOG	RSG	URW	LWR	IHV
EQS	.281	.165	.235	.119	.235	.135
RGM	.175	.232	.260	.186	.211	.189
MST	.165	.223	.156	.235	.119	.260
DLG	.186	.175	.205	.251	.260	.189
EDT	.147	.151	.197	.182	.154	.182

Table 14
Normalized matrix.

	GWF	AOG	RSG	URW	LWR	IHV
EQS	.640	.385	.492	.265	.518	.309
RGM	.398	.542	.546	.415	.465	.433
MST	.376	.519	.327	.525	.262	.596
DLG	.422	.408	.429	.562	.575	.433
EDT	.335	.351	.412	.408	.341	.416

Table 15
Weighted matrix.

	GWF	AOG	RSG	URW	LWR	IHV
EQS	.107	.067	.078	.047	.081	.051
RGM	.067	.095	.086	.074	.073	.072
MST	.063	.091	.052	.093	.041	.099
DLG	.071	.071	.068	.100	.090	.072
EDT	.056	.061	.065	.072	.053	.069

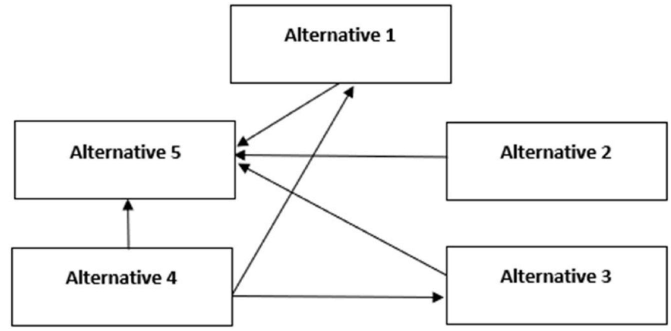

Fig. 4. Impact-relation map for the alternatives.

Table 18
Net superior, inferior, and overall values of the alternatives.

Alternatives	Net Superior Values	Net Inferior Values	Overall Values
EQS	−.424	−.436	.013
RGM	1.332	−.799	2.131
MST	−.227	.054	−.281
DLG	2.003	−1.866	3.869
EDT	−2.684	3.048	−5.732

Table 19
Comparative overall ranking results for the alternatives.

Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	4	5
DLG	1	1	1
EDT	5	5	4

5. Discussions and policy recommendations

Today, there is an increasing consciousness toward environmentally friendly CSR activities for companies in the energy industry across the globe. Increased consciousness of the prospects and confrontations that the SDGs pose for the oil and gas industry, and the ways in which the industry may address them is important in improving the long-term performance of the companies. This study offers an outline of the opportunities and challenges to show the possible contributions of the oil and gas industry to the achievement of the SDGs. In this frame, it develops a framework for the responsibilities of the energy companies in boosting the industry's commitment to sustainable development, alongside existing resources, which could assist the industry builds useful contributions to the achievement of the SDGs.

The study primarily presents implications for energy companies. Companies should find new connections between their existing operations and the SDGs. The findings imply that energy companies should spend more on modern energy technologies and integrate them into the process of production to develop the execution of energy efficiency-based strategies for long-term sustainability. The results also validate that energy companies increase their overall efficiency by investing more in renewable energy projects in order to decrease carbon emissions. Crafting a renewable energy mindset and its implementation process as a part of the company's culture will create a sustainable competitive advantage that could have positive implications on managerial and financial corporate performance.

Table 16
Concordance and discordance interval matrices.

Alternatives	Concordance Matrix					Discordance Matrix				
	EQS	RGM	MST	DLG	EDT	EQS	RGM	MST	DLG	EDT
EQS	.000	.324	.482	.325	.657	.000	.681	1.000	1.000	.499
RGM	.676	.000	.657	.333	1.000	1.000	.000	.778	1.000	.000
MST	.518	.343	.000	.340	.685	.928	1.000	.000	1.000	.454
DLG	.675	.667	.660	.000	1.000	.688	.897	.549	.000	.000
EDT	.343	.000	.315	.000	.000	1.000	1.000	1.000	1.000	.000

Table 17
Concordance, discordance, and aggregated index matrices.

