

# **Analyzing Challenges to Utilizing Renewable Energy in the Context of Developing Countries: Policymaking Implications for Achieving Sustainable Development Goals**

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## **Abstract**

Utilizing renewable energy (RE) to minimize the use of fossil fuels is an emerging concept throughout the globe to attain energy sufficiency while reducing the negative impact on the environment. Since the existing infrastructures and concepts of energy consumption stand on burning fossil fuels for hundreds of years, ideas for replacing those by implementing RE often stumble with several barriers, especially in developing countries where there are numerous resource constraints. These barriers create critical policymaking challenges to achieving comprehensive energy sustainability. Several studies discovered the challenges to utilizing RE in the context of developing nations. However, no study has yet been conducted to prioritize the challenges and examine the relations among them. This study, thereby, utilizes the decision-making trial, and evaluation laboratory (DEMATEL) method to identify the prioritization, and examine the relations among the critical challenges to utilizing RE in the context of developing countries. Thirteen challenges were identified from reviewing literature and expert feedback, which were then analyzed by the DEMATEL method. The findings revealed that ‘Large land requirement’, ‘Uncertain supply’, and ‘End life management difficulties’ are the three most prominent challenges to utilizing RE in developing countries. The explored cause-effect relations among the challenges indicate ‘Long economic recovery periods’ to be the most causative and ‘Lack of social awareness and acceptance’ to be the least causative challenge. This study is expected to assist the policymakers of developing nations in successfully utilizing RE sources to achieve long-term energy sustainability, thus achieving sustainable development goals (SDGs).

## **Keywords**

Renewable energy, Developing countries, Challenges, Decision-making trial and evaluation laboratory, Sustainable development goals.

## **1. Introduction**

Energy scarcity has already become one of the most challenging issues to overcome all over the world, which is going to be more severe in the upcoming years (Mahmud et al., 2021). This challenge becomes even further critical when global warming due to greenhouse gas (GHG) emissions from burning fossil fuels is taken into consideration (Moorthy et al., 2019). Researchers and practitioners have been thinking about utilizing RE because of its diverse benefits over fossil fuels for a long ago. United Nations (UN) SDGs since 2015 for a better world to live in by ensuring both social and environmental sustainability mobilize global and local policymakers to this idea as well (Bertheau, 2020).

Nowadays, the concept of utilizing RE is one of the emerging concepts among the global community to achieve SDGs all over the world. Along with environmental sustainability, RE has robust influences on many other economic and social factors (Fashina et al., 2018). However, the existing energy consumption infrastructures throughout the globe highly depend on burning fossil fuels, which hinders the implementation of RE on a large scale, especially in developing countries (Luthra et al., 2015; Adebayo et al., 2022). It requires an initial investment, returns on investment, government policies, social awareness, research and development facilities, supply chain stability, and many more to make a successful transition from fossil fuel to RE, with which developing countries cannot keep up due to resource constraints (Engelken et al., 2016; Ghimire and Kim, 2018). Moreover, the emerging economy of a developing country often demands a very quick return on investment, which phenomenon obstructs policymakers to think of long-term sustainability (Nasirov et al., 2015). Therefore, it is always more challenging to implement RE in a developing country than in a developed one.

There are several recent works in the existing literature to address the barriers, drivers, and other aspects of implementing RE in the context of developing countries. For instance, Asante et al. (2022) prioritized strategies to eliminate barriers to RE adoption; Fatima et al. (2021) discovered the influencing factors for RE implementation; Balakrishnan et al. (2020) described the barriers to RE by depicting the existing scenario and the prospect of utilizing RE; Moorthy et al. (2019) determined and analyzed the barriers to utilizing RE; Ghimire and Kim (2018) prioritized the barriers to RE utilization; Schwerhoff and Sy (2017) analyzed key challenges to financing renewable energy projects; Engelken et al. (2016) presented a comparison between different barriers, drivers and opportunities to propose renewable energy business model; and so on. So far, no study has been observed that discovered the policymaking challenges to utilizing RE and analyzed those challenges for prioritizing and correlating for having SDGs policy implication insights. Moreover, very few studies have applied numerical analysis methods to depict a causal model of the challenges. This can be addressed as a research gap to be explored. Therefore, this study is going to discover the prioritization of the challenges and the causal relationships among those in the context of a developing country. For this purpose, this study is going to utilize the DEMATEL approach for determining both prioritization and a causal model.

