Exploring the Barriers to Implementing Solar Energy in an Emerging Economy: Implications for Sustainability

Spandan Basak Payel, S.M. Faysal Ahmed
Department of Mechanical Engineering
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh.
spandanbasak@gmail.com, smfaysalahmed@gmail.com

Md. Zahidul Anam, Md. Tanvir Siraj
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh.
zahidulmahedi@gmail.com, tanvir25392@gmail.com

Abstract

The use of solar energy as a renewable energy source is becoming increasingly popular globally as a way to reduce dependence on fossil fuels and minimize negative environmental impacts. However, in emerging economies, the implementation of solar energy is often hindered by several barriers. These barriers present significant challenges for policymakers in achieving comprehensive energy sustainability. This study aims to identify and analyze the most significant barriers to implementing solar energy in emerging economies, as well as the relationships between these barriers. Thirteen barriers were identified through a review of the literature and input from experts and were analyzed using the decision-making trial and evaluation laboratory (DEMATEL) method. The results revealed that 'High upfront costs', and 'Limited access to land and resources for large-scale projects' are the two most prominent barriers to implementing solar energy in emerging economies. Analysis of the cause-and-effect relationships between these barriers identified 'Limited access to land and resources for large-scale projects' as the most significant cause and 'Limited access to financing' as the least significant cause. The findings of this study are expected to assist policymakers in emerging economies in addressing these barriers and successfully implementing solar energy to achieve long-term energy sustainability and support sustainable development goals (SDGs).

Keywords
Solar energy, Barriers, Decision-making trial and evaluation laboratory, Sustainable Development Goals.

Introduction
Solar energy is becoming increasingly popular all over the world as a clean, renewable energy source that does not produce emissions or pollutants, making it a popular choice for reducing greenhouse gas emissions and addressing climate change (Shahsavari and Akbari 2018; Anam et al. 2022a). With technological advances, solar energy is becoming more accessible and cost-competitive with traditional fossil fuel sources (Balakrishnan et al. 2020). Additionally, solar energy can be generated on-site, which means it can be used in remote and off-grid locations, and thus can be more convenient (Phuangpornpitak and Tia 2013). Developed countries around the world are promoting solar energy through subsidies, tax incentives, and mandatory renewable energy targets which also drive the growth of the solar energy industry (Haukkala 2015). However, countries with emerging economies often stumble due to several barriers to implementing solar energy on a large scale (Ansari et al. 2013; Ohunakin et al. 2014; Shahsavari and Akbari 2018). Therefore, researchers and policymakers need to explore the barriers to implementing solar energy in an emerging economy to overcome those barriers and attain sustainability in the energy sector.

The global supply chain for fossil fuels has been greatly disrupted in recent years due to the Covid-19 pandemic and global political crises, such as the Russia-Ukraine war (Anam et al. 2022a; Welfens 2023). These disruptions are influencing policymakers to consider implementing more sustainable energy sources, and solar energy is seen as an effective solution (Troeger 2023). However, existing critical barriers to the implementation of solar energy in emerging economies are preventing those countries from realizing the benefits of solar energy. By this, those countries are struggling to achieve SDGs in several ways. Firstly, it limits access to a clean and renewable energy sources, which can contribute to air and water pollution and increase dependence on fossil fuels (Qazi et al. 2019). Secondly, it can increase energy costs for households and businesses, which can have a negative impact on economic development (Kannan and Vakeesan 2016). Thirdly, it can limit the expansion of the energy sector and the creation of new jobs in the renewable energy industry (Maka and Alabid 2022). Additionally, not implementing solar energy in developing nations can also limit access to electricity in rural and remote areas, hindering socio-economic development and access to basic services such as education, healthcare, and communication (Buragohain 2012). Furthermore, not implementing solar energy can also limit a country's ability to meet its energy needs and reduce dependence on energy imports, which can have an impact on energy security and economic stability (Madsen and Hansen 2019).

Several recent studies have analyzed the drivers and barriers of various sources of renewable energy in different countries. For instance, Kardooni et al. (2015) examined expert perceptions and understanding of the barriers to renewable energy development by applying a theoretical framework and depicted that the intention to use renewable energy is influenced by the cost of renewable energy technology and the best way to overcome these barriers is the government should play a powerful leadership. del Río and Janeiro (2016) analyzed the causes and consequences of overcapacity in electricity generation as a barrier to further renewable energy source penetration. Ghimire and Kim (2018) attempted to identify and rank the barriers to developing renewable energy technologies in a developing country and found that the two most important barrier categories are economic and political. Shukla et al. (2018) provided an overview of the solar energy potential and status in a developing country, where the government has initiated policies to encourage industries and individuals to use solar energy-powered systems for electricity generation.