Alternatives	Concordance Matrix					Discordance Matrix					Aggregated Matrix				
	EQS	RGM	MST	DLG	EDT	EQS	RGM	MST	DLG	EDT	EQS	RGM	MST	DLG	EDT
EQS	0	0	0	0	1	1	1	0	0	1	0	0	0	0	1
RGM	1	0	1	0	1	0	1	0	0	1	0	0	0	0	1
MST	1	0	0	0	1	0	0	1	0	1	0	0	0	0	1
DLG	1	1	1	0	1	1	0	1	1	1	1	0	1	0	1
EDT	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

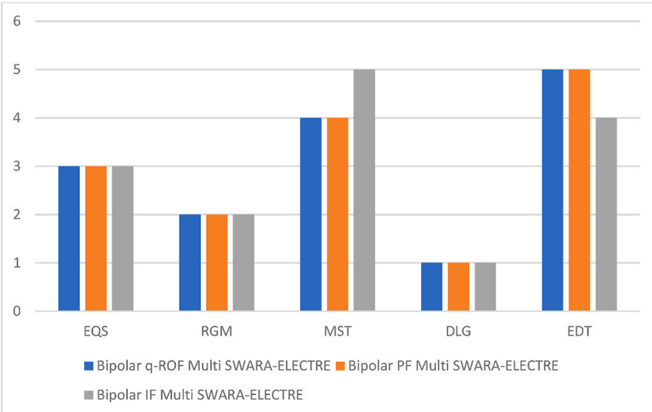

Fig. 5. Comparative ranking results.

On the regulatory side, governments and regulatory authorities may develop policies that are compatible with the SDGs to enhance understanding of the relationship between the SDGs and the oil and gas industry. Regulatory actions will improve the multi-stakeholder dialogue and collaboration toward enhancing the contribution of the oil and gas industry to the achievement of the SDGs. In this sense, the study draws the attention of policy-makers to implement refined environmental and renewable energy policies to increase the SDGs-oriented performance of companies. Founding strict regulations and rigorous measures are indeed in favor of not only the environment but also society. Nonetheless, setting a new agenda or building a new roadmap with specific targets is not an easy job as it becomes a challenging issue requiring time to execute strategies, develop a supportive culture, to train personnel, and it requires considerable financial resources. Thus, policymakers should be keen on practicing realistic, attainable, and less costly objectives.

6. Conclusions and future research directions

The Sustainable Development Goals adopted in 2015 by the United Nations represent an exclusive blueprint of actions for social inclusion, environmental sustainability, and economic development. Achieving the SDGs by 2030 requires cooperation and collaboration among governments, NGOs, corporations, and societies. While the legal authorities have the main obligation to execute and implement approaches to covering the SDGs, the industry itself plays a major role in the accomplishment of national plans. In this respect, the oil and gas industry is an important sector that has both positive and negative impacts on a range of areas covered by the SDGs. This study intends to facilitate awareness of the ways in which oil and gas companies can help to achieve the SDGs.

This study analyses the performance of the energy business model alternatives for the energy companies operating in the oil and gas industry. For this purpose, we construct a new model by considering the SDGs-oriented CSR Index. The first stage calculates the weights with bipolar q-ROF M-SWARA, while the second stage evaluates the SDGs-oriented CSR Index performance of the energy industry. In this context, we used bipolar q-ROF ELECTRE, and the calculations are also run with the PFSs and IFSs.

The findings indicate that clean or renewable energy projects are the most important factor in the SGDs-oriented CSR Index for the energy industry. Activities and organizations for good health and well-being and gender equity in the workforce are other significant factors. The results also show that drilling is the best alternative for the oil and gas industry. Refining and marketing can be another ideal alternative for the industry. Moreover, supplying the materials used in energy production is ranked as the third factor.

The findings indicate that the global warming problem caused by

Table 20
Sensitivity results for ranking alternatives.

Case 1			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	4	5
DLG	1	1	1
EDT	5	5	4
Case 2			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	4	5
DLG	1	1	1
EDT	5	5	4
Case 3			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	5	5
DLG	1	1	1
EDT	5	4	4
Case 4			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	4	5
DLG	1	1	1
EDT	5	5	4
Case 5			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	5	5
DLG	1	1	1
EDT	5	4	4
Case 6			
Alternatives	Bipolar q-ROF Multi SWARA-ELECTRE	Bipolar PF Multi SWARA-ELECTRE	Bipolar IF Multi SWARA-ELECTRE
EQS	3	3	3
RGM	2	2	2
MST	4	4	5
DLG	1	1	1
EDT	5	5	4

fossil fuels in energy production must be primarily solved to achieve sustainable development goals. In this frame, it is necessary to implement the right strategies to increase the share of renewable energy projects in the energy industry. In this sense, governments should provide cost-reducing support to clean energy investors. Additionally, carbon capture and sequestration technology prevent the formation of the carbon emission problem generated by energy companies that use fossil fuels. Regulatory authorities should make necessary legal arrangements for energy companies to use carbon emission-preventing technologies (Yüksel et al., 2021; Wan et al., 2022). In this sense, the industry's extensive global footprint presents an opportunity to have a sustainable impact on the achievement of the SDGs. These actions will also improve the reputation of companies.

Finally, drilling is identified as the best alternative for the oil and gas industry. Drilling is an application that includes complex processes and is quite difficult to implement. It refers to the energy obtained from the use of underground resources. To increase efficiency in drilling investments, energy companies should have the proper technological infrastructure. In this context, energy companies should closely follow technological developments. This will help companies to implement more effective drilling activities and will significantly reduce costs. Thus, technological improvements are of vital importance. Energy firms must also have qualified staff to increase efficiency in drilling (Vasilescu and Dinu, 2021; Zhdaneev et al., 2021).

