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REVIEW PAPERS

Demystifying sustainability challenges for the energy sector in developing economy

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Abstract The accelerated standards of living and upsurge in population have made energy security the key priority for policymakers globally. This poses a major challenge for the energy sources which are traditionally fossil-based and non-renewable. The depletion of these fuel sources is posing a threat to decision-makers. India, as an emerging economy, has a favorable tropical climate, which will help in generating clean energy with renewable resources. However, there are many barriers to achieving sustainable clean energy. In this study, we have collected 113 barriers from the existing literature, which are a major challenge for implementing sustainable energy, for our evaluation. In this study, the Fuzzy Delphi method is used to attain justifiable and dependable attributes using qualitative information. According to the ranking given by the industry experts, major barriers are further transformed into a comparable scale and presented through qualitative information. The study demystified major challenges to sustainability in the energy sector, Political interference, High investments in transmission and distribution networks, Lack of flexible generation, Interprets intervention effects and time lags differently, and Lack of grid expansion. Policy formulation is recommended to mitigate the above stated impediments in sustainable energy adoption.

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1 Introduction

The increased use of fossil fuels in the past decades has raised questions over the exhaustion of fossil resources in near future (Chandel et al. 2016). According to the prediction of the World energy forum, less than 10 years are available for the exhaustion of fossil-based fuels—Coal, Oil, and gas (Ritchie and Roser 2020). India ranks fourth in carbon emission production after, China, the USA, and the European Union, with the energy sector responsible for contributing nearly half of it in India (Chandel et al. 2016). In India, 74.456% of energy came from fossil fuels (Ritchie and Roser 2020). India's average per capita consumption of energy is higher than that of developed countries and is anticipated to aggravate more due to rapid industrialization and expected economic growth (Sen et al. 2016). The population explosion in India has led to the scarcity of fossil fuels. Consequently, energy shortages will be faced by India due to the rise in energy prices and energy insecurity over the coming decades (Varun and Singal 2007). The depletion of natural resources and the rising demand for conventional sources of energy have forced policymakers to look for alternate, sustainable resources (Kumar et al. 2010). Thereby arises the need for the sustained high growth of the economy at the rate of 8–10% every year for the next 25 years (IEP 2006). To achieve this growth a very significant amount of diversification is required in the energy system, but unless some dynamic changes are made to the sector to become greener, it would be difficult to be sustainable in the long run (Bhattacharyya 2010).

The best alternative is renewable energy, the one which we have in abundance and is inexhaustible should be utilized in full capacity by the Energy sector. Renewable energy helps to reduce carbon emissions on our planet and move a step forward toward sustainable development (Kumar et al. 2010). Carbon emissions are the emissions that are stemming from burning of fossil fuels like coal, one of the main input in generating electricity as they include carbon dioxide, methane, sulphur dioxide and other harmful gases which are the major drivers of climate change due to global warming. Many sustainable policies have been framed to promote renewable energies both at the national and international levels (Varun and Singal 2007). However, there are many challenges that the energy sector needs to overcome to focus on green energy. Prior studies have discussed the barriers to sustainability in the energy sector based on major indicators. A study by Bhattacharyya (2010). Claimed that supply management, managing energy investment projects effectively, resource management, and environmental and social responsibility management reflect the major management challenges faced in the energy sector in implementing sustainable energy. An entrepreneur faces cost barriers, bureaucratic obstacles, unavailability of skilled labor, and technological challenges to run a sustainability-driven venture (Haldar 2021). Wing energy-based power-producing technologies face industrial and policy development challenges as reported by Sitharthan et al. (2018). High upfront investments, corruption, and lack of long-term planning are some of the barriers stated by Engelken et al. (2016) to sustainable business model barriers. Shifting to Solar PV technology includes international barriers with a high initial cost, Wind energy technology includes challenges like the expiration of the Generation Based Incentive scheme, inadequate grid infrastructure, Biofuel industry faces challenges in terms of, dependency on sugarcane molasses, kerosene subsidies, and shortage of ethanol supply are some of the barriers (Tagotra 2017). In reality, it is hard to determine a viewpoint and conclusion from quantitative information, as linguistic ambiguity leads to deviation in the understanding of linguistic preferences (Bui et al. 2020). From the above-stated research gap by Bui et al. (2020), the following research questions need attention from the decision-makers:

(a) What are the prominent challenges that are hindering the sustainability performance of the Energy sector?

(b) How these challenges can be shortlisted for a closer focus on enhancing the sector's performance?