Shahsavari and Akbari (2018) reviewed the sources of energy-related emissions, risks of climate change, global solar energy potential, and benefits of solar energy utilization, and discusses the barriers that prevent the widespread use of solar energy in developing countries. Irfan et al. (2019) identified key barriers to implementing solar energy and proposed important policy recommendations for institutions and governments to overcome these barriers and utilize maximum solar energy in the country. Anam et al. (2022a) identified the key drivers behind the sustainable development of solar energy and concluded that favorable geographical location, government policy, the need to reduce greenhouse gas emissions, and large bodies of water are the most significant drivers for sustainable development of solar energy. However, none of those studies explored the barriers to implementing solar energy in an emerging economy and identify the cause-effect relationship among those barriers, especially using the DEMATEL technique. This study, thereby, aims to identify the critical barriers and the relationship between them by utilizing the DEMATEL method.

The DEMATEL method analyzes complex relationships between a set of factors or variables. It is particularly useful for identifying the cause-and-effect relationships between different factors and determining the most important factors that influence a particular outcome (Asadi et al. 2022). The method is effective because it allows for the identification of both direct and indirect relationships between factors, and it accounts for the potential feedback loops that can exist between factors (Si et al. 2018). The DEMATEL method has been previously applied to identify causal relationships among the drivers or barriers to implementing different social and technological issues such as electric vehicle use (Asadi et al. 2022), renewable energy utilization (Siraj et al. 2022), e-commerce technologies implementation (Yadav et al. 2022), green construction development (Kamranfar et al. 2022), and e-waste management implementations (Anam et al. 2022b). However, to the best of our knowledge, the DEMATEL method has not been utilized in any previous research to analyze the relationships between the barriers to implementing solar energy in an emerging economy, thus declaring the novelty of this ongoing work.

The following objectives will enable this study to contribute to the literature:
a) To explore the most relevant barriers to implementing solar energy in an emerging economy.
b) To determine the prioritization of the barriers and cause-effect relationships among them.
The remaining sections of the paper are organized as follows: Section 2 will conceptualize and identify the barriers; Section 3 will describe the DEMATEL methodology and calculations; Section 4 will discuss the findings from this

study; and Section 5 will illustrate the implications of the study's findings. The study will come to a close in Section 6 when it summarizes the noteworthy findings and discusses the study's limitations to suggest some potential areas for further research.

1.Conceptualizing the barriers to implementing solar energy

Implementing solar energy in emerging economies can be difficult for the lack of infrastructure and resources to support the development and installation of solar energy systems (Liang et al. 2022). Additionally, there may be a lack of government support and regulations, making it difficult for private companies to invest in solar energy projects (Hussain et al. 2022). Financial constraints can also be a barrier, as the initial cost of installing solar systems can be high, and access to funding and investment may be limited (Hayat et al. 2019). Cultural and social factors can also play a role, as there may be resistance to change and unfamiliar technologies (Linnerud et al. 2019). Amid this situation, a structured conceptualization of the barriers is required.

Barriers identification

For this study, at the first stage, an extensive literature review has been conducted to identify the most critical and visible 10 barriers to implementing solar energy in an emerging economy. The Google Scholar search string was, "Barrier" AND "Solar Energy" OR "Solar energy implementation" OR "Barriers" AND "Renewable energy", and so on. Then, with feedback from purposively selected 12 experts on the renewable energy sector, the identified barriers were validated for further analysis with the DEMATEL method. Purposive selection of the evaluators is important for decision-making research works to achieve the best outcome (Bari et al. 2022). The experts suggested 3 more barriers to include with the primary list. Table 1 is presenting a brief profile of the experts and Table 2 is depicting a list of 13 barriers to be analyzed.

Table 1. Brief profile of the experts who participated in this study

Professional expertise	Year of experience	Number of experts	Percentage
Energy auditor	More than 15 years	4	33.3%
Electrical engineer	10 to 15 years	5	41.7%
Environment professional	10 to 15 years	3	25.0%