In summary, with effective strategic planning and its implementation process, the oil and gas industry could have the chance to contribute across all SDGs. In this new road map, companies in this industry will achieve their goal through all SDGs, either by enhancing their constructive contributions as well as lessening negative impacts. Overall, the oil and gas industry can boost economic and social development by providing access to affordable energy, prospects for decent employment, know-how, and better-quality setups. To achieve these targets, they should integrate the SDGs into the companies' core business through a common understanding by all stakeholders of how the SDGs can add value and align it with the corporate goals. In this sense, energy companies can execute and implement new strategies to incorporate the SDGs into their core business practices.

We acknowledge that this study has some limitations. First, it only offers insights to improve the performance of the energy industry. The results were not elaborated on a company basis. Second, the Sustainable Development Goals are closely interlinked. This study does not discuss the interlinkages among the SGDs. Future studies may employ a similar methodology by taking an integrated approach to the SDGs to examine how interventions in one area may bring synergies or trade-offs in other areas in the energy industry. Third, the proposed model could be improved in terms of the calculation process by choosing different fuzzy numbers. For example, picture fuzzy sets can be identified. Finally, different methods can be employed in the decision-making processes. In this context, the VIKOR technique can be taken into consideration for future research.

Credit author statement

Hasan Dincer – Conceptualization, Formal Analysis and Investigation, Writing (original draft), Serhat Yuksel – Methodology, Modeling, Writing (original draft), Umit Hacioglu – Conceptualization, Analysis, Writing (original draft), Mustafa K. Yilmaz – Supervision, Conceptualization, Methodology, Review & Editing, Dursun Delen – Conceptualization, Methodology, Validation, Review & Editing, Submitting to the Journal (as the corresponding author).

Declaration of competing interest

The co-authors listed below declare that they do not have any conflict of interest to declare.

Data availability

Data will be made available on request.

Abbreviations

CSR Corporate Social Responsibility
ELECTRE Elimination and Choice Translating Reality
M-SWARA Multi-Stepwise Weight Assessment Ratio Analysis
q-ROF Q-rung Orthopair Fuzzy
SDGs Sustainable Development Goals
VIKOR VIse Kriterijumsa Optimizacija I Kompromisno Resenje

Appendix

$$I = \{\langle \vartheta, \mu_I(\vartheta), n_I(\vartheta) \rangle / \vartheta \varepsilon U\} \tag{1}$$

$$0 \leq \mu_I(\vartheta) + n_I(\vartheta) \leq 1 \tag{2}$$

$$P = \{\langle \vartheta, \mu_P(\vartheta), n_P(\vartheta) \rangle / \vartheta \varepsilon U\} \tag{3}$$

$$0 \leq (\mu_P(\vartheta))^2 + (n_P(\vartheta))^2 \leq 1 \tag{4}$$

$$Q = \left\{\langle \vartheta, \mu_Q(\vartheta), n_Q(\vartheta) \rangle / \vartheta \varepsilon U\right\} \tag{5}$$

$$0 \leq \left(\mu_Q(\vartheta)\right)^q + (n_Q(\vartheta))^q \leq 1, q \geq 1 \tag{6}$$

$$B = \{\langle \vartheta, \mu_B{}^+(\vartheta), \mu_B{}^-(\vartheta) \rangle / \vartheta \varepsilon U\} \tag{7}$$

$$B_I = \left\{\langle \vartheta, \mu_{B_I}{}^+(\vartheta), n_{B_I}{}^+(\vartheta), \mu_{B_I}{}^-(\vartheta), n_{B_I}{}^-(\vartheta) \rangle / \vartheta \varepsilon U\right\} \tag{8}$$

$$B_P = \left\{\langle \vartheta, \mu_{B_P}{}^+(\vartheta), n_{B_P}{}^+(\vartheta), \mu_{B_P}{}^-(\vartheta), n_{B_P}{}^-(\vartheta) \rangle / \vartheta \varepsilon U\right\} \tag{9}$$

$$B_Q = \left\{\langle \vartheta, \mu_{B_Q}{}^+(\vartheta), n_{B_Q}{}^+(\vartheta), \mu_{B_Q}{}^-(\vartheta), n_{B_Q}{}^-(\vartheta) \rangle \Big/ \vartheta \varepsilon U\right\} \tag{10}$$

$$0 \leq \left(\mu_{B_I}{}^+(\vartheta)\right) + (n_{B_I}{}^+(\vartheta)) \leq 1, -1 \leq \left(\mu_{B_I}{}^-(\vartheta)\right) + (n_{B_I}{}^-(\vartheta)) \leq 0 \tag{11}$$