In this context, the current study examines the prominent challenges from literature. This study utilizes the Fuzzy Delphi method (FDM) to demystify the sustainable challenges in the energy sector. The rest of the study is divided as follows: Sect. 2 outlines the methods in detail. Section 3 describes the analysis of data. The results of the fuzzy set theory are discussed in Sect. 4. Lastly, the limitations and future scope of the study are presented in Sect. 5.

2 Review of literature

In an examination by Chu and Majumdar (2012), extensive literature review has been done to analyse the opportunities and challenges for a sustainable energy future. Making use of eco-friendly and efficient energy sources is a necessary component of ensuring the sustainability of energy to benefit both current and future generations. Streimikiene and Siksnelyte (2016) assessed which electricity market organization systems are the best using sustainability criteria as a guide where the sustainability of the power industry in various developed nations was found to benefit from the liberalization of the electricity market. The economic and technical viability of wind power systems was studied by Morea and Poggi (2017) and found that it can be achieved by the advantages of using Shari'ah-compliant Sukuk instruments and their applicability. Rösch et al (2017) studied the indicators required for political decision-making to effectively address sustainability aspects of the energy system and its transition. It also seeks to advance existing indicator systems, where using the indicator system in the right way can help with the development of resilient political strategies. An in-depth examination of the current state and prospects of Bangladesh's renewable energy sector was presented by Hil Baky et al (2017). Spanish energy policies and their implications for sustainable energy development were focused on by Gabaldón-Estevan et al. (2018). Lata-García et al (2018) aimed to discover and evaluate the degree of integration and performance of alternative clean ways of producing electricity into the country's energy system, the findings of this study demonstrate that the administration's actions over the past sixteen years have conformed with the principles outlined in the strategic planning for the decade from 2013 to 2022. A Renewable energy sustainability index designed by Cîrstea et al. (2018) revealed that by enhancing positive effect indicators and reducing negative impact indicators, the suggested index can offer strategies to boost a country's sustainability. Sitorus and Brito-Parada (2020) ranked the sustainability criteria of renewable energy technologies under uncertainty using a multi-criteria decision-making method. A Sustainable hybrid renewable system to reduce carbon emissions in Iran was investigated by Razmjoo et al (2021) where appropriate implementation of policies of new enabling technologies and investments in renewable energy resources were found to be useful indicators to reduce the emissions. A study by Ahmad et al. (2021), shows Artificial intelligence is the future magic tool in replacing the traditional methods and improving the operational energy efficiency.

Based on the findings, multiple sector-specific challenges were encountered in implementing sustainability. Anuar and Abdullah (2016) identified feedstock, environmental issues, waste glycerol glut problem, product commercialization, and acceptance by society as the major barriers to the bio-diesel industry. Solar manufacturing challenges identified by Sahoo (2016) in India were reliance on imported wafers for the production of cells, high cost of capital and finance, competition with Taiwan and China, Low demand, and a lack of technical expertise, particularly in the upstream sector. Financial challenges were also identified as a key factor in the implementation of sustainable development goals in Africa by Schwerhoff and Sy (2017). The development of the alternative and renewable energy sector and the implementation of energy efficiency projects in Azerbaijan are impeded by visible hurdles such as institutional operation, expensive renewable energy plants, and other economic and policy barriers (Vidadili et al. 2017). Despite the significant problems associated with the use of coal, such as the emissions of greenhouse gases and air pollutants like sulfur dioxide (SO_2) and carbon dioxide (CO_2), coal has remained a very important commodity in South-East Asia as a whole as well as Malaysia's energy supply (Oh et al. 2018). Challenges identified by Ugwu et al. (2021) in Nigeria includes insufficient infrastructure, contradictory government regulations, and enormous metering gaps.

3 Research methodology

India alone negatively contributed, 1.8 metric tonnes of per capita carbon emissions in 2018 (World Bank 2018). The energy sector contributes the most to it, with India still producing 85% power from coal. Even though modernization and industrialization have catered to many businesses, it has also raised the opportunity cost of negative environmental impacts. With the growing population in India, and to keep pace with the global economy, the power demand is mounting (Pathak et al. 2016). So, it's important to implement synchronous solutions that would be more sustainable.

This study helps to demystify the sustainability challenges that result in the negative performance of the Energy sector. To search relevant literature, we have explicitly typed the combination of words such as: 'Sustainability + Energy sector', 'Sustainable energy + implementation challenges', Sustainability + MCDM',' Sustainable energy + Fuzzy Delphi method', and ' Energy sector + carbon emissions' on Scopus, web of science and google scholar to get the required data. This session discusses the identification of challenges and addresses the proposed Fuzzy Delphi method.