Table 2. Enlisted barriers to be analyzed

Denotations	Barrier	Source
B1	Lack of technical expertise	Irfan et al. 2019; Adenle 2020
B2	Limited markets for the sale of excess energy	Lu et al. 2020; Setyawati 2020
B3	Limited access to financing	Solangi et al. 2021
B4	Lack of standardization and quality control in the industry	Majid 2020
B5	Government policies and regulations	Moorthy et al. 2019, Do et al. 2020
B6	Limited access to land and resources for large-scale projects	Burke et al. 2019; Siraj et al. 2022
B7	Limited access to education and training	Adenle 2020; Majid 2020
B8	Limited capacity for research and development	Irfan et al. 2019; Elavarasan et al. 2020
B9	Limited awareness and understanding of solar energy	Irfan et al. 2019; Moorthy et al. 2019
B10	Political instability and lack of government support	Solangi et al. 2021; Pathak et al. 2022
B11	High upfront costs	Expert opinion
B12	Lack of infrastructure	Expert opinion
B13	Limited grid connectivity and capacity	Expert opinion

1.1. Describing the barriers to implementing solar energy in emerging economies

Lack of technical expertise (B1) is a barrier as it can limit access to trained personnel for installation, maintenance, and repair of solar equipment, leading to unreliable equipment and poor performance, hindering the adoption and expansion of solar energy (Irfan et al. 2019; Adenle 2020).

Limited markets for the sale of excess energy (B2) can be a barrier as the electricity grid infrastructure may not be developed enough to allow for the integration of distributed solar energy systems, meaning that excess energy generated by individuals or businesses cannot be fed back into the grid (Lu et al. 2020). Even if the grid infrastructure

is developed, there may not be enough regulatory framework or policies in place to support the sale of excess energy, making it difficult for individuals or businesses to monetize their excess energy (Setyawati 2020).
Limited access to financing (B3) can hamper to implementation of solar energy as the financial institutions in these economies may not be able to provide the necessary financing due to a lack of capacity or lack of trust in the solar energy sector (Solangi et al. 2021).

Lack of standardization and quality control in the industry (B4) can be a barrier as lack of quality control can lead to unreliable equipment, poor installation, and maintenance, which can result in low energy generation and high maintenance costs. Besides this, a lack of standardization and quality control can also lead to the proliferation of counterfeit or substandard products, which can further undermine confidence in the technology and make it difficult to expand the adoption of solar energy (Majid 2020).

Government policies and regulations (B5) can be a barrier as without clear and supportive policies and regulations in place, it can be difficult for individuals and businesses to navigate the process of installing and operating solar energy systems (Moorthy et al. 2019). Moreover, without adequate incentives or subsidies, the cost of solar energy may be too high for many people in these economies to afford. Additionally, a lack of transparency, accountability and predictability in the decision-making process of the government can also discourage potential investors, making it difficult to attract private investment in the sector (Do et al. 2020).

Limited access to land and resources for large-scale projects (B6) can be a barrier as in many emerging economies, land may be scarce or in high demand for other uses, making it difficult to secure the large tracts of land needed for large-scale solar projects (Siraj et al. 2022). Besides this, there may be limited access to natural resources such as water, which is needed for cleaning and maintaining solar panels (Burke et al. 2019).

Limited access to education and training (B7) can be a barrier as without access to education and training, it can be difficult for individuals and businesses to acquire the knowledge and skills needed to install, operate, and maintain solar energy systems (Adenle 2020). This can also limit the development of a skilled workforce needed to support the growth of the solar energy industry (Majid 2020).

Limited capacity for research and development (B8) can be a barrier as without the necessary resources and facilities to conduct research and development, it can be difficult to develop and improve new technologies, such as new solar cells or storage systems, that could make solar energy more efficient and cost-effective (Irfan et al. 2019). This can also limit the ability to optimize and customize solar energy systems for specific local conditions or needs (Elavarasan et al. 2020).

Limited awareness and understanding of solar energy (B9) can be a barrier as without proper education and outreach, people may not be aware of the potential and benefits of solar energy, and therefore may not be motivated to adopt it. Limited awareness and understanding can also make it more difficult to secure support from governments, businesses, and utilities for the development of solar energy projects (Irfan et al. 2019). This can also make it difficult to attract private investment in the sector as investors may not be familiar with the technology and its potential benefits (Moorthy et al. 2019).

Political instability and lack of government support (B10) can be a barrier as without a stable and supportive government, it can be difficult to establish and implement policies and regulations that support the development of the solar energy industry (Solangi et al. 2021). Political instability can make it difficult for businesses and investors to plan for the long term and make investments in the sector due to uncertainty (Pathak et al. 2022).

High upfront costs (B11) can be a significant barrier to implementing solar energy as many people in these economies may not have the financial resources to afford the initial investment required to install solar panels or other equipment. There may not be enough financing options available, such as loans or grants, to help with the initial costs. Governments in these economies may not have the resources to invest in solar energy infrastructure.