$$0 \leq \left(\mu_{B_P}{}^+(\vartheta)\right)^2 + (n_{B_P}{}^+(\vartheta))^2 \leq 1, 0 \leq \left(\mu_{B_P}{}^-(\vartheta)\right)^2 + (n_{B_P}{}^-(\vartheta))^2 \leq 1 \tag{12}$$

$$0 \leq \left(\mu_{B_Q}{}^+(\vartheta)\right)^q + (n_{B_Q}{}^+(\vartheta))^q \leq 1, -1 \leq \left(\mu_{B_Q}{}^-(\vartheta)\right)^q + (n_{B_Q}{}^-(\vartheta))^q \leq 0 \tag{13}$$

$$B_{Q1} = \left\{ \langle \vartheta, \mu_{B_{Q1}}{}^{+}(\vartheta), n_{B_{Q1}}{}^{+}(\vartheta), \mu_{B_{Q1}}{}^{-}(\vartheta), n_{B_{Q1}}{}^{-}(\vartheta) \rangle \middle/ \vartheta \varepsilon U \right\} \text{ and } B_{Q2} = \left\{ \langle \vartheta, \mu_{B_{Q2}}{}^{+}(\vartheta), n_{B_{Q2}}{}^{+}(\vartheta), \mu_{B_{Q2}}{}^{-}(\vartheta), n_{B_{Q2}}{}^{-}(\vartheta) \rangle \middle/ \vartheta \varepsilon U \right\}$$

$$B_{Q1} \oplus B_{Q2} = \left(\left(\left(\mu_{B_{Q1}}{}^{+}\right)^{q} + \left(\mu_{B_{Q2}}{}^{+}\right)^{q} - \left(\mu_{B_{Q1}}{}^{+}\right)^{q} . \left(\mu_{B_{Q2}}{}^{+}\right)^{q} \right)^{\frac{1}{q}}, \left(n_{B_{Q1}}{}^{+} . n_{B_{Q2}}{}^{+}\right), -\left(\mu_{B_{Q1}}{}^{-} . \mu_{B_{Q2}}{}^{-}\right), -\left(\left(n_{B_{Q1}}{}^{-}\right)^{q} + \left(n_{B_{Q2}}{}^{-}\right)^{q} - \left(n_{B_{Q1}}{}^{-}\right)^{q} . \left(n_{B_{Q2}}{}^{-}\right)^{q} \right)^{\frac{1}{q}} \right) \tag{14}$$

$$B_{Q1} \otimes B_{Q2} = \left(\left(\mu_{B_{Q1}}{}^{+} . \mu_{B_{Q2}}{}^{+}\right), \left(\left(n_{B_{Q1}}{}^{+}\right)^{q} + \left(n_{B_{Q2}}{}^{+}\right)^{q} - \left(n_{B_{Q1}}{}^{+}\right)^{q} . \left(n_{B_{Q2}}{}^{+}\right)^{q} \right)^{\frac{1}{q}}, -\left(\left(\mu_{B_{Q1}}{}^{-}\right)^{q} + \left(\mu_{B_{Q2}}{}^{-}\right)^{q} - \left(\mu_{B_{Q1}}{}^{-}\right)^{q} . \left(\mu_{B_{Q2}}{}^{-}\right)^{q} \right)^{\frac{1}{q}}, -\left(n_{B_{Q1}}{}^{-} . n_{B_{Q2}}{}^{-}\right) \right) \tag{15}$$

$$\lambda B_{Q1} = \left(\left(1 - \left(1 - \left(\mu_{B_{Q1}}{}^{+}\right)^{q} \right)^{\lambda} \right)^{1/q}, \left(n_{B_{Q1}}{}^{+}\right)^{\lambda}, -\left(-\mu_{B_{Q1}}{}^{-} \right)^{\lambda}, -\left(1 - \left(1 - \left(-n_{B_{Q1}}{}^{-} \right)^{q} \right)^{\lambda} \right)^{1/q} \right), \lambda > 0 \tag{16}$$

$$B_{Q1}{}^{\lambda} = \left(\left(\mu_{B_{Q1}}{}^{+}\right)^{\lambda}, \left(1 - \left(1 - \left(n_{B_{Q1}}{}^{+}\right)^{q} \right)^{\lambda} \right)^{1/q}, -\left(1 - \left(1 - \left(-\mu_{B_{Q1}}{}^{-} \right)^{q} \right)^{\lambda} \right)^{\frac{1}{q}}, -\left(-n_{B_{Q1}}{}^{-} \right)^{\lambda} \right), \lambda > 0 \tag{17}$$

$$S(\vartheta)_{B_I} = \left(\left(\mu_{B_I}{}^{+}(\vartheta)\right) - \left(n_{B_I}{}^{+}(\vartheta)\right) \right) - \left(\left(\mu_{B_I}{}^{-}(\vartheta)\right) - \left(n_{B_I}{}^{-}(\vartheta)\right) \right) \tag{18}$$