3.1 Identification of challenges

The decision-makers include 10 experts, 2 academicians, and 8 experts from the energy sector. All the experts have extensive knowledge and experience in the Energy sector,

Table 2 Evaluation table for FDM

Linguistic terms (importance)	Code	Corresponding fuzzy values
Extremely Important	EI	(0.75,1.0,1.0)
Important	I	(0.5,0.75,1.0)
Moderately Important	MI	(0.25,0.5,0.75)
Least Important	LI	(0,0.25,0.50)
Not Important	NI	(0,0,0.25)

Table 1 Experts who participated in the decision-making process

Expert's background	No	Expert's position	Expert's work experience
Industrial Expert (Government Sector)	5	Deputy Manager (Finance)	Above 20 years
		Deputy Manager (HR)	Above 20 years
		Senior Operations Manager	10–15 years
		Civil Engineer	5–10 years
		Junior Project Officer	0–5 years
Academicians/University Professors	2	Professor (Private University)	Above 20 years
		Assistant Professor (Public University)	5–10 years
Technical Expert (Government Sector)	3	Deputy Manager	Above 20 years
		Junior Officer	0–5 years
		Project Manager	5–10 years

in India. The details of the decision-makers are given in Table 1. Evaluation of linguistic terms for fuzzy set theory is given in Table 2

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3.2 Fuzzy Delphi method (FDM)

Delphi is a method developed by Dalkey and Helmer (1963) where expert comments and feedback are taken after several discussions with them. A formal communication strategy or technique which was first imagined as a systematic, interactive predictive process based on an expert panel, is built on an expert opinion survey with three features: unnamed responses, monitored input iterations, and statistical responses by group (Mabrouk 2020). The method has been applied to several areas, including industrial quality evaluation, investment decisions, production prediction, etc. (Dong and Huo 2017). The judgments of the decision-maker are generally subjective, quantifying the same using crisp numbers is a tedious task, thereby paving the way for fuzzy set theory. A study by Wang et al. (2019), demonstrated that the Fuzzy Delphi process relies on an exchange of information to produce subjective determinations based on the objective judgments of various experts. Alternatively, the robustness of FDM lies in the fact that to achieve consensus, experts' opinions are considered and integrated thereby reducing investigation times and decision-making costs (Kuo and Chen 2008; Lee et al. 2018; Padilla-Rivera et al. 2021). Therefore, the uncertainty of the survey process can be resolved by collective expert judgment when the fuzzy set theory is integrated into the conventional Delphi approach, which entails multiple survey rounds to obtain acceptable decisions. Additionally, it would be able to speed up the surveying procedure (Md Hashim et al. 2022).

The challenges proposed for measurement are presented in Table 3. According to expert p, attribute q has a significant value as stated by O = (l_{pq};m_{pq};n_{pq}), where p = 1,2,3,…….,y; q = 1,2,3,…….,z; then weight O_q of element q is O_q= (l_q;$m_{q;}n_q$), where l_q = min(l_{pq}), m_q=$(\prod_1^y m_{pq})^{1/y}$, and n_q = max(n_q). Then, the fuzzy numbers and linguistic terms are converted into linguistic values. Convex combination G_q is generated by the following equations and are created by adding a β cut to reach the result (Bui et al. 2020; Wu et al. 2016).

$$x_q = n_q - \beta(n_q - m_q),\ w_q = l_q - \beta(m_q - m_{lq}),\quad q = 1, 2, 3, \ldots, z \tag{1}$$

Generally, β is denoted by 0.5. It ranges between 0 and 1 according to negative or positive expert opinions.

The exact value of G_q can be generated using the following equation:

$$G_q = \int (x_q, w_q) = \gamma\left[x_q + (1-\gamma)w_q\right] \tag{2}$$

where γ describes the positive opinion of the expert and helps in attaining an equilibrium among all the expert judgments.

Then $\delta = \sum_p^y (G_q/y)$ serves as the key to filtering out the required attributes. If $G_q \geq \delta$, then attribute q is accepted, else rejected.

3.3 Data analysis

This study is focused on 113 challenges i.e., the initial set of challenges proposed in Table 3 which was collected from literature reviews and decision-makers. Post evaluation, the scaling is done by the decision-makers based on linguistic terms and their corresponding fuzzy numbers given in Table 2. Further, these challenges are refined using FDM, which has been divided into two phases. In the first phase, accepted attributes have been screened out in Table 3 using Eqs. (1) and (2) with threshold $\delta = 0.329$.