Lack of infrastructure (B12) can obstruct to implementation of solar energy as there may not be adequate transmission and distribution systems in place to effectively transport and distribute power generated by solar panels to consumers. This can make it difficult for solar energy to be integrated into the existing power grid.

Limited grid connectivity and capacity (B13) can be a barrier as without an adequate transmission and distribution infrastructure, it can be difficult to integrate solar energy systems into the existing power grid. Limited grid capacity can make it difficult to provide reliable power to all customers, especially during peak demand periods, as the grid might not be able to handle the additional energy generated by solar systems. Besides this, limited grid connectivity can also make it difficult to provide power to remote or rural areas, which can be a hindrance to the expansion of solar energy systems. This can all make it challenging for individuals, businesses, and governments to adopt solar energy as a viable source of power.

2. DEMATEL methodology and calculations

The DEMATEL method uses a numerical approach to analyze the subjective judgment of decision-makers by collecting feedback from experts through a semi-structured survey questionnaire. The method, as outlined by Si et al. (2018), involves a series of steps to determine the key decision-making units and attributes, identify causal relationships among them, and create a dynamic model to simulate the behavior of the decision-making system, described below-

2.1. DEMATEL

Step 1: A direct comparison relation matrix is created for each expert based on their feedback. The feedback is obtained using a 6-point linguistic scale, as described in Table 3.

Table 3. A 6-point linguistic scale to collect experts' feedback

Linguistic scale	Numerical scale
No influence	0
Very Low influence	1
Low influence	2
Medium influence	3
High influence	4
Very high influence	5

Mathematically, the matrix is as Equation (1) for the k^{th} expert.

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

Step 2: The final direct comparison relation matrix is obtained by combining the feedback from multiple experts using the arithmetic mean.

Step 3: Normalization is done by using Equations (2) and (3).

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

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

Step 4: The total-relation matrix (T) is as Equation (4).

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

Where I stand for the identity matrix.

Step 5: The row (Di) and column (Rj) sums are calculated. For each row (i) and column (j), the sum can be determined from the total-relation matrix (T) by using Equations (5) and (6).

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

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

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

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

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

The value of Pi for a barrier represents its prominence or influence on other barriers. If the value of Ei is greater than zero, it indicates that the barrier is a causal or driving factor. If the value of Ei is less than zero, it indicates that the barrier is an effect or driven factor. These values are plotted on a two-dimensional axis (Pi vs. Ei) to create a cause-effect diagram for each factor.

Step 7: A threshold value is established and a directed graph is plotted using the information from the total-relation matrix (T) to depict how one challenge influences another. To eliminate insignificant effects, a threshold value (θ) is set, which can be determined from the mean (μ) and standard deviation (σ) of the elements of the total-relation matrix, T. A directed arrow is incorporated into the analysis when $T_{ij} > \theta$ for any challenge i, indicating that it influences or causes the other challenge j.

2.2. Calculations

The responses from 12 experts in this study were combined using the simple arithmetic mean calculation. The resulting aggregated direct comparison relation matrix can be found in Table 4.

Table 4. Aggregated direct relation matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**
B1	0.00	0.00	3.00	0.67	0.25	0.83	0.33	0.00	1.17	0.58	1.00	0.17	0.17
B2	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.75	0.00	0.33
B3	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	1.00
B4	0.00	0.00	1.17	0.00	0.00	0.00	0.17	0.00	0.00	0.00	1.00	0.00	0.00
B5	0.42	0.00	1.58	0.00	0.00	0.83	0.17	3.17	4.50	0.42	0.67	0.00	0.33
B6	2.08	1.33	1.42	1.83	2.75	0.00	1.50	1.25	3.25	1.92	1.92	1.58	1.25
B7	0.00	0.00	3.00	0.17	0.00	0.17	0.00	0.83	0.25	0.00	0.75	0.17	0.17
B8	0.00	0.00	1.33	0.00	0.75	0.00	0.33	0.00	3.92	0.00	0.50	0.00	0.00
B9	0.25	0.00	0.83	0.00	0.58	0.00	0.00	1.00	0.00	0.00	1.08	0.00	0.08
B10	0.67	0.00	0.33	0.58	0.17	0.92	0.33	0.17	0.42	0.00	1.17	0.50	1.83
B11	2.58	0.00	1.08	3.33	3.33	2.42	2.83	0.83	3.33	2.33	0.00	2.33	0.00
B12	0.00	0.00	2.00	0.00	0.00	0.67	0.00	0.00	0.00	0.67	0.92	0.00	0.00
B13	2.42	0.58	0.17	0.00	3.00	0.67	0.67	0.33	1.25	2.75	1.00	0.00	0.00

Once the aggregated direct comparison relation matrix was normalized using Equations (2) and (3), the total relation matrix was calculated using Equation (4). The resulting total relation matrix can be found in Table 5 in this study.

