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Barriers to the adoption of solar and wind energy technologies: a systematic literature review

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Abstract

Purpose – Renewable energy (RE) sources hold immense potential to address future energy demands and mitigate greenhouse gas emissions. Despite the abundant availability of these resources, their global contribution to energy generation remains limited. This study aims to review relevant literature to explore the barriers hindering the development and integration of RE sources worldwide.

Design/methodology/approach – A systematic literature review was conducted using the Scopus database, with article selection guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses method. A citation frequency analysis and Pareto analysis were conducted to evaluate the barriers to the adoption of solar and wind energy.

Findings – The review identified 39 barriers, categorised into nine taxonomies: economic/financial, technical/technological, sociocultural, policy, political, institutional, market, geographical and environmental. Among these, the technical/technological and economic/financial categories were the most frequently cited taxonomies, with a lack of skilled labour and high investment costs emerging as the most significant challenges within these categories. In addition, the study analysed and ranked eleven strategies to overcome these barriers.

Originality/value – This paper enriches the theoretical discourse on RE by providing an in-depth analysis of global challenges and mitigation strategies, thereby paving the way for a more effective energy transition.

Keywords Barriers, Renewable energy, Systematic literature review, Energy mix, Pareto analysis

Paper type Research paper

1. Introduction

The usage of fossil fuels is linked to significant global economic growth (Barahmand and Eikeland, 2022). However, these resources are non-renewable and unreliable and cannot be naturally replenished (Chisale and Lee, 2023). Although significant to global economic growth, burning fossil fuels for electricity generation negatively impacts the environment (Barahmand and Eikeland, 2022). The emission of greenhouse gases (GHGs) from the continuous combustion of fossil fuels is the primary reason for global warming. The global GHG emissions are projected to reach 40GtCO_2 by 2030 (Asante *et al.*, 2022). To curb these CO_2 emissions, numerous countries have vowed to lower and ultimately eliminate their reliance on fossil fuel burning for electricity generation (Chisale and Lee, 2023).

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Renewable energy (RE) is recognised worldwide as the most suitable alternative to fossil fuels for generating reliable, clean and cost-effective energy while reducing carbon emissions (Khattak *et al.*, 2006; Shah *et al.*, 2019). Renewable energy is described as energy derived from natural resources and transformed into electrical energy (Al-akayshee *et al.*, 2020). It includes sources such as wind, solar, water, tides, biofuel/bioenergy and geothermal heat (Al-akayshee *et al.*, 2020). Renewable energy sources are more economical and sustainable than traditional conventional energy sources. Their development is socially, economically and environmentally beneficial (Oryani *et al.*, 2021). They are associated with job creation, reduced energy poverty and improved health conditions (Asante *et al.*, 2022).

The global penetration of renewable energy into the energy system is steadily advancing. Renewable energy sources, particularly solar and wind sources, are fast becoming the most cost-effective option for adding new power generation capacity in most countries. By 2024, the total global renewable energy capacity reached 4,448GW, representing an increase of 15% from 2023 (International Renewable Energy Agency (IRENA), 2025). Depicted in Figure 1, is the regional contribution to the global capacity at the end of 2024. Asia is leading the contribution with 54% of the total capacity, with China being the dominant contributor at 77% (International Renewable Energy Agency (IRENA), 2025). Despite this significant growth, the International Renewable Energy Agency (IRENA) highlights that the current rate of RE expansion is insufficient to meet the Paris Agreement targets of 2030. Achieving these targets will require an increased capacity of 17% a year until 2030. This underscores the urgent need to enhance the integration of renewable energy sources into the energy system, meeting energy demand sustainably while transitioning towards a low-carbon future through 2030 and beyond.