DEMATEL is a prominent numerical approach that is widely used by researchers in a complex decision-making environment where the subjective judgment of the decision-makers needs to be presented numerically (Braga et al., 2021). For deciding on multiple factors or alternatives, two tasks are very important. First, determining a prioritization or ranking of the alternatives, and second, determining the relationships among the alternatives. DEMATEL is capable of doing both of these tasks simultaneously (Si et al., 2018). For overcoming the challenges of utilizing RE, policymakers need to address the top prioritized challenges first, then hierarchically the remaining challenges. In addition to this, a cause-effect relationship among the challenges can provide a robust model during implementation. Moreover, numerical or objective data on critical challenges are not readily available to apply an empirical statistical approach. Therefore, experts' evaluation-based numerical analyzing method DEMATEL is considered as a suitable tool for this study. DEMATEL has been applied in many recent decision-making studies such as analyzing barriers to waste management (Meas et al., 2022); accessing the challenges of international business (Ghag et al., 2022); analyzing the enabler of service quality assurance (Gupta et al., 2022); discovering critical success factors of the supply chain (Prakash et al., 2021); examining the relationships among the determinants of a smart city (Braga et al., 2021) and so on. However, no study has yet been found to explore prioritization and causal relations of the challenges to utilizing RE by applying the DEMATEL method. Therefore, it is depicting the nobility of this ongoing study.

This study, in the context of developing countries, is going to fulfill the following objectives as a contribution to the RE implementation literature-

- a) To identify the most relevant challenges to utilizing RE
- b) To determine the prioritization of the challenges to be addressed hierarchically
- c) To explore cause-effect relationships among the examined challenges
- d) To discuss policymaking implications to attain SDGs

The rest of the paper is constructed as Section 2 will summarize the challenges to utilizing RE from the existing closely related literature to this study, Section 3 will describe the detailed procedure of data collection, numerical methodology, and calculations of the study, and Section 4 will discuss the obtained results. Then, Section 5 will present the policymaking implications to achieve SDGs, and finally, Section 6 will conclude the paper by presenting the unique results and limitations of the study, as well as suggesting some future development scope of this study. An Appendix is provided at the end of the paper for presenting some detailed steps of the data collection procedure.

## **2. Overview of the Challenges to Utilizing RE in Developing Countries**

Achieving environmental sustainability is considered a global challenge and reducing GHG emissions is the key critical success factor to overcome this challenge. Implementing RE in all sectors of energy consumption can highly affect the reduction of GHG emissions whether in a developed or a developing country (Khan et al., 2021). Existing literature suggests that the implementation of RE in a developing country is always more challenging than implementing it in a developed country (Moorthy et al., 2019). Several studies have identified many critical challenges to overcome in developing nations. Among those identified challenges by previous researchers, the twelve policymaking challenges are discussed here to be analyzed in this study-

**Lack of social awareness and acceptance:** Sen and Ganguly (2017), as well as Ghimire and Kim (2018), claimed that developing countries are falling behind in the case of RE utilization due to the lack of social awareness and acceptance from the native. RE implementation demands active participation from all walks of life.

**Absence of policies favoring renewable energy:** Developing countries are short of policies that favor utilizing RE in different sectors (Ghimire and Kim, 2018). Long-term government policies to attain SDGs are always important for establishing a new RE-based energy model by replacing the existing fossil fuel-based model. It seems difficult for a developing country to keep the balance between excessive demand and limited supply in its emerging economy where fossil fuels are the readily available source of energy.

**Inadequate research and development facility:** Luthra et al. (2015), Ghimire and Kim (2018), and Shahsavari and Akbari (2018) identified the inadequacy of research and development facilities in the developing countries obstruct them to utilize the benefits of RE. Climate, geographic position, socio-economic structure, and many other factors demand country-wise independent research facilities to develop RE implementing structure.

**Uncertain supply:** Conventional energy sources are capable of meeting the demand uncertainty due to their controllable production. On the other hand, RE sources (solar energy, wind energy, hydro energy, etc.) are highly dependable on various natural phenomena (such as weather), thus creating uncertainty in the energy supply (Engelken et al., 2016; Gernaat et al., 2021).

**Absence of grid connection technology:** Luthra et al. (2015) and Ghimire and Kim (2018) described that the proper utilization of RE requires smart grid technology with which most developing countries are not familiar. In those countries, RE infrastructures are scattered rather than clustered because of the absence of grid connection technology.

**High initial installation cost:** As RE is an emerging sector and the technologies involved with this are not fully matured yet, utilizing RE requires a high initial installation cost. Luthra et al. (2015), as well as Schwerhoff and Sy (2017), identified this challenge as one of the major challenges to overcome in developing countries.

**Long economic recovery periods:** Nasirov et al. (2015) and De La Peña et al. (2022) showed that long economic recovery periods from the RE investment are slowing up the implementation in developing countries. Developing countries demand a quick return on investment (ROI) from their projects to hold their economic sustainability.

**Large land requirement:** Existing technologies of RE (solar photovoltaic technology, wind turbine, hydro-electric power, etc.) occupy a large amount of land to install power generation infrastructures compared to the same energy output from fossil fuel-based power sources. Most developing countries in the world are densely populated with a shortage of living and agricultural land, and huge land requirements for RE utilization can be a major policymaking challenge for them (Gyamfi et al., 2015; Elavarasan et al., 2020).