Table 5. Total relation matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**D**
B1	0.01	0.01	0.14	0.04	0.03	0.04	0.03	0.01	0.07	0.04	0.06	0.02	0.02	**0.52**
B2	0.01	0.01	0.19	0.01	0.01	0.01	0.01	0.00	0.01	0.06	0.04	0.01	0.03	**0.40**
B3	0.01	0.05	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.04	0.00	0.04	**0.22**
B4	0.01	0.00	0.05	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.05	0.00	0.00	**0.17**
B5	0.03	0.01	0.10	0.01	0.03	0.04	0.02	0.15	0.23	0.03	0.05	0.01	0.02	**0.73**
B6	0.12	0.06	0.14	0.10	0.15	0.03	0.09	0.09	0.21	0.11	0.13	0.08	0.07	**1.38**
B7	0.01	0.01	0.13	0.01	0.01	0.01	0.01	0.04	0.03	0.01	0.04	0.01	0.01	**0.33**
B8	0.01	0.00	0.07	0.01	0.04	0.01	0.02	0.01	0.18	0.01	0.03	0.00	0.00	**0.39**
B9	0.02	0.00	0.05	0.01	0.03	0.01	0.01	0.05	0.02	0.01	0.05	0.01	0.01	**0.27**
B10	0.05	0.01	0.04	0.04	0.03	0.05	0.03	0.02	0.05	0.02	0.07	0.03	0.08	**0.52**
B11	0.13	0.01	0.13	0.16	0.17	0.12	0.14	0.08	0.22	0.12	0.06	0.11	0.03	**1.49**
B12	0.01	0.01	0.09	0.01	0.01	0.03	0.01	0.01	0.02	0.04	0.05	0.01	0.01	**0.30**
B13	0.12	0.03	0.06	0.02	0.15	0.05	0.04	0.04	0.11	0.13	0.07	0.01	0.02	**0.86**
R	**0.53**	**0.22**	**1.22**	**0.43**	**0.69**	**0.42**	**0.41**	**0.52**	**1.17**	**0.59**	**0.74**	**0.31**	**0.35**	

A ranking of the barriers based on the descending value of the Prominence (D+R) can be found in Table 6.

Table 6. A rank of the barriers based on their overall prominence

Denotation	**Barrier**	**D+R**	**Ranking**
B11	High upfront costs	2.228	1
B6	Limited access to land and resources for large-scale projects	1.801	2
B3	Limited access to financing	1.438	3
B9	Limited awareness and understanding of solar energy	1.438	4
B5	Government policies and regulations	1.418	5

B13	Limited grid connectivity and capacity	1.214	6
B10	Political instability and lack of government support	1.115	7
B1	Lack of technical expertise	1.053	8
B8	Limited capacity for research and development	0.910	9
B7	Limited access to education and training	0.743	10
B2	Limited markets for the sale of excess energy	0.621	11
B12	Lack of infrastructure	0.611	12
B4	Lack of standardization and quality control in the industry	0.603	13

The challenges analyzed in this study are divided into two groups: the Cause group (net effect positive) and the Effect group (net effect negative). The division is based on the descending order of the net effect value (D-R), and the results can be found in Table 7.

Table 7. Cause-effect division of the barriers

Denotation	Barrier	D-R	Group
B6	Limited access to land and resources for large-scale projects	0.9533	**Cause Group**
B11	High upfront costs	0.7556	
B13	Limited grid connectivity and capacity	0.5133	
B2	Limited markets for the sale of excess energy	0.1887	
B5	Government policies and regulations	0.0417	
B12	Lack of infrastructure	-0.0110	**Effect Group**
B1	Lack of technical expertise	-0.0136	
B10	Political instability and lack of government support	-0.0711	
B7	Limited access to education and training	-0.0777	
B8	Limited capacity for research and development	-0.1241	
B4	Lack of standardization and quality control in the industry	-0.2640	
B9	Limited awareness and understanding of solar energy	-0.8926	
B3	Limited access to financing	-0.9985	

3. Result and discussions

The barriers to implementing solar energy in emerging economies were evaluated using the DEMATEL approach. The results, as shown in Table 6, indicate that B11 is the most prominent or visible barrier, followed by B6, B3, B9, B5, B13, B10, B1, B8, B7, B2, B12, and B4. Additionally, the barriers in the cause group are ordered as B6, B11, B13, B2, and B5, while the barriers in the effect group are ordered as B12, B1, B10, B7, B8, B4, B9, and B3. The prominence diagram in Figure 1 shows the ranking of the barriers.