Based on this result, a questionnaire is circulated for additional assessment and used as an input for FDM Phase 2. 47 challenges are accepted and renamed as Phase 1 set, Using the same equations, the barriers are further screened in Table 4 with threshold $\delta = 0.436$.

Based on this result, a final set of challenges is prepared and renamed in Table 5.

Five of the biggest challenges are ranked from most to least important according to their weights and are further studied for implications. The problems are Political Interference (FC14), High investments in transmission and distribution networks (FC3), Lack of flexible generation capacity (FC7), Interprets interventions effects and time lags differently (FC5), and Lack of grid expansion (FC10).

4 Results and discussion

The final result indicates that Political Interference (FC14), is the most important issue in implementing sustainability in the energy sector. Excess political interference has slowed down the implementation of many political reforms in the energy sector.

Table 3 FDM Phase 1—screening out attributes

Initial Challenges	Description	References	x(q)	w(q)	G(q)	Accept/Reject
C1	Absence of communication between companies	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C2	Absence of cooperation	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C3	Absence of financial commitments	Bui et al. (2020) and Fernando (2019)	0.736	– 0.236	0.309	Reject
C4	Absence of partnerships and public cooperation	Bui et al. (2020) and Fernando (2019)	0.625	0.125	0.344	Accept
C5	Absence of program participation	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C6	Absence of staff capability	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C7	Apathy in the workplace and society	Alavi Moghadam et al. (2009) and Bui et al. (2020)	0.625	0.125	0.344	Accept
C8	Barriers relating to distance	Aid et al. (2017) and Bui et al. (2020)	0.679	– 0.179	0.295	Reject
C9	By–product must undergo extensive processing before reuse	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C10	Conflicting interests	Bui et al. (2020) and Yukalang et al. (2017)	0.771	0.104	0.412	Accept
C11	Difficulty in raising capital from external sources	Aid et al. (2017) and Bui et al. (2020)	0.625	0.125	0.344	Accept
C12	Due to higher commitments, less priority is given to RE	Mustapa et al. (2010)	0.5	0	0.25	Reject
C13	Efforts to promote renewable energy is hampered by final energy costs	Mustapa et al. (2010)	0.5	0	0.25	Reject
C14	Energy generation from Renewable Energy is intermittent	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C15	The energy system is vulnerable to a variety of Exogenous shocks	Yalew (2022)	0.5	0	0.25	Reject
C16	Environmental sustainability	Papadis and Tsatsaronis (2020)	0.895	– 0.02	0.442	Accept
C17	Financial margins are unpredictable	Aid et al. (2017) and Bui et al. (2020)	0.711	– 0.211	0.303	Reject
C18	Focusses on gathering and analyzing irrelevant data	Bui et al. (2020) and Seadon (2010)	0.877	– 0.002	0.438	Accept
C19	Future Energy demand forecasts are uncertain	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C(20	High investments in transmission and distribution networks	Papadis and Tsatsaronis (2020) and Razi and Dincer (2022)	0.959	0.291	0.552	Accept
C21	High market uncertainty	Narwane et al. (2021)	0.5	0	0.25	Reject
C22	High payback period	Narwane et al. (2021)	0.782	0.093	0.414	Accept
C23	Ignoring the adverse effects of an intervention	Bui et al. (2020) and Seadon (2010)	0.808	0.067	0.421	Accept
C24	Immigrants and population increase	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C25	Implementing irreversible interventions instead of mechanisms	Bui et al. (2020) and Seadon (2010)	0.881	– 0.006	0.439	Accept
C26	Inability to respond and over-correction when using greater interventions	Bui et al. (2020) and Seadon (2010)	0.727	– 0.227	0.307	Reject
C27	Inadequacy in planning and strategy	Bui et al. (2020) and Yukalang et al. (2017)	0.806	0.069	0.42	Accept
C28	Inadequacy of information and Training systems	Bui et al. (2020) and Yukalang et al. (2017)	0.881	– 0.006	0.439	Accept
C29	Inadequate and ineffective regulation	Bui et al. (2020) and Yukalang et al. (2017)	0.856	0.019	0.433	Accept
C30	Inadequate communication	Bui et al. (2020) and Yukalang et al. (2017)	0.799	0.076	0.419	Accept

Table 3 (continued)