$$S(\vartheta)_{B_P} = \left(\left(\mu_{B_P}{}^{+}(\vartheta)\right)^{2} - \left(n_{B_P}{}^{+}(\vartheta)\right)^{2} \right) + \left(\left(\mu_{B_P}{}^{-}(\vartheta)\right)^{2} - \left(n_{B_P}{}^{-}(\vartheta)\right)^{2} \right) \tag{19}$$

$$S(\vartheta)_{B_Q} = \left(\left(\mu_{B_Q}{}^{+}(\vartheta)\right)^{q} - \left(n_{B_Q}{}^{+}(\vartheta)\right)^{q} \right) - \left(\left(\mu_{B_Q}{}^{-}(\vartheta)\right)^{q} - \left(n_{B_Q}{}^{-}(\vartheta)\right)^{q} \right) \tag{20}$$

$$\varphi = \frac{a}{b} \tag{21}$$

$$\varphi = \frac{1 + \sqrt{5}}{2} = 1.618\ldots \tag{22}$$

$$\varphi = \frac{\mu_{G_{B_Q}}}{n_{G_{B_Q}}} \tag{23}$$

$$G_{B_Q} = \left\{ \langle \vartheta, \mu_{G_{B_Q}}{}^{+}(\vartheta), n_{G_{B_Q}}{}^{+}(\vartheta), \mu_{G_{B_Q}}{}^{-}(\vartheta), n_{G_{B_Q}}{}^{-}(\vartheta) \rangle \middle/ \vartheta \varepsilon U \right\} \tag{24}$$

$$0 \le \left(\mu_{G_{B_Q}}{}^{+}(\vartheta)\right)^{q} + \left(n_{G_{B_Q}}{}^{+}(\vartheta)\right)^{q} \le 1, -1 \le \left(\mu_{G_{B_Q}}{}^{-}(\vartheta)\right)^{q} + \left(n_{G_{B_Q}}{}^{-}(\vartheta)\right)^{q} \le 0 \tag{25}$$

$$0 \le \left(\mu_{G_{B_Q}}{}^{+}(\vartheta)\right)^{2q} + \left(n_{G_{B_Q}}{}^{+}(\vartheta)\right)^{2q} \le 1, 0 \le \left(\mu_{G_{B_Q}}{}^{-}(\vartheta)\right)^{2q} + \left(n_{G_{B_Q}}{}^{-}(\vartheta)\right)^{2q} \le 1 \; q \ge 1 \tag{26}$$

$$Q_k = \begin{bmatrix} 0 & Q_{12} & \cdots & \cdots & Q_{1n} \\ Q_{21} & 0 & \cdots & \cdots & Q_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Q_{n1} & Q_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{27}$$

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \tag{28}$$

$$q_j = \begin{cases} 1 & j = 1 \\ \dfrac{q_{j-1}}{k_j} & j > 1 \end{cases} \tag{29}$$

$$\mathit{If}\ s_{j-1} = s_j, q_{j-1} = q_j;\ \mathit{If}\ s_j = 0, k_{j-1} = k_j$$

$$w_j = \frac{q_j}{\sum\limits_{k=1}^{n} q_k} \tag{30}$$

$$X_k = \begin{bmatrix} 0 & X_{12} & \cdots & \cdots & X_{1m} \\ X_{21} & 0 & \cdots & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{31}$$

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum\limits_{i=1}^{m} X_{ij}^{2}}} . \tag{32}$$

$$v_{ij} = w_{ij} \times r_{ij} \tag{33}$$

$$C = \begin{bmatrix} - & c_{12} & \cdots & \cdots & c_{1n} \\ c_{21} & - & \cdots & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{34}$$

$$D = \begin{bmatrix} - & d_{12} & \cdots & \cdots & d_{1n} \\ d_{21} & - & \cdots & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{35}$$

$$c_{ab} = \left\{ j \middle| v_{aj} \geq v_{bj} \right\} \tag{36}$$

$$d_{ab} = \left\{ j \middle| v_{aj} < v_{bj} \right\} \tag{37}$$

$$c_{ab} = \sum_{j \in c_{ab}} w_j \tag{38}$$

$$d_{ab} = \frac{max_{j \in d_{ab}} \left| v_{aj} - v_{bj} \right|}{max_j \left| v_{mj} - v_{nj} \right|} \tag{39}$$

$$E = \begin{bmatrix} - & e_{12} & \cdots & \cdots & e_{1n} \\ e_{21} & - & \cdots & \cdots & e_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ e_{n1} & e_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{40}$$

$$F = \begin{bmatrix} - & f_{12} & \cdots & \cdots & f_{1n} \\ f_{21} & - & \cdots & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_{n1} & f_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{41}$$