The adoption of renewable energy into the energy system is a global issue. Different countries face unique challenges and barriers. According to Shah *et al.* (2019) and Pathak *et al.* (2022), these barriers are contextual and interrelated. Therefore, their impact on the

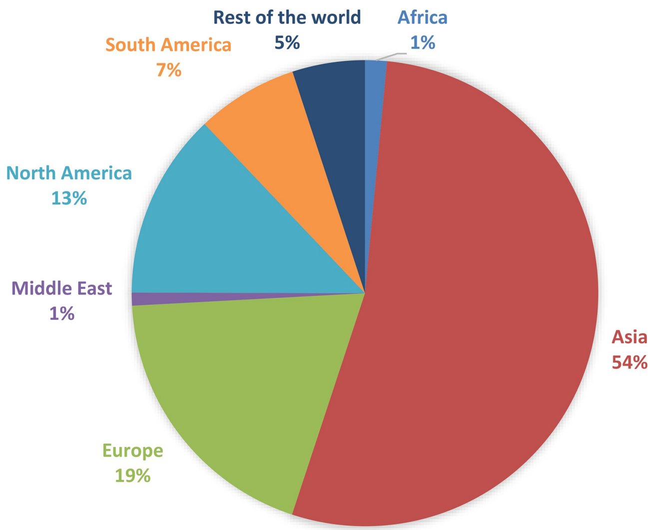

Figure 1. Total global renewable energy capacity (GW) by 2024
Source: International Renewable Energy Agency (IRENA), 2025

integration of RE varies from one country to another depending on that country's political, geographical, social, economic, financial and technical conditions.

Various studies have been carried out globally to identify and categorise the barriers according to their significance (Asante *et al.*, 2022; Pathak *et al.*, 2022). Several of these studies have also proposed suggestions and recommendations that can be implemented to mitigate these barriers, facilitating the efficient integration of RE into the power system (Asante *et al.*, 2022).

This study seeks to address the following research questions (RQs):

RQ1. What are the key barriers hindering the development of wind and solar energy technologies?

RQ2. What strategies can be employed to manage these barriers and facilitate the effective integration of renewable energy?

Although an increasing number of studies have been conducted to assess renewable energy barriers globally, gaps still remain that need to be addressed. The study by Obuseh *et al.* (2025) explored renewable energy barriers globally but did not employ a systematic literature review to synthesise the research in this field. Furthermore, the study did not prioritise the barriers using either citation frequency analysis or Pareto analysis. Research by Wu *et al.* (2022) analysed barriers to the adoption of PV in China without a systematic approach and categorised the barriers into only four categories: policy, social, economic and technological. This narrow categorisation overlooked other critical aspects, including political, market, institutional, geographic and environmental factors. However, renewable energy barriers are complex, and their analysis requires a multidimensional approach that incorporates all relevant aspects from a social, economic, political and environmental perspective (Molepo *et al.*, 2025; Pereira *et al.*, 2025).

This research study aims to address these gaps by making the following key contributions: Firstly, it identifies the barriers globally through a structured, systematic literature review approach to analytically identify relevant literature pertaining to the research. Secondly, the barriers are categorised into distinct taxonomies, providing a systematic, structured and multidimensional approach to analyse, prioritise and overcome them. Thirdly, a mean citation frequency and Pareto analysis are deployed to rank and prioritise barrier taxonomies and barriers in this field. Fourthly, mitigation strategies to overcome these barriers are identified and evaluated using Pareto analysis to analyse their significance. Finally, the study offers theoretical and practical implications. The paper is organised into five sections. Section 2 outlines the research methodology, Section 3 presents the findings, Section 4 provides the discussion and Section 5 concludes the study by highlighting its limitations and offering recommendations for future research.

2. Research methodology

2.1 Data collection

The research employed a Systematic Literature Review (SLR) approach to identify studies addressing barriers to renewable energy development. SLR is a robust and meticulous scientific method designed to generate new knowledge, build theoretical frameworks and consolidate research findings (Wuni, 2022). This approach is widely used due to its comprehensiveness and ability to minimise biases, thereby ensuring the reliability and validity of the conclusions drawn. Several studies have used this methodology to identify and analyse barriers at different levels. An example is the study conducted by Wuni (2022) to investigate and map the barriers to the adoption of a circular economy in the construction industry.

Another study by Tikwayo and Mathaba (2023) was conducted to investigate the benefits and barriers to adopting Industry 4.0 technology, with a focus on warehouse management.