Initial Challenges	Description	References	x(q)	w(q)	G(q)	Accept/Reject
C31	Inadequate control methods	Bui et al. (2020) and Fernando (2019)	0.794	0.081	0.417	Accept
C32	Inadequate environmental knowledge, education, and attitudes in society	Alavi Moghadam et al. (2009) and Bui et al. (2020)	0.5	0	0.25	Reject
C33	Inappropriate media	Bui et al. (2020) and Yukalang et al. (2017)	0.868	0.007	0.436	Accept
C34	Inefficiency in socio-political and Institutional Environment	Lu et al. (2019)	0.5	0	0.25	Reject
C35	Institutional incapacity	Bui et al. (2020) and Fernando (2019)	0.5	0	0.25	Reject
C36	Instruments and modern technology are in short supply	Bui et al. (2020) and Fernando (2019)	0.5	0	0.25	Reject
C37	Internally accessible capital is in short supply	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C38	Interprets intervention effects and time lags differently	Bui et al. (2020) and Seadon (2010)	1	0.625	0.656	Accept
C39	Interventions may be irreversible	Bui et al. (2020) and Seadon (2010)	0.375	0	0.188	Reject
C40	Investment cycle differences	Aid et al. (2017) and Bui et al. (2020)	0.832	0.043	0.427	Accept
C41	Lack of a defined procedure for collecting and analyzing data	Bui et al. (2020) and Esmaeilian et al. (2018)	0.819	– 0.319	0.33	Accept
C42	Lack of awareness among companies regarding Sustainable incentives provided by the Government	Mustapa et al. (2010) and Razi and Dincer (2022)	0.946	0.304	0.549	Accept
C43	Lack of collaboration between private and public sectors	Bui et al. (2020) and Srivastava et al. (2005)	0.375	0	0.188	Reject
C44	Lack of effective storage facilities	Narwane et al. (2021)	0.5	0	0.25	Reject
C45	Lack of Energy efficient policies	Papadis and Tsatsaronis (2020)	0.811	– 0.311	0.328	Reject
C46	Lack of energy-efficient supply chain standards	Narwane et al. (2021)	0.852	0.023	0.432	Accept
C47	Lack of Entrepreneurship support	Engelken et al. (2016) and Narwane et al. (2021)	0.5	0	0.25	Reject
C48	Lack of Flexible generation capacity	Papadis and Tsatsaronis (2020)	0.94	– 0.065	0.454	Accept
C49	Lack of flexible thermal plants	Papadis and Tsatsaronis (2020)	0.828	– 0.328	0.332	Accept
C50	Lack of functioning institutional network	Mustapa et al. (2010)	0.806	0.069	0.42	Accept
C51	Lack of Governmental support for sustainable solutions	Narwane et al. (2021)	0.928	– 0.053	0.451	Accept
C52	Lack of Grid Expansion	Papadis and Tsatsaronis (2020)	0.911	– 0.036	0.446	Accept
C53	Lack of investment and capital allowances for RE implementation	Mustapa et al. (2010)	0.5	0	0.25	Reject
C54	Lack of Investments in energy conversion systems	Papadis and Tsatsaronis (2020)	0.782	– 0.282	0.321	Reject
C55	Lack of Policy formulation and Implementation	Razi and Dincer (2022)	0.5	0	0.25	Reject
C56	Lack of professional training institutes	Narwane et al. (2021)	0.5	0	0.25	Reject
C57	Lack of R&D facilities	Narwane et al. (2021)	0.5	0	0.25	Reject
C58	Lack of skills in equipment handling in developing economies	Mustapa et al. (2010)	0.5	0	0.25	Reject
C59	Lack of Socially compatible design	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C60	Lack of storage and transportation of energy-efficient fuels	Razi and Dincer (2022)	0.856	0.019	0.433	Accept
C61	Lack of subsidies/incentives for creating competition among the producers of sustainable energy-efficient fuels	Narwane et al. (2021)	0.806	– 0.306	0.327	Reject
C62	Lack of supporting laws	Aid et al. (2017) and Bui et al. (2020)	0.83	0.045	0.426	Accept
C63	Lack of trained and skilled Human resources	(Engelken et al. (2016; Narwane et al. (2021);	0.5	0	0.25	Reject

Table 3 (continued)