$$G = \begin{bmatrix} - & g_{12} & \cdots & \cdots & g_{1n} \\ g_{21} & - & \cdots & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ g_{n1} & g_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{42}$$

$$\begin{cases} e_{ab} = 1 \ \ if \ c_{ab} \geq \overline{c} \\ e_{ab} = 0 \ \ if \ c_{ab} < \overline{c} \end{cases} \tag{43}$$

$$\overline{c} = \sum_{a=1}^{n} \sum_{b}^{n} c_{ab} \, / \, n(n-1) \tag{44}$$

$$\begin{cases} f_{ab} = 1 \quad if \ d_{ab} \leq \overline{d} \\ f_{ab} = 0 \quad if \ d_{ab} > \overline{d} \end{cases} \tag{45}$$

$$\overline{d} = \sum_{a=1}^{n} \sum_{b}^{n} d_{ab} \, / \, n(n-1) \tag{46}$$

$$g_{ab} = e_{ab} \times f_{ab} \tag{47}$$

$$c_a = \sum_{b=1}^{n} c_{ab} - \sum_{b=1}^{n} c_{ba} \tag{48}$$

$$d_a = \sum_{b=1}^{n} d_{ab} - \sum_{b=1}^{n} d_{ba} \tag{49}$$

$$o_a = c_a - d_a \tag{50}$$

References

Aksoy, M., Yilmaz, M.K., Tatoglu, E., Basar, M., 2020. Antecedents of corporate sustainability performance in Turkey: the effects of ownership structure and board attributes on non-financial companies. J. Clean. Prod. 276, 124284 https://doi.org/10.1016/j.jclepro.2020.124284.

Armani, C.G., de Oliveira, K.F., Munhoz, I.P., Akkari, A.C.S., 2021. Proposal and application of a framework to measure the degree of maturity in Quality 4.0: a multiple case study. Advances in Mathematics for Industry 4.0, 131–163 (Academic Press).

Atanassov, K.T., 1999. Intuitionistic fuzzy sets. In: Intuitionistic Fuzzy Sets. Physica, Heidelberg, pp. 1–137.

Barauskaite, G., Streimikiene, D., 2021. Corporate social responsibility and financial performance of companies: the puzzle of concepts, definitions and assessment methods. Corp. Soc. Responsib. Environ. Manag. 281, 278–287.

Benayoun, R., Roy, B., Sussman, B., 1966. ELECTRE: une méthode pour guider le choix en présence de points de vue multiples. Note de travail 49.

Braam, G.J., de Weerd, L.U., Hauck, M., Huijbregts, M.A., 2016. Determinants of corporate environmental reporting: the importance of environmental performance and assurance. J. Clean. Prod. 129, 724–734. https://doi.org/10.1016/j.jclepro.2016.03.039.

Carroll, A.B., 2021. Corporate social responsibility: perspectives on the CSR construct's development and future. Bus. Soc. 606, 1258–1278.

Chowdhury, M.S., Rahman, K.S., Selvanathan, V., Nuthammachot, N., Suklueng, M., Mostafaeipour, A., et al., 2021. Current trends and prospects of tidal energy technology. Environ. Dev. Sustain. 236, 8179–8194.

Dhirasasna, N., Sahin, O., 2021. A system dynamics model for renewable energy technology adoption of the hotel sector. Renew. Energy 163, 1994–2007.

Dinçer, H., Yüksel, S., Martínez, L., 2022. Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. Energy Rep. 8, 377–389.

Dong, X., Zhang, X., Zhang, C., Bi, C., 2023. Building sustainability education for green recovery in the energy resource sector: a cross country analysis. Resour. Pol. 81, 103385.

Effatpanah, S.K., Ahmadi, M.H., Aungkulanon, P., Maleki, A., Sadeghzadeh, M., Sharifpur, M., Chen, L., 2022. Comparative analysis of five widely-used multi-criteria decision-making methods to evaluate clean energy technologies: a case Study. Sustainability 143, 1403.

Fang, S., Zhou, P., Dinçer, H., Yüksel, S., 2021. Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. Saf. Sci. 141, 105333.

Fernando, Y., Tseng, M.L., Aziz, N., Ikhsan, R.B., Wahyuni-Td, I.S., 2022. Waste-to-Energy supply chain management on circular economy capability: an empirical study. Sustain. Prod. Consum. 31, 26–38.

Hacioglu, U., Dincer, H., 2017. The Global Financial Crisis and its Ramifications on Capital Markets. Springer, Berlin. https://doi.org/10.1007/978-3-319-47021-4.

Huang, J., Zhang, H., Peng, W., Hu, C., 2021. Impact of energy technology and structural change on energy demand in China. Sci. Total Environ. 760, 143345.

Husin, H., Zaki, M., 2021. A critical review of the integration of renewable energy sources with various technologies. Protection and Control of Modern Power Systems 61, 1–18.