**Inadequate skilled manpower:** Shortage of skilled manpower is another critical challenge for developing countries in implementing highly sophisticated RE technologies (Luthra et al., 2015; Engelken et al., 2016; Ghimire and Kim, 2018). People in developing countries mainly develop their skills to operate the existing conventional energy sources. The lack of opportunity of gaining practical knowledge from existing RE infrastructures is limited in those countries, and it is one of the major challenges for policymakers to overcome.

**Inability to become the only energy source:** Luthra et al. (2015) identified a critical challenge that RE cannot solely meet the overall energy demand. Moreover, one RE source cannot meet the energy demand all over the country. For this, many local energy hubs need to be installed for different energy media (solar, wind, hydro, etc.) based on the availability of that specific source availability. This obstructs the establishment of a centralized RE structure.

**Low-price electricity from fossil fuel:** Conventional global supply chain of fossil fuels, power generation, transmission, and distribution systems are already established. Therefore, the unit price of electricity generated by burning fossil fuels is comparatively lower than the generated electricity from RE (Shahsavari and Akbari, 2018; Moorthy et al., 2019). This temporary financial benefit often creates challenges for policymakers of developing nations to think of long-term sustainability by utilizing RE.

**Inadequate publicity and information:** Accessible information and publicity for RE implementation are not commonly observed in developing countries due to the lack of a proper methodological approach (Fashina et al., 2018). Attaining SDGs through energy sustainability often gets obstructed by this existing challenge.

### 3. Methodology of the Study

Due to the lack of readily available objective data for analysis, this study has utilized experience-based subjective judgment from purposively selected three decision-makers. Purposive selection of decision-makers is highly observed in such decision-making problems where expertise in a specific field is more significant than random response (Bari et al., 2022). The inclusion criteria for the experts of this study were, having at least a bachelor's degree, having at least 10 years of working experience in RE implementing sectors, and having an understanding ability of the semi-structured survey questionnaire for the DEMATEL method. The research methodology can be found in Figure 1.

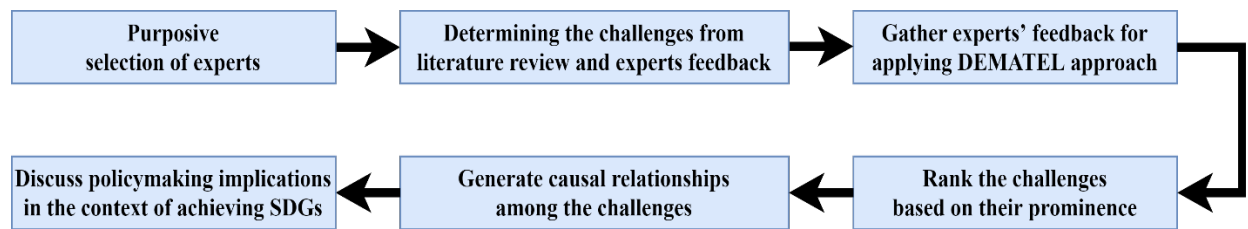


Figure 1. Research methodology

#### 3.1. Identifying the Critical Challenges

The identified critical challenges to utilizing RE in the context of developing countries by the existing literature were accumulated to analyze in this study. The Google Scholar search string for gathering data was: (“renewable energy” OR “implementing renewable energy” OR “utilizing renewable energy”) AND (“challenges” OR “barriers” OR “policymaking” OR “sustainable development goals” OR “developing countries”). At the first stage of data collection, among all the barriers and challenges, 12 policymaking challenges to utilizing RE were sorted out. Then those were presented to the experts for checking the relevance of the gathered data. One of the experts proposed one more challenge for the policymakers, that is “End-life management difficulties”, to include in the list. Finally, a list of 13 challenges was prepared for further analysis which can be found in Table 1.

Table 1. Challenges to Utilizing Renewable Energy in the Context of Developing Countries

Denotation	Critical challenges for developing countries	Source
C1	Lack of social awareness and acceptance	Sen and Ganguly (2017); Ghimire and Kim (2018)
C2	Absence of policies favoring renewable energy	Ghimire and Kim (2018)
C3	Inadequate research and development facility	Luthra et al. (2015); Ghimire and Kim (2018); Shahsavari and Akbari (2018)
C4	Uncertain supply	Engelken et al. (2016); Gernaat et al. (2021)
C5	Absence of grid connection technology	Luthra et al. (2015); Ghimire and Kim (2018)
C6	High initial installation cost	Luthra et al. (2015); Schwerhoff and Sy (2017)
C7	Long economic recovery periods	Nasirov et al. (2015); De La Peña et al. (2022)
C8	Large land requirement	Gyamfi et al. (2015); Elavarasan et al. (2020)
C9	Inadequate skilled manpower	Luthra et al. (2015); Engelken et al. (2016); Ghimire and Kim (2018)
C10	Inability to become the only energy source	Luthra et al. (2015)
C11	Low-price electricity from fossil fuel	Shahsavari and Akbari (2018); Moorthy et al. (2019)