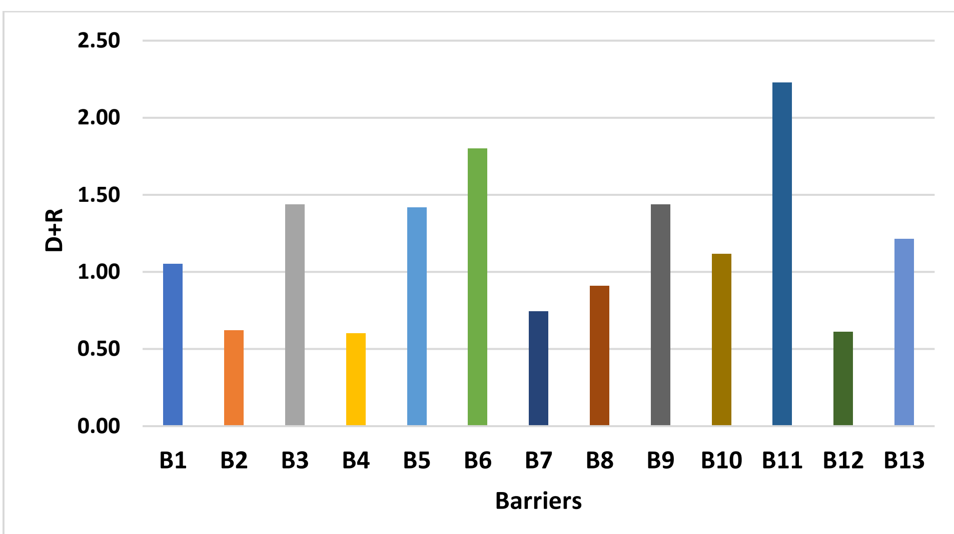

Figure 1. Ranking of the barriers based on their prominence (D+R)

The causal diagram in Figure 2 shows that there are 5 barriers in the cause group and 8 barriers in the effect group. The causal relationship diagram in Figure 2 illustrates the connections between the barriers. The threshold value used to create this diagram was 0.0950, as calculated using the total relation matrix in Table 5. The equation used to determine the threshold value can be adjusted to simplify the diagram, and this study used a method of (mean + standard deviation) to filter out less significant relation lines. Only relations that are greater than or equal to the threshold value are shown in Table 5 and are highlighted with color.

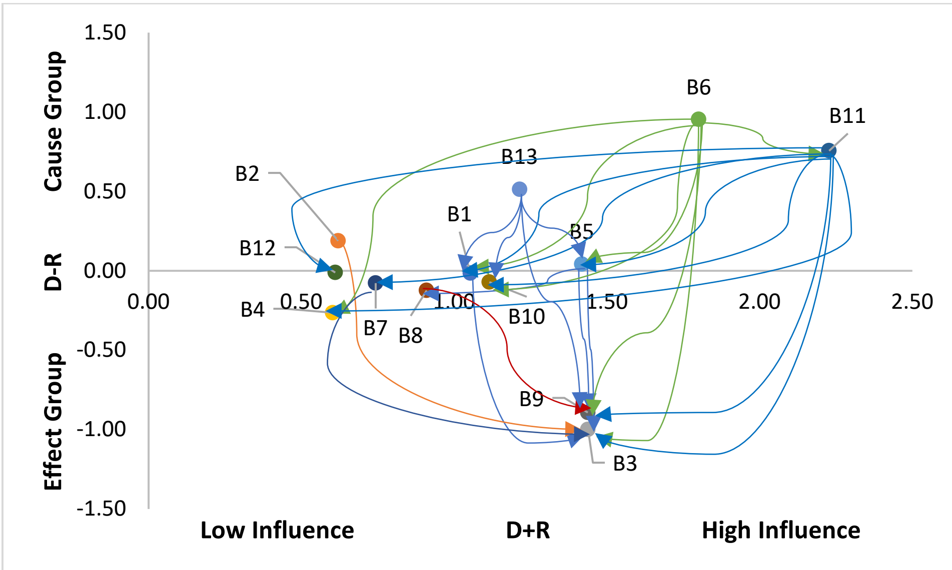

Figure 2. Casual diagram with digraph

The results of this study are important for understanding the role of solar energy in both theoretical and practical contexts. According to the prominence ranking of barriers in Table 6, the main obstacle to implementing solar energy in an emerging economy is the 'High upfront costs (B11)'. It can be difficult for individuals or organizations in these countries to afford the initial investment required to install and maintain solar systems. This can be especially challenging in regions with lower economic development and limited access to financing. Additionally, the lack of local manufacturing and supply chain infrastructure can also contribute to the high cost of solar energy in emerging economies. Furthermore, in many emerging economies, the cost of electricity from traditional sources, such as coal and natural gas, may be lower than the cost of electricity generated by solar, which also can make it harder to compete on price (Hayat et al. 2019).