Islam, T., Islam, R., Pitafi, A.H., Xiaobei, L., Rehmani, M., Irfan, M., Mubarak, M.S., 2021. The impact of corporate social responsibility on customer loyalty: the mediating role of corporate reputation, customer satisfaction, and trust. Sustain. Prod. Consum. 25, 123–135.

Kassouri, Y., Kacou, K.Y.T., Alola, A.A., 2021. Are oil-clean energy and high technology stock prices in the same straits? Bubbles speculation and time-varying perspectives. Energy 232, 121021.

Keršuliene, V., Zavadskas, E.K., Turskis, Z., 2010. Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis SWARA. J. Bus. Econ. Manag. 112, 243–258.

Khesin, B., Wang, H., 2022. The golden ratio and hydrodynamics. Math. Intel. 44, 22–27.

Lane, L., Dhal, S., Srivastava, N., 2021. Gender empowerment and community of practice to promote clean energy sustainability. In: Affordable and Clean Energy. Springer International Publishing, Cham, pp. 689–698.

Ławińska, O., Korombel, A., Zajemska, M., 2022. Pyrolysis-based municipal solid waste management in Poland—swot analysis. Energies 152, 510.

Lee, C.C., Chen, P.F., Chu, P.J., 2023. Green recovery through financial inclusion of mobile payment: a study of low-and middle-income Asian countries. Econ. Anal. Pol. 77, 729–747.

Leisen, R., Steffen, B., Weber, C., 2019. Regulatory risk and the resilience of new sustainable business models in the energy sector. J. Clean. Prod. 219, 865–878. https://doi.org/10.1016/j.jclepro.2019.01.330.

Liu, Y., Gong, X., Yüksel, S., Dinçer, H., Aydın, R., 2021. A multidimensional outlook to energy investments for the countries with continental shelf in East Mediterranean region with hybrid decision making model based on IVIF logic. Energy Rep. 7, 158–173.

Luo, S., Zeng, Z., Wang, H., Xiong, W., Song, B., Zhou, C., et al., 2021. Recent progress in conjugated microporous polymers for clean energy: synthesis, modification, computer simulations, and applications. Prog. Polym. Sci. 115, 101374.

Mahyari, K.F., Rafiee, S., Keyhani, A., Jafari, A., Mahyari, M.F., Khorasanizadeh, Z., Mahyari, Z.F., 2022. Optimal economic planning for the development of waste management system by a superstructural model. Comput. Chem. Eng. 157, 107634.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., Yüksel, S., 2021a. A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. Financial Innovation 71, 1–34.

Meng, Y., Zhou, R., Dinçer, H., Yüksel, S., Wang, C., 2021b. Analysis of inventive problem-solving capacities for renewable energy storage investments. Energy Rep. 7, 4779–4791.

Mukhtarov, S., Yüksel, S., Dinçer, H., 2022. The impact of financial development on renewable energy consumption: evidence from Turkey. Renew. Energy 187, 169–176.

Mukoro, V., Sharmina, M., Gallego-Schmid, A., 2022. A review of business models for access to affordable and clean energy in Africa: do they deliver social, economic, and environmental value? Energy Res. Social Sci. 88, 102530.

Mussagy, C.U., Farias, F.O., Santos-Ebinuma, V.C., Pereira, J.F., Pessoa Jr., A., 2023. Sustainable One-Pot Platform for the Green Recovery of Carotenoids from Phaffia Rhodozyma Yeast and Their Use as Natural Additives in Soap Formulation. Environmental Technology & Innovation, 103029.

Obileke, K., Onyeaka, H., Meyer, E.L., Nwokolo, N., 2021. Microbial fuel cells, a renewable energy technology for bio-electricity generation: a mini-review. Electrochem. Commun. 125, 107003.

Onubi, H.O., Yusof, N.A., Hassan, A.S., Bahdad, A.A.S., 2022. Effect of energy management and waste management on schedule performance: role of technological complexity and project size. Environ. Sci. Pollut. Control Ser. 2919, 29075–29090.

Owusu-Manu, D.G., Sackey, D.M., Osei-Asibey, D., Agyapong, R.K., Edwards, D.J., 2021. Improving women's energy access, rights and equitable sustainable development: a Ghanaian perspective. Ecofeminism and Climate Change 31, 23–40.

Shayan, N.F., Mohabbati-Kalejahi, N., Alavi, S., Zahed, M.A., 2022. Sustainable development goals SDGs as a framework for corporate social responsibility CSR. Sustainability Switzerland 143, 1–27. https://doi.org/10.3390/su14031222.

Singh, S., Ru, J., 2022. Accessibility, affordability, and efficiency of clean energy: a review and research agenda. Environ. Sci. Pollut. Control Ser. 29, 18333–18347.