Initial Challenges	Description	References	x(q)	w(q)	G(q)	Accept/Reject
C64	Lack of transparency and accountability	(Lu et al. (2019)	0.848	0.027	0.431	Accept
C65	Lack of well-designed and flexible electricity markets	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C66	Laws that are complicated and uncertain	Aid et al. (2017) and Bui et al. (2020)	0.771	0.104	0.412	Accept
C67	Legislation is weak and insufficient	Bui et al. (2020) and Yukalang et al. (2017)	0.852	0.023	0.432	Accept
C68	Less labor productivity and quantity	Bui et al. (2020) and Fernando (2019)	0.946	0.304	0.549	Accept
C69	Limited participation due to absence of social responses	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C70	Local strategy is lacking	Bui et al. (2020) and Fernando (2019)	0.5	0	0.25	Reject
C71	Long planning duration	Papadis and Tsatsaronis (2020)	0.868	– 0.368	0.342	Accept
C72	Long term Investment yield	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C73	Need for Education efforts with career opportunities	Razi and Dincer (2022)	0.5	0	0.25	Reject
C74	Need for Global Coal phase out	Papadis and Tsatsaronis (2020)	0.76	0.115	0.409	Accept
C75	Need for Universal Standardization	Razi and Dincer (2022)	0.5	0	0.25	Reject
C76	Negative public perceptions	Bui et al. (2020) and Yukalang et al. (2017)	0.852	0.023	0.432	Accept
C77	New energy systems have low trip efficiency	Papadis and Tsatsaronis (2020)	0.25	0	0.125	Reject
C78	No long term planning for sustainability	Bui et al. (2020) and Seadon (2010)	0.832	0.043	0.427	Accept
C79	No procedure to ensure job rotation among employees	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C80	Organizational income and cost-sharing	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C81	Organizational politics	Bui et al. (2020) and Yukalang et al. (2017)	0.906	– 0.031	0.445	Accept
C82	Organizational resistance to change	Aid et al. (2017) and Bui et al. (2020)	0.881	– 0.006	0.439	Accept
C83	Political interference	Bui et al. (2020) and Fernando (2019)	0.967	– 0.092	0.46	Accept
C84	Poor communication	Bui et al. (2020) and Yukalang et al. (2017)	0.873	– 0.373	0.343	Accept
C85	Poor regulatory framework	Bui et al. (2020) and Fernando (2019)	0.844	– 0.344	0.336	Accept
C86	Poor working conditions	Narwane et al. (2021)	0.5	0	0.25	Reject
C87	Public apathy	Alavi Moghadam et al. (2009) and Bui et al. (2020)	0.786	– 0.286	0.321	Reject
C88	The public is waiting for the government to act	Alavi Moghadam et al. (2009) and Bui et al. (2020)	0.778	– 0.278	0.319	Reject
C89	Pursuing Only mandatory level of Environmental Restrictions	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C90	A rise in the overall sustainability cost	Mustapa et al. (2010.)	0.873	0.002	0.437	Accept
C91	Risk of corruption in the Supply chain	Lu et al. (2019)	0.5	0	0.25	Reject
C92	Scarcity of knowledge, education, and communication in human resource development	Bui et al. (2020) and Srivastava et al. (2005)	0.729	– 0.229	0.307	Reject
C93	Scarcity of knowledge about the potential benefits	Aid et al. (2017) and Bui et al. (2020)	0.846	0.029	0.43	Accept
C94	Shifting regulations and producer risk	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C95	Space limitations	Bui et al. (2020) and Yukalang et al. (2017)	0.5	0	0.25	Reject
C96	Staff members are overworked	Bui et al. (2020) and Yukalang et al. (2017)	0.763	– 0.263	0.316	Reject
C97	Supportive policies for the primary extraction industry	Aid et al. (2017); Bui et al. (2020)	0.5	0	0.25	Reject

Table 3 (continued)