'Limited access to land and resources for large-scale projects (B6)' is the second most prominent barrier to the implementation of solar energy in emerging economies for several reasons. One of the main reasons is that developing countries often have limited land available for large-scale solar projects. This can be due to a variety of factors such as population density, competition for land uses, and lack of land ownership rights (Siraj et al. 2022). Additionally, in many emerging economies, the available land may be of poor quality or may be located in remote areas that are difficult to access, which can make it difficult to build and maintain large-scale solar projects. Furthermore, many emerging economies lack the resources, such as water and transmission infrastructure, necessary to support large-scale solar projects (Burke et al. 2019). These factors can make it difficult to build large-scale solar projects, which can limit the amount of solar energy that can be generated in these countries.

'Limited access to financing (B3)' is determined as the third most significant barrier to implementing solar energy in emerging economies for several reasons. One reason is that many of these economies have underdeveloped financial systems, which makes it difficult for individuals and businesses to secure loans or other forms of financing for solar projects. Additionally, many of these economies have high levels of poverty and income inequality, which means that many people lack the financial resources to invest in solar energy (Solangi et al. 2021).

The barriers existing in the cause group have causal impacts on the barriers existing in the effect group. This can be visible in Figure 2. The cause group barriers have comparatively more connecting lines to other barriers, which means

those barriers are affecting the effect group barriers. According to the causal relationship obtained from this study, barriers that do not directly affect the structure of implementing solar energy in emerging economies are still important to consider in policymaking strategies. However, when creating a plan of action to address these barriers, it is important to address both the underlying causes of the problems and the barriers themselves at the same time. This can be done by creating a hierarchical plan that addresses both the underlying issues and the resulting barriers.
The results of this study are distinct from previous studies that have explored the barriers to implementing solar energy in other economies or used different research methods. These findings are unique because no prior study has been conducted specifically on the ranking and relationship of the barriers to implementing solar energy in the context of emerging economies.

4. Implications for achieving SDGs

The results of this study are going to assist the policymakers of emerging economies in achieving some of the significant SDGs, such as SDG 1 (No poverty), SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation, and infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate action).

Removing barriers to implementing solar energy in emerging economies can help in achieving SDG 1 by providing a low-cost and clean energy source for low-income communities and rural areas, where access to energy is often limited. This can improve the standard of living for people living in poverty by providing them with access to electricity for lighting, heating, and other basic needs. Additionally, the implementation of solar energy projects can create jobs in the construction, installation, and maintenance of solar systems, which can provide a source of income for individuals living in poverty, helping to lift them out of poverty. Additionally, the cost savings from using solar energy can help reduce the burden of energy expenses on low-income households, leaving more money for other necessities.

Removing barriers to implementing solar energy in emerging economies can help in achieving SDG 7, which is to ensure access to affordable, reliable, sustainable, and modern energy for all. By removing barriers, solar energy can be more easily and affordably implemented, increasing access to clean, renewable energy. This can reduce the reliance on fossil fuels, which can be expensive and lead to air pollution and health hazards. Additionally, the implementation of solar energy projects can also increase the resiliency and reliability of energy systems, by providing a decentralized and distributed power source. This can reduce the risk of power outages and improve energy security.

Removing barriers to implementing solar energy in emerging economies can help in achieving SDG 9, which is to build resilient infrastructure, promote sustainable industrialization, and foster innovation. Removing barriers such as limited access to financing, lack of technical expertise, or lack of supportive policies can enable more solar energy projects to be developed and implemented. This can help to build a more resilient infrastructure by providing a decentralized and distributed power source, reducing dependence on fossil fuels, and increasing energy security. Additionally, implementing solar energy can also promote sustainable industrialization by creating jobs in the construction, installation, and maintenance of solar systems. This can help to diversify the economy and create new opportunities for business development and growth. Furthermore, fostering innovation in solar energy technologies can also help to improve efficiency and reduce costs, which can make solar energy more accessible to a wider range of people and businesses.