The search for relevant literature was conducted in June 2025, utilising the Scopus database as the primary source for data collection. Scopus is widely recognised as one of the most advanced databases for literature indexation and management, particularly in the field of engineering (Wuni and Shen, 2020). The study focused on articles published between 2018 and 2025 that identified and categorised renewable energy barriers using Multi-Criteria Decision-Making (MCDM) methods. The decision to select articles employing MCDM methods is because MCDM techniques have been proven suitable for addressing multidimensional and complex decision-making problems (Asante *et al.*, 2022). MCDM methods are widely used in energy planning to address the complex challenges of renewable energy development. This approach ensured that the selected articles provided a comprehensive analysis of the multidimensional complexities associated with renewable energy barriers, aligning with the research objectives.

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which is widely regarded as the most cited and reliable guideline for systematic reviews. PRISMA promotes transparency, reduces bias and enhances the validity of the results (Sarkis-Onofre *et al.*, 2021). The article selection and inclusion process consisted of three key steps: identification, screening and eligibility assessment. The PRISMA flow chart is presented in Figure 2. The flowchart summarises the

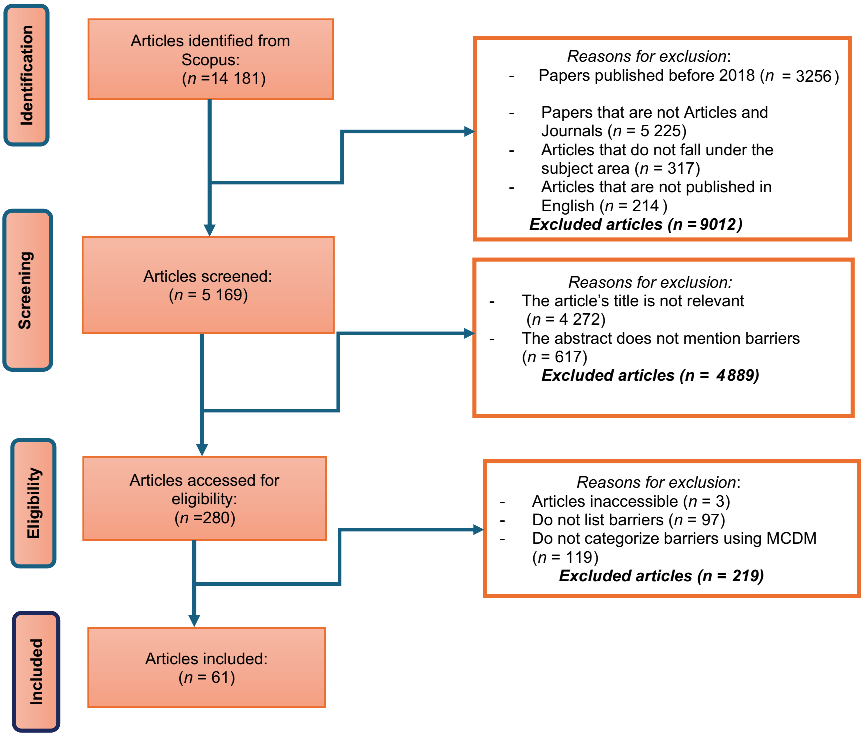

Figure 2. Systematic literature review process
Source: Authors' own work

number of documents identified, the articles included and excluded and the reasons for exclusions, ensuring a transparent and systematic presentation of the methodology.

2.1.1 Identification. To initiate the search, keywords were carefully formulated to align with the research aim and questions. The keywords (*development, OR integration, OR adoption, OR analysis, AND renewable AND energy, AND barriers, OR impediments, OR challenges, AND solar, OR wind*) were plugged into the search string in Scopus and yielded 14,181 documents.

2.1.2 Screening. The initial 14,181 papers identified in the search were screened based on specific criteria to ensure relevance and quality. Firstly, the publication year was restricted to the period between 2018 and 2025, leading to the removal of 3,256 articles. Next, only articles from journals were included, as they undergo rigorous peer-review processes, ensuring credible knowledge. Further screening was conducted by narrowing down documents by relevant subject areas and including only those published in English. As a result, 5,756 articles were excluded: 5,225 were not classified as journals or articles, 317 fell outside the relevant subject areas and 214 were not published in English. The remaining 5,169 articles were assessed for eligibility, forming the basis for further analysis.