C12	Inadequate publicity and information	Fashina et al. (2018)
C13	End-life management difficulties	Expert Opinion

### 3.2. DEMATEL Method

The DEMATEL method can analyze subjective judgment from decision-makers with a numerical approach. For this, a semi-structured survey questionnaire needs to be prepared to collect experts' feedback. A sample of the prepared questionnaire for this study can be found in the Appendix section. Procedures of the DEMATEL (Si et al., 2018) are as-

**Step 1:** A direct comparison relation matrix is developed for each of the experts by utilizing that expert's feedback. The feedback is gathered with a 5-point linguistic scale which can be found in Table 2.

Table 2. 5-point linguistic scale for expert's evaluation collection for DEMATEL

Linguistic term	Numerical values
No influence	0
Low influence	1
Medium influence	2
High influence	3
Very high influence	4

Mathematically, the matrix can be expressed as Equation (1) for the  $k^{\text{th}}$  expert.

$$Z = [z_{ij}^k] \quad (1)$$

**Step 2:** Aggregated direct comparison relation matrix is achieved by the arithmetic mean of multiple experts' feedback.

**Step 3:** Normalization of the direct comparison relation matrix is done by using Equations (2) and (3).

$$L = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n z_{ij}} \quad (2)$$

$$X = L \times Z \quad (3)$$

Where L is the normalization factor, Z is the aggregated direct comparison relation matrix, and X is the normalized matrix.

**Step 4:** The total-relation matrix (T) is figured out by Equation (4).

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

Where I stand for the identity matrix.

**Step 5:** The row ( $D_i$ ) and column ( $R_j$ ) sums are computed. For each row (i) and column (j), the sum can be obtained from the total-relation matrix (T) by using Equations (5) and (6).

$$D_i = [\sum_{j=1}^n T_{ij}] \quad \forall i \quad (5)$$

$$R_j = [\sum_{i=1}^n T_{ij}] \quad \forall j \quad (6)$$

**Step 6:** The overall prominence ( $P_i$ ) and the net effect ( $E_i$ ) are computed by Equations (7) and (8).

$$P_i = [D_i + R_j] \quad \forall i = j \quad (7)$$

$$E_i = [D_i - R_j] \quad \forall i = j \quad (8)$$

The greater the value of  $P_i$  for a challenge, the greater the prominence (i.e., the influence, importance, and visibility) of that challenge in terms of the overall relationship with other challenges. If  $E_i > 0$  for a challenge, then that challenge is a causal (or a driver) challenge. On the other hand, if  $E_i < 0$  for a challenge, then that challenge is an effect (or a driven) challenge. These values are plotted on a two-dimensional axis ( $P_i$  vs.  $E_i$ ) for each factor to create the cause-effect diagram.

**Step 7:** The threshold value is set and the digraph by the given information of the total-relation matrix (T) is plotted. How one challenge influences another can be depicted by the obtained directed graph (digraph). To avoid comparably negligible effects, analysts or decision-makers need to set a threshold value ( $\theta$ ). The threshold value can be obtained from the mean value ( $\mu$ ), and standard deviation ( $\sigma$ ) of the elements of the total-relation matrix, T. If  $T_{ij} > \theta$  for any

challenge  $i$ , then, it influences or causes the other challenge  $j$ , and a directed arrow is incorporated into the analysis. A digraph showing causal relations can be plotted from the data set:  $((D_i+R_j), (D_i-R_j)) \forall i = j$

### 3.3. Calculations

Gathered responses from three experts in this study were aggregated with the simple arithmetic mean calculation. Aggregated direct comparison relation matrix calculated in this study can be found in Table 3