Initial Challenges	Description	References	x(q)	w(q)	G(q)	Accept/Reject
C98	Technical problems related to conversion technologies	Narwane et al. (2021)	0.5	0	0.25	Reject
C99	The deficit in Base and peak Energy	Saraswat and Digalwar (2021)	0.834	0.041	0.427	Accept
C100	The high opportunity cost of public investments in the Energy sector	Yalew (2022)	0.5	0	0.25	Reject
C101	The intervention's side effects are ignored or undervalued	Bui et al. (2020) and Seadon (2010)	0.5	0	0.25	Reject
C102	The sector is inextricably interwoven with macroeconomics and the environment	Yalew (2022)	0.5	0	0.25	Reject
C103	The situation of stranded assets	Papadis and Tsatsaronis (2020)	0.838	− 0.338	0.334	Accept
C104	The variety of energy resources varies greatly between geographical and administrative regions	Yalew (2022)	0.5	0	0.25	Reject
C105	Time gaps between action and outcomes are frequently overlooked	Bui et al. (2020) and Seadon (2010)	0.697	− 0.197	0.299	Reject
C106	Too much time in the construction of Energy conversion systems	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C107	Transaction expenses are High	Aid et al. (2017 and Bui et al. (2020)	0.881	− 0.006	0.439	Accept
C108	Unavailability of data on ecological impacts	Narwane et al. (2021)	0.743	− 0.243	0.311	Reject
C109	Uncertainty regarding long term biomass supply and price fluctuations	Mustapa et al. (2010)	0.877	− 0.002	0.438	Accept
C110	Unreliable Power supply	Mustapa et al. (2010.)	0.5	0	0.25	Reject
C111	Unstable market	Aid et al. (2017) and Bui et al. (2020)	0.5	0	0.25	Reject
C112	Unstable political conditions	Papadis and Tsatsaronis (2020)	0.5	0	0.25	Reject
C113	Weak electricity grids	Engelken et al. (2016)	0.786	− 0.286	0.321	Reject
Threshold					0.329	

A study by Kwakwa et al. (2021) found that the effort to lessen the causes and effects of climate change, the political system of a nation has a considerable impact on the quality of its institutions, and concluded that there is a positive influence between political regime and access to clean fuelss reported by Bhattacharyya (2010) the reduced state funding and inadequate mobilization of private capital widened the gap between planned and actual capacity expansions, worsening the country's demand–supply imbalance. In India, electricity losses tend to spike right before state assembly elections, and agricultural price subsidies rise dramatically in the year leading up to an election (Verma et al. 2020). Also, private sector engagement in renewable energy projects is hampered by a lack of power and delays in clearances and allotments for private sector projects (Mirza et al. 2009). To achieve efficiency in the energy industry, stable, strict, long-lasting reforms and single window clearance systems must be introduced immediately. The High investments in Transmission and Distribution networks (FC3) have led to poor performance in the energy sector. Renewable energy developers may find themselves in a disadvantageous situation due to intermittent generation characteristics of renewable technologies and their site-specific nature in terms of power transmission contract structuring, the site-specific character of renewables is a disadvantage for some transmission pricing schemes that are based on distance (Mirza et al. 2009). As per, Mani and Dhingra (2013) Transmission infrastructure costs for offshore wind farms are very high, as sub-sea cabling requires superior engineering skills. So, the government should bear these expenses and recover the cost by a small increase in the tariff. The Lack of flexible generation capacity (FC7) generates similar concerns. Storage, connectivity, demand-side response, and fast-acting generators can all be used to increase operational flexibility (Das

Table 4 List of FDM—Phase 2 Screening out Attributes

Initial Challenges	Phase 1—set	u(y)	l(y)	Db	Accept/Reject
C4	P1	0.578	– 0.203	0.238	Reject
C7	P2	0.578	– 0.203	0.238	Reject
C10	P3	0.720	– 0.220	0.305	Reject
C11	P4	0.794	0.081	0.417	Reject
C16	P5	0.888	– 0.013	0.441	Accept
C18	P6	0.909	0.341	0.540	Accept
C20	P7	0.959	0.291	0.552	Accept
C22	P8	0.819	0.056	0.423	Reject
C23	P9	0.782	0.093	0.414	Reject
C25	P10	0.846	0.029	0.430	Reject
C27	P11	0.806	0.069	0.420	Reject
C28	P12	0.832	0.043	0.427	Reject
C29	P13	0.819	0.056	0.423	Reject
C30	P14	0.909	0.341	0.540	Accept
C31	P15	0.806	0.069	0.420	Reject
C33	P16	0.794	0.081	0.417	Reject
C38	P17	0.946	0.304	0.549	Accept
C40	P18	0.806	0.069	0.420	Reject
C41	P19	0.786	– 0.286	0.321	Reject
C42	P20	0.909	0.341	0.540	Accept
C46	P21	0.794	– 0.294	0.324	Reject
C48	P22	0.959	0.291	0.552	Accept
C49	P23	0.921	0.329	0.543	Accept
C50	P24	0.819	0.056	0.423	Reject
C51	P25	0.877	– 0.002	0.438	Accept
C52	P26	0.946	0.304	0.549	Accept
C60	P27	0.819	0.056	0.423	Reject
C62	P28	0.771	0.104	0.412	Reject
C64	P29	0.806	0.069	0.420	Reject
C66	P30	0.806	0.069	0.420	Reject
C67	P31	0.846	0.029	0.430	Reject
C68	P32	0.921	0.329	0.543	Accept
C71	P33	0.916	– 0.041	0.448	Accept
C74	P34	0.763	– 0.263	0.316	Reject
C76	P35	0.838	0.037	0.428	Reject
C78	P36	0.806	0.069	0.420	Reject
C81	P37	0.940	– 0.065	0.454	Accept
C82	P38	0.838	0.037	0.428	Reject
C83	P39	0.986	0.264	0.559	Accept
C84	P40	0.873	0.002	0.437	Accept
C85	P41	0.940	– 0.065	0.454	Accept
C90	P42	0.877	– 0.002	0.438	Accept
C93	P43	0.806	0.069	0.420	Reject
C99	P44	0.877	– 0.002	0.438	Accept
C103	P45	0.819	0.056	0.423	Reject
C107	P46	0.846	0.029	0.430	Reject
C109	P47	0.846	0.029	0.430	Reject
Threshold				0.436	