2.1.3 Eligibility. The 5,169 documents were further screened for eligibility by reading the article's title. During this process, 169 articles were deemed irrelevant to the renewable energy field and subsequently excluded. The remaining 5,000 were exported to a Microsoft Excel workbook, and the eligibility assessment continued, eliminating an additional 4,103 articles that are irrelevant to the study. The remaining 897 articles were further assessed by reading through their abstracts. Of these 897 articles, 617 were removed for not mentioning the barriers to renewable energy in the abstract, and 280 articles were selected for in-depth analysis.

2.1.4 Included. Of the 280 articles, 277 were successfully downloaded from reputable sources, while 3 were inaccessible. The 277 articles were assessed further by skim-reading their main body. During this analysis, 97 articles were excluded because they did not list RE barriers, and an additional 119 articles were excluded because they listed barriers but did not prioritise or categorise them using MCDM techniques. Ultimately, 61 articles that listed the barriers and prioritised/categorised them using the MCDM method were selected and analysed further. These articles were further scrutinised to understand their objectives.

2.2 Data analysis

The study systematically extracted data from academic articles, recording key variables such as the country of study, year of publication, renewable energy technology, barrier taxonomy, specific barriers and mitigation strategies.

A bibliometric analysis was conducted to identify research trends and advancements over time (Passas, 2024). Following this, a frequency analysis was performed on barrier taxonomy, specific barriers and mitigation strategies to rank them based on their frequency of occurrence.

To further refine the prioritisation, Pareto analysis was conducted to rank the most significant barrier taxonomies and mitigation strategies. Pareto analysis is a decision-making tool that prioritises factors based on their frequency or impact (Sarkar *et al.*, 2013). This approach is crucial in identifying the most significant barriers to renewable energy development and determining which mitigation strategies should be prioritised to achieve the most effective solution.

Pareto charts with prioritisation thresholds were used to categorise the highest, moderate and lowest occurring barrier taxonomies and mitigation strategies. This approach provided a clear understanding of global trends and regional differences in renewable energy barriers, facilitating strategic decision-making for addressing key challenges.

3. Findings

3.1 Bibliometric analysis

Bibliometric analysis is a rigorous scientific research method for examining and assessing large quantities of scientific data (Donthu *et al.*, 2021). It enables researchers to systematically analyse the trends and patterns within a particular field of study (Passas, 2024). Depending on the research objective, various bibliometric techniques such as co-word analysis, co-authorship analysis, co-citation analysis and bibliographic analysis can be performed.

The analysis of the number of studies conducted per country is illustrated in Figure 3, highlighting global trends in renewable energy research. It is evident from this analysis that Africa lags behind other countries in this field of research. Ghana is making a commendable effort in conducting and publishing research pertaining to renewable energy barriers. However, these efforts are insufficient, considering the state of energy generation in Africa, the abundance of renewable energy resources and the potential impact that renewable energy can have on this continent. Conversely, India is leading the search with a significant number of studies conducted between 2018 and early 2025, reflecting its strong commitment to addressing renewable energy challenges and advancing clean energy solutions. This analysis indicates that most countries worldwide recognise and acknowledge the role of renewable energy in alleviating the energy crisis and are actively examining the barriers that impede its effective integration into their energy systems.