Table 3. Aggregated direct relation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.67	0.67	1.67	1.33	2.67	0.33
C2	1.67	0.00	2.33	0.33	1.67	1.67	1.33	1.33	1.67	1.33	1.33	1.67	0.67
C3	0.33	2.00	0.00	2.00	2.00	1.67	1.00	1.33	0.00	2.33	0.00	0.00	1.67
C4	2.67	2.67	1.33	0.00	1.33	1.33	2.67	1.33	1.33	3.67	3.67	1.33	2.67
C5	1.33	0.33	1.00	2.33	0.00	0.00	0.00	2.67	2.00	3.67	2.67	1.67	2.33
C6	1.00	2.00	1.00	1.00	2.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
C7	1.00	2.67	3.67	3.67	2.33	1.00	0.00	1.33	1.33	3.33	3.33	2.00	2.67
C8	3.67	3.33	3.33	0.33	2.67	3.67	3.67	0.00	1.33	2.67	3.67	1.33	2.33
C9	0.33	0.00	0.00	1.33	0.00	0.67	0.00	1.33	0.00	0.00	0.00	0.00	0.67
C10	1.33	1.67	1.33	3.67	1.33	0.00	0.67	0.67	0.67	0.00	0.67	0.33	0.00
C11	2.33	1.33	0.67	1.33	0.33	0.00	0.00	0.67	0.00	1.67	0.00	0.67	0.00
C12	3.67	1.33	1.67	2.33	0.33	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.33
C13	1.67	2.67	3.00	2.33	1.33	3.67	1.33	3.67	1.33	1.67	3.67	1.33	0.00

After normalizing the aggregated direct comparison relation matrix using Equations (2) and (3), the total relation matrix was calculated with Equation (4). The obtained total relation matrix in this study is shown in Table 4.

Table 4. Total relation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	D
C1	0.03	0.07	0.02	0.03	0.02	0.01	0.01	0.04	0.03	0.07	0.06	0.10	0.02	<b>0.52</b>
C2	0.10	0.05	0.12	0.06	0.09	0.08	0.07	0.08	0.08	0.10	0.09	0.08	0.06	<b>1.07</b>
C3	0.06	0.12	0.05	0.11	0.10	0.09	0.06	0.09	0.03	0.13	0.06	0.04	0.09	<b>1.04</b>
C4	0.16	0.17	0.12	0.09	0.10	0.09	0.12	0.11	0.08	<b>0.20</b>	0.19	0.10	0.13	<b>1.67</b>
C5	0.11	0.08	0.09	0.14	0.05	0.05	0.04	0.13	0.09	0.18	0.15	0.09	0.11	<b>1.32</b>
C6	0.06	0.09	0.06	0.06	0.09	0.02	0.02	0.06	0.02	0.07	0.03	0.02	0.02	<b>0.62</b>
C7	0.13	0.18	<b>0.19</b>	<b>0.20</b>	0.14	0.09	0.05	0.12	0.09	<b>0.21</b>	0.19	0.12	0.14	<b>1.86</b>
C8	<b>0.21</b>	<b>0.20</b>	0.19	0.11	0.16	0.17	0.16	0.08	0.09	<b>0.19</b>	<b>0.20</b>	0.11	0.13	<b>2.00</b>
C9	0.03	0.02	0.02	0.05	0.02	0.04	0.01	0.05	0.01	0.02	0.02	0.01	0.03	<b>0.34</b>
C10	0.09	0.10	0.08	0.15	0.07	0.03	0.05	0.06	0.05	0.06	0.07	0.04	0.03	<b>0.86</b>
C11	0.10	0.07	0.04	0.07	0.03	0.02	0.02	0.04	0.02	0.08	0.03	0.04	0.02	<b>0.57</b>
C12	0.15	0.08	0.08	0.10	0.04	0.03	0.03	0.08	0.02	0.05	0.04	0.03	0.04	<b>0.77</b>
C13	0.14	0.18	0.17	0.15	0.11	0.17	0.09	0.18	0.08	0.15	<b>0.19</b>	0.10	0.06	<b>1.79</b>
R	<b>1.39</b>	<b>1.40</b>	<b>1.24</b>	<b>1.32</b>	<b>1.01</b>	<b>0.89</b>	<b>0.74</b>	<b>1.12</b>	<b>0.69</b>	<b>1.52</b>	<b>1.33</b>	<b>0.88</b>	<b>0.89</b>	

A ranking of the challenges based on the descending value of the Prominence (D+R) can be found in Table 5.

Table 5. A rank of the challenges based on their overall prominence

Rank	Denotations	D	R	D+R
1	<b>C8</b>	2.00	1.12	3.13
2	<b>C4</b>	1.67	1.32	2.99
3	<b>C13</b>	1.79	0.89	2.67
4	<b>C7</b>	1.86	0.74	2.60

5	<b>C2</b>	1.07	1.40	2.47
6	<b>C10</b>	0.86	1.52	2.38
7	<b>C5</b>	1.32	1.01	2.33
8	<b>C3</b>	1.04	1.24	2.28
9	<b>C1</b>	0.52	1.39	1.90
10	<b>C11</b>	0.57	1.33	1.90
11	<b>C12</b>	0.77	0.88	1.65
12	<b>C6</b>	0.62	0.89	1.51
13	<b>C9</b>	0.34	0.69	1.03

The analyzed challenges in this study are divided into two groups, one is the Cause group (net effect positive), and another is the Effect group (net effect negative). This divisional arrangement based on the descending order of the net effect value (D-R) can be found in Table 6.