Removing barriers to implementing solar energy in emerging economies can help in achieving SDG 11, which is to make cities and human settlements inclusive, safe, resilient, and sustainable. By removing barriers to solar energy, it can become more accessible and more affordable to a wider range of people and businesses, which can increase the adoption and deployment of this clean energy source in urban areas. This can help to reduce the dependence on fossil fuels, which can lead to air pollution and health hazards, and improve energy security. Furthermore, the implementation of solar energy can also help to increase the resilience of energy systems, by providing a decentralized and distributed power source that can reduce the risk of power outages. This can improve the quality of life for residents and make cities more livable, especially for low-income communities.

Removing barriers to implementing solar energy in emerging economies can help in achieving SDG 13, which is to take urgent action to combat climate change and its impacts. Solar energy is a clean and renewable energy source that does not emit any greenhouse gases, so by increasing its implementation, the reliance on fossil fuels can be reduced, and the emissions of greenhouse gases can be lowered. This can help to mitigate the impacts of climate change and support the transition to a low-carbon economy. Additionally, by removing barriers to solar energy, it can become more accessible and more affordable to a wider range of people and businesses, which can increase the adoption and deployment of this clean energy source. Furthermore, the widespread use of solar energy can also help to reduce the dependence on fossil fuels and decrease the impacts of air pollution and deforestation, which are often associated with the extraction and use of fossil fuels.

5. Conclusions

In recent years, the concept of sustainability has gained significant attention in political and economic discussions. Policymakers have recognized the harmful effects of traditional fossil fuel-based energy systems on the environment. However, despite the potential benefits of solar energy, there is a lack of research linking the use of solar energy and the Sustainable Development Goals in emerging economies. The current study aims to bridge this gap by connecting these two important concepts to promote a sustainable future.

The unique aspect of this study is its use of the DEMATEL method to identify, prioritize and understand the cause-and-effect relationships between the barriers to implementing solar energy. An interesting finding from the results is that the most prominent barrier and the most causal barrier are not always the same. This highlights that a barrier may be important, but may not necessarily be the root cause of other barriers.

This study analyzed 13 barriers related to the implementation of solar energy, of which 5 were identified as the root causes and the remaining 8 as the effects. Policymakers must understand these causal relationships between the barriers to achieving specific Sustainable Development Goals. Emerging economies should pay particular attention to the barriers identified as causes in this study to minimize the negative impact of other barriers that may arise and achieve long-term sustainability in line with the UN SDGs.

The study has limitations that need to be addressed in future research, such as the DEMATEL method only considering influencing capabilities and not other criteria in decision-making, and the difficulty of applying the method with a large number of alternatives. To improve the study, other flexible numerical analysis tools and methods can be incorporated. Additionally, the study was conducted in the context of emerging economies, so more studies in different countries are needed to develop a broad understanding of the topic. A prospective research scope could be determining the feasibility of various renewable energy sources in different countries.

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Author Biographies

Spandan Basak Payel is a Sub-divisional Engineer of Northern Electricity Supply Company Ltd., Bangladesh. He completed his Bachelor of Mechanical Engineering in 2016 from the Bangladesh University of Engineering and Technology (BUET). His research interest includes Waste Management, Operations Research, Decision Science, Optimization, and Renewable Energy.

S.M. Faysal Ahmed is a graduate student in the department of Mechanical Engineering at the Bangladesh University of Engineering and Technology (BUET). He completed his Bachelor of Mechanical Engineering in 2019 from the Rajshahi University of Engineering and Technology (RUET), Bangladesh. Currently, he is working as a Boiler Safety Engineer at RMG Sustainability Council, Bangladesh. His research interest includes Thermal Engineering, Energy Efficiency, Renewable Energy, Thermo-Fluids, Data Analysis, and Industrial Engineering.

Md. Zahidul Anam is a graduate student in the department of Industrial and Production Engineering at the Bangladesh University of Engineering and Technology (BUET). He completed his Bachelor of Science in Electrical and Electronics Engineering in 2014 from the Islamic University of Technology. Currently, he is working as a Quality, Reliability, and Safety Engineer at Singer Bangladesh Limited. His research interest includes Renewable Energy, Energy Management, Decision Science, Operations Research, and Optimization.

Md. Tanvir Siraj is a graduate student in the department of Industrial and Production Engineering at the Bangladesh University of Engineering and Technology (BUET). He completed his Bachelor of Mechanical Engineering in 2016 from BUET. Currently, he is working as a Boiler Safety Engineer at RMG Sustainability Council, Bangladesh. His research interest includes Operations Research, Decision Science, Optimization, Renewable Energy, and so on.