Singhal, S., Thapar, S., Kumar, M., Jain, S., 2022. Impacts of sustainable consumption and production initiatives in energy and waste management sectors: examples from India. Environ. Dev. Sustain. 247 https://doi.org/10.1007/s10668-021-02026-3.

Stjepcevic, J., Siksnelyte, I., 2017. Corporate social responsibility in energy sector. Transform. Bus. Econ. 16, 21–33.

Su, C., Urban, F., 2021. Circular economy for clean energy transitions: a new opportunity under the COVID-19 pandemic. Appl. Energy 289, 116666.

Tibiletti, V., Marchini, P.L., Furlotti, K., Medioli, A., 2021. Does corporate governance matter in corporate social responsibility disclosure? Evidence from Italy in the "era of sustainability". Corp. Soc. Responsib. Environ. Manag. 282, 896–907.

Tiep, L.T., Huan, N.Q., Hong, T., 2021. Role of corporate social responsibility in sustainable energy development in emerging economy. Int. J. Energy Econ. Pol. 112, 172–186.

United Nations, 2015. The 2030 Agenda for Sustainable Development. United Nations, New York, USA.

Vangchuay, S., Niklaus, A., 2021. Renewable energy employment gender gap. In: Book: Transitioning to Decent Work and Economic Growth. https://doi.org/10.3390/books978-3-03897-779-7-8.

Vardon, M., Lucas, P., Bass, S., Agarwala, M., Bassi, A.M., Coyle, D., et al., 2023. From COVID-19 to Green Recovery with natural capital accounting. Ambio 521, 15–29.

Vasilescu, V.F., Dinu, D., 2021. Installation of submarine cables and pipes in shallow waters and connecting them to the shore by the method of horizontal directional drilling. In: E3S Web of Conferences, vol. 286. EDP Sciences, 04007.

Vyas, S., Prajapati, P., Shah, A.V., Varjani, S., 2022. Municipal Solid Waste Management: Dynamics, Risk Assessment, Ecological Influence, Advancements, Constraints and Perspectives. Science of The Total Environment, 152802.

Wan, Q., Zhao, X., Liu, H., Dinçer, H., Yüksel, S., 2022. Assessing the new product development process for the industrial decarbonization of sustainable economies. Sage Open 121, 21582440211067231.

Wang, J., Dong, K., Wang, K., 2023. Towards green recovery: Platform economy and its impact on carbon emissions in China. Econ. Anal. Pol. 77, 969–987.

Wei, J., Dınçer, H., Yüksel, S., 2021. Pattern recognition of green energy innovation investments using a modified decision support system. IEEE Access 9, 162006–162017.

Yager, R.R., 2013. Pythagorean fuzzy subsets. In: 2013 Joint IFSA World Congress and NAFIPS Annual Meeting IFSA/NAFIPS. IEEE, pp. 57–61.

Yager, R.R., 2016. Generalized orthopair fuzzy sets. IEEE Trans. Fuzzy Syst. 255, 1222-123.

Yang, Q., Du, Q., Razzaq, A., Shang, Y., 2022. How volatility in green financing, clean energy, and green economic practices derive sustainable performance through ESG indicators? A sectoral study of G7 countries. Resour. Pol. 75, 102526.

Yilmaz, M.K., Hacioglu, U., Nantembelele, F.A., Sowe, S., 2021. Corporate board diversity and its impact on the social performance of companies from emerging economies. Global Business and Organizational Excellence 411, 6–20. https://doi.org/10.1002/joe.22135.

Yuan, G., Xie, F., Dinçer, H., Yüksel, S., 2021. The theory of inventive problem solving TRIZ-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. Int. J. Energy Res. 458, 12284–12300.

Yüksel, S., Dinçer, H., 2022. Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. Prog. Nucl. Energy 145, 104103.

Yüksel, S., Ubay, G.G., Çelebi, B., 2021. The negative role of environmental pollution on international trade: strategy recommendation to solve this problem. In: Handbook of Research on Recent Perspectives on Management, International Trade, and Logistics. IGI Global, pp. 122–138.

Zachariadis, T., Giannakis, E., Taliotis, C., Karmellos, M., Fylaktos, N., Howells, M., et al., 2023. Science policy frameworks for a post-pandemic green economic recovery. Energy Strategy Rev. 45, 101035.
Zhang, W.R., 1994. Bipolar fuzzy sets and relations: a computational framework for cognitive modelling and multiagent decision analysis. In: NAFIPS/IFIS/NASA'94. Proceedings of the First International Joint Conference of the North American Fuzzy Information Processing Society Biannual Conference. The Industrial Fuzzy Control and Intellige. IEEE, pp. 305–309.
Zhdaneev, O.V., Frolov, K.N., Petrakov, Y.A., 2021. Predictive systems for the well drilling operations. Cyber-Physical Systems: Design and Application for Industry 4.0 347–368 (Springer, Cham).