Table 6. Cause-effect division of the challenges

Group	Denotations	<b>D</b>	<b>R</b>	<b>D-R</b>
Cause group	<b>C7</b>	1.86	0.74	1.12
	<b>C13</b>	1.79	0.89	0.90
	<b>C8</b>	2.00	1.12	0.88
	<b>C4</b>	1.67	1.32	0.34
	<b>C5</b>	1.32	1.01	0.31
Effect Group	<b>C12</b>	0.77	0.88	-0.11
	<b>C3</b>	1.04	1.24	-0.21
	<b>C6</b>	0.62	0.89	-0.27
	<b>C2</b>	1.07	1.40	-0.33
	<b>C9</b>	0.34	0.69	-0.35
	<b>C10</b>	0.86	1.52	-0.66
	<b>C11</b>	0.57	1.33	-0.76
	<b>C1</b>	0.52	1.39	-0.87

#### 4. Results and Discussion

The level of significance of the challenges to utilizing RE in developing countries was determined using the DEMATEL approach, as shown in Table 5, C8> C4> C13> C7> C2> C10> C5> C3> C1> C11> C12> C6> C9. Moreover, the ordering of the cause group challenges is specified (see Table 6) as: C5> C9> C3> C7> C2, whereas, the effect group challenges are ordered as: C6> C13> C10> C4> C1> C11> C12> C8.

The causal diagram as illustrated in Figure 2 exhibits that 5 CSFs in the cause group  $\{(D-R > 0)\}$  and another 8 challenges in the effect group  $\{(D-R < 0)\}$ .

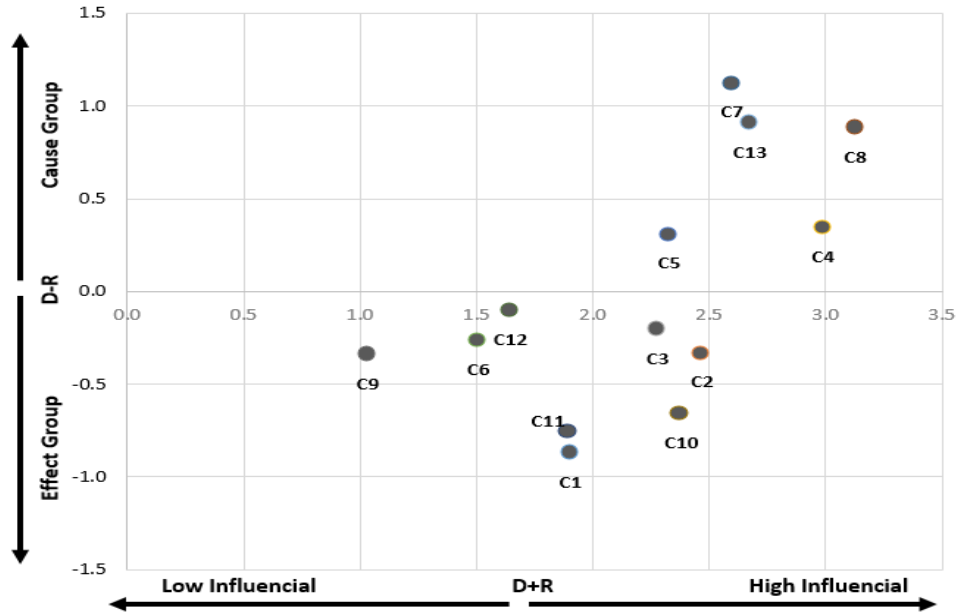


Figure 2. Causal diagram of the challenges

The cause-and-effect relationships between the challenges are depicted in the causal relationship diagram in Figure 3. To generate this digraph, a threshold value of 0.193 was determined using the total relation matrix (see Table 4). The mathematical equation for determining a threshold value is not constant, rather it can be varied with the studies to minimize the digraph's visual complexities. This study employed,  $\theta = (\text{mean} + 2 \text{ times of standard deviation})$  to filtrate the comparatively less important relation lines for visual simplicity. The relations which are equal to or greater than the threshold value (0.193) are highlighted with color in Table 4.