et al. 2020). The lack of incentives for flexible generation capacity makes securing energy supply at all times a major concern, especially when certain technologies are phased out at the same time (Papadis and Tsatsaronis 2020). Thus, the need for economically sustainable technologies arises. Interprets interventions effects and time lags differently (FC5) is another challenge in the implementation of sustainable energy. Time lags between treatments and their effects are underestimated, which leads people to mistakenly believe that there is a lack of response and so a need for stronger interventions, which leads to overcorrection that needs to be corrected (Seadon 2010). When implementing complex regulations, there is ambiguity, which makes it difficult to foster teamwork and leads to a pricey, drawn-out, and challenging governmental approval process. Therefore, superfluous law hinders symbiotic transfers and limits beneficial environmental activities.

Lack of grid expansion (FC10), where the supply needs to keep up with the growing energy demand. For a successful energy transition to take place, innovative sustainable technologies need to be adopted to increase the supply and overcome the challenge. It would also help to generate electricity cost-effectively in rural areas as well.

5 Limitations

Nevertheless, limitations exist. First, this study is in its preliminary stage and needs to be more elaborated to attain a holistic approach. The extension of which will be forwarded in future studies. Second, this study is reliable on the decision maker's judgments, hence in further studies more Multi-criteria decision-making techniques will be adopted to attain more technical validity. Third, more number decision-makers could be contacted to get more reliable results.

6 Conclusion and recommendation

The overexploitation of fossil fuels by the energy sector has led to not only its exhaustion but also raised many environmental concerns. Hence, this study aims to demystify the challenges to sustainability in the energy sector. A set of 113 barriers are stated and analyzed using FDM. Fuzzy set theory helps to transform the quantitative data by experts into qualitative linguistic terms. This study identified political interference, high investments in transmission and distribution networks, lack of flexible generation capacity, Interprets intervention effects and time lags differently, and Lack of grid expansion as the most important challenges that hinder the performance of sustainability in the energy sector. Therefore, it is recommended that necessary policies to be taken

Table 5 List of final challenges

Phase -2 set	Final challenges	Description	Ranking
P5	FC1	Environmental sustainability	8
P6	FC2	Focuses on gathering and analyzing irrelevant data	5
P7	FC3	High investments in transmission and	
distribution networks	2		
P14	FC4	Inadequate control methods	5
P17	FC5	Interprets interventions effects and time lags differently	3
P20	FC6	Lack of awareness among companies regarding	
Sustainable incentives provided by the Government	5		
P22	FC7	Lack of Flexible generation capacity	2
P23	FC8	Lack of flexible thermal plants	4
P25	FC9	Lack of Governmental support for sustainable solutions	9
P26	FC10	Lack of Grid Expansion	3
P32	FC11	Less labor productivity and quantity	4
P33	FC12	Long planning duration	7
P37	FC13	Organizational politics	6
P39	FC14	Political interference	1
P40	FC15	Poor communication	10
P41	FC16	Poor regulatory framework	6
P42	FC17	Risk of corruption in the Supply chain	9
P44	FC18	The high opportunity cost of public investments	
in the Energy sector	9		

by the government regarding technology, investments and administration for combating the challenges for the implementation of sustainable energy.

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Declarations

Conflict of interest The authors confirm that this work has not been published elsewhere and also it has not been submitted simultaneously for publication elsewhere. No potential conflicts were recorded during this work.

Human participants and/or animals All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee, Authors declare the accomplishment of all ethical standards in this work.

Informed financial consent The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence work. No funding was received and/or applied in this research work.

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