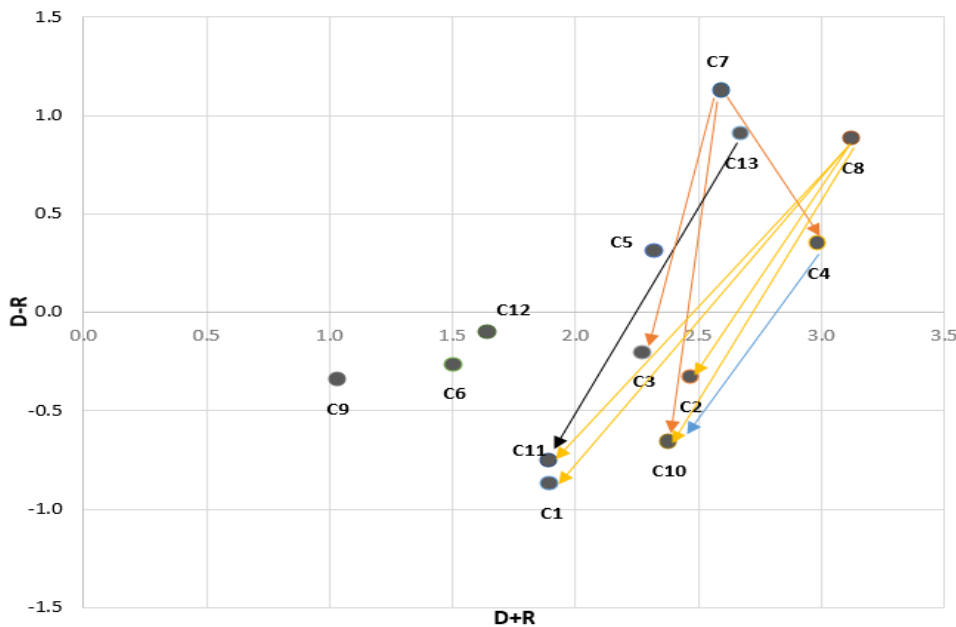


Figure 3. Causal relationships diagram

The obtained results from this study are noteworthy for utilizing RE in the case of both theoretical and policymaking applications. The prominence ranking of challenges shown in Table 5 indicates 'Large land requirement (C8)' to have



the most influence and be a key fact to create hindrances in utilizing RE in developing countries. The scarcity of agricultural land, ensuring accommodation for all the population, and space allotment for industrial expansion often keep the policymakers in a dilemma, as utilizing RE also occupies a huge amount of land (Zhang et al., 2022). Therefore, policymakers of developing countries need to overcome this challenge first by finding an optimum solution to ensure the efficient diversification of land use for various purposes (Elavarasan et al., 2020).

‘Uncertain supply (C4)’ was determined to be the second most influential policymaking challenge to utilizing RE in developing countries. In essence, the major portion of the RE sources are solar, wind, and hydro-energy which are highly weather-dependent energy sources, and those have also seasonal impacts (Gernaat et al., 2021). Most of the cases, developed countries in the world have surplus energy to some extent whereas developing countries are in a shortage of energy supply. Therefore, policymakers of least-developed countries cannot take the risk of that uncertainty, rather they try to ensure the reliability of supply from the energy source. Moreover, developing countries mainly rely on imports for the required technologies for RE utilization (Doğan et al., 2022). Supply chain interruption in such an import-based model also creates the challenge of an uncertain supply of energy.

‘End-life management difficulties (C13)’, the third most significant challenge determined from this study, indicates that the lack of facilities to recycle the waste product generated from RE technologies is a concerning issue for the policymakers of developing countries. As most of the RE technologies are import-based, developing countries are lagging in the case of recycling the end-products and bi-products of the RE sources. This creates a major hindrance for the policymakers to implement RE to attain long-term sustainability.

‘Long economic recovery periods (C7)’ is found as the fourth most influential challenge in this study. At the same time, this has been determined as the most causative challenge (see Table 6) that has the maximum causal impact over other challenges. In any policymaking issue, economic factors are the major drivers for a developing country to uphold its emerging development. Policymakers of developing countries need to address this challenge as a root cause for initiating other challenges to utilizing RE. To accelerate the replacement of the conventional energy source with RE, a public-private partnership (PPP) is necessary. But long economic recovery periods discourage private investment in the RE sector (Nasirov et al., 2015).

In the Cause group (see Table 6), ‘End-life management difficulties (C13)’, ‘Large land requirement (C8)’, ‘Uncertain supply (C4)’, and ‘Absence of grid connection technology (C5)’ are the other causative challenges respectively that have high causal impacts on the rest of the challenges analyzed in this study. Addressing these causal challenges sequentially, a stratified policymaking strategy can be developed by developing nations.

In the Effect group (see Table 6), challenges tend to be easily influenced by causal challenges. Despite not having a direct effect on the structure, these challenges certainly carry some significance in policymaking strategies. However, when planning for a hierarchical action plan for policymaking, the effect group challenges are supposed to be mitigated simultaneously while addressing the causal challenges.

The derived outcomes are notably distinct from the results of other relevant studies that have explored the challenges of utilizing RE from the perspective of other economies, or that have used distinct methodological techniques. In contrast to the outcomes of those studies described earlier, ‘Large land requirement’ is found as the most important policymaking challenge in developing countries. However, these findings are significantly unique since no study has been performed prior on the ranking and showing relationships of the challenges to utilizing RE, especially in the context of developing countries.

## **5. Policymaking Implications for Achieving Sustainable Development Goals**

Most developed countries such as the European countries, the USA, Canada, Australia, etc. are highly familiar with the utilization of RE on a large scale. However, this study has been conducted in the context of developing countries and their emerging economies, where RE utilization is not much popular and well-practiced activity. Therefore, discussing the implications of this study from a distinct point of view from the existing works on RE implementation is necessary.

The study has provided a framework for identifying challenges to utilizing RE. This framework can be utilized to identify challenges to policymaking issues in other contexts as well. Sorting out the most relevant challenges to policymakers while implementing RE in developing countries is another noteworthy theoretical implication of this

study. Applying the DEMATEL method to capture the cause-effect relationships among the selected challenges can guide the policymakers of the energy sector to implement RE by analyzing the most prominent challenges and their cause-effect relationships. The ranking of the challenges can readily be used by policymakers to think of hierarchical strategic planning in the case of various critical decision-making situations.

Moreover, the identified and examined challenges have a diverse range of impacts on RE utilization for meeting SDGs. Utilizing RE can transform the traditional energy sector of developing nations into a sustainable one, thus ensuring an improved social engagement with the people by ensuring energy equity, protecting the environment from undesired GHG emissions, and developing the economy. In this way, the triple bottom line (TBL) of sustainability- social equity, environmental protection, and economic viability can be achieved.

Some specific SDGs can be correlated directly to the outcomes of this study. For instance, utilizing RE is aligned with SDG-7 (affordable and clean energy), SDG-9 (industry, innovation, and infrastructure), SDG-11 (sustainable cities and communities), SDG-12 (responsible consumption and production), and SDG-13 (climate action). Therefore, challenges to utilizing RE can also be considered challenges to achieving these SDGs. Policymakers can utilize insights from this study not only in the energy sector but also in other sectors of developing nations to achieve SDGs more appropriately and methodologically.

## **6. Conclusions**

Over the last few years, the term ‘sustainability’ has gained much momentum in political and economic debate. Global policymakers have realized the negative consequences of the conventional fossil fuel-based energy model on the environment. However, despite the potential benefits of utilizing RE, there is still a lack of studies incorporating RE utilization and SDGs in the context of developing nations. Amid this situation, the present study is an attempt to connect these promising concepts to have a sustainable future.

The novel approach of utilizing the DEMATEL to identify, prioritize and determine the cause-effect relationships among the challenges to utilizing RE is the procedural significance of this study. An interesting observation from the obtained result is to get a different prominence ranking and a cause-effect ranking at the same time, where the most prominent challenge and the most causal challenge are different. It shows that a challenge may be very significant, but may not be a powerful causative challenge to initiate other challenges.

A total of thirteen challenges were selected and analyzed, among which five challenges were identified as the cause, and the remaining eight were identified as the effect. Understanding the interpretation of the causal relationships among the challenges is required for policymakers to achieve some specific SDGs. Developing countries can pay special attention to the Cause group derived from this study. This action will minimize the impacts of other challenges to utilizing RE that may emerge in developing countries, thus assisting in achieving long-term sustainability directed by the UNSDGs.

Some limitations of the study can be mentioned, that need to be addressed in future research. The DEMATEL method prepares a ranking of alternatives (challenges) considering their influencing capabilities, but other criteria are not considered in the decision-making process. Fuzzy-DEMATEL and Grey-DEMATEL can also be applied to minimize human decision-making vagueness. Moreover, a crucial limitation of the DEMATEL method is it deals with a limited number of alternatives. The application of this numerical approach becomes exceedingly challenging if the number of alternatives increases. To overcome this, other flexible numerical analysis tools can be incorporated into the future development of this study. This generalized study was carried out in the context of developing countries. However, the outcomes of a similar study may differ from country to country due to various socio-economic, political, geographical, and many other factors. Therefore, more studies in different countries from different continents are needed to develop a broad picture of this specific topic. Determining the feasibility of various renewable energy sources in the context of different countries can also be a prospective research scope.

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## Appendix

Sample questionnaire to collect experts' feedback on the challenges to utilizing RE for utilizing the DEMATEL method (with a sample response):

Questions	Responses				
	No	Low	Medium	High	Very High
How much influence does C1 have over C2?		✓			
How much influence does C1 have over C3?	✓				
How much influence does C1 have over C4?	✓				
How much influence does C1 have over C5?	✓				
How much influence does C1 have over C6?	✓				
How much influence does C1 have over C7?	✓				
How much influence does C1 have over C8?		✓			
How much influence does C1 have over C9?		✓			
How much influence does C1 have over C10?			✓		
How much influence does C1 have over C11?		✓			
How much influence does C1 have over C12?					✓
How much influence does C1 have over C13?	✓				
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How much influence does C13 have over C12?				✓	

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