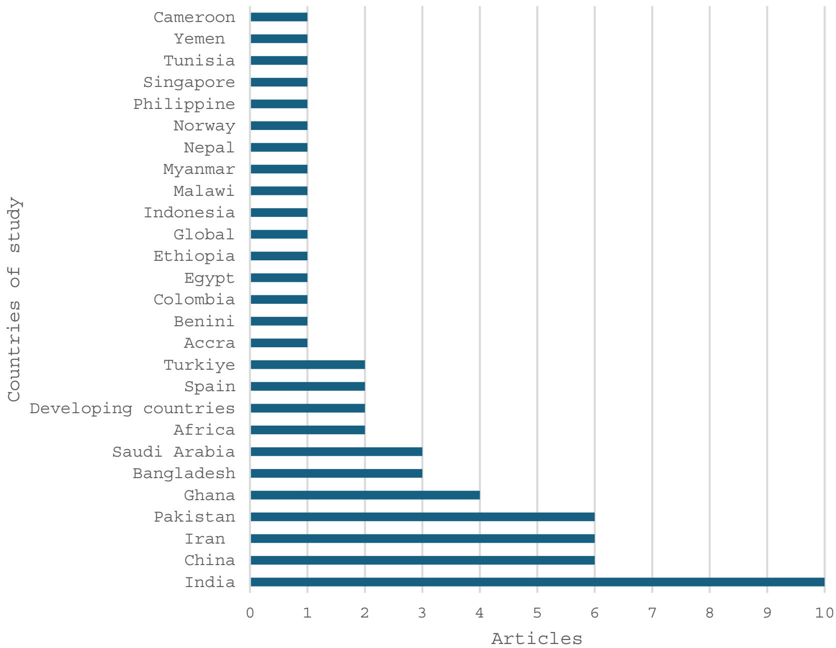

Figure 3. Number of articles per country
Source: Authors' own work

The analysis presented in Figure 4 illustrates the annual distribution of articles published between 2018 and early 2025. The data reveals a steady increase in the number of publications from 2018 to 2022, signifying a growing academic interest in understanding and addressing the barriers to renewable energy integration. However, a slight decline in the number of articles is observed between 2022 and 2023. The apparent drop between 2024 and 2025 is attributed to the fact that data was extracted in June 2025, with additional publications expected throughout the year 2025. The upward trend observed from 2018 to 2022 highlights the increasing recognition of the challenges and complexities associated with integrating renewable energy into the global energy mix. It also highlights the research community's commitment to addressing these barriers.

It is essential to consider that various factors can impact the ability to conduct and publish research. These factors include limited funding, inadequate policy frameworks, insufficient support from government institutions and the extended timeframes required to complete thorough research studies (Chou *et al.*, 2023). These constraints may partially explain fluctuations in publication trends.

3.2 Barriers to renewable energy adoption

3.2.1 Barriers taxonomies. A total of thirty-nine (39) barriers to renewable energy adoption were identified globally through a comprehensive literature review. These barriers were categorised into nine distinct taxonomies as follows: economic/financial (EFB), technical/technological (TB), sociocultural (SB), policy and regulatory (PB), institutional (IB), political (PB), market (MB), environmental (EB) and geographical (GB).

The barriers, along with their respective taxonomies, are ranked by frequency of occurrence in Table 1 by converting the number of articles that cited each taxonomy and barrier into the frequency of citations. Notably, some barriers overlap across multiple taxonomies, reflecting their multifaceted nature, as highlighted by (Painuly, 2001). The citation frequency analysis reveals that the technical/technological and economic/financial categories are the most frequently cited. Moreover, the most common barriers include high investment costs, limited public awareness, lack of public acceptance, insufficient funding and a shortage of skilled labour. Environmental and geographical

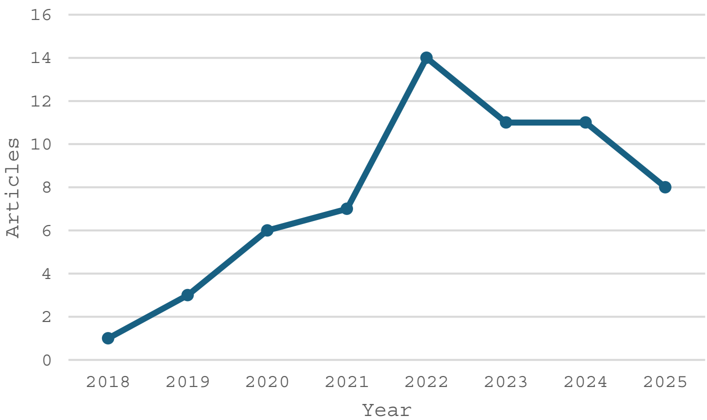

Figure 4. Number of articles published per year
Source: Authors' own work

Table 1. Frequency ranking of renewable energy barriers

Barrier category	Barrier	Frequency	Reference
Economic/ Financial		*55*	Addae *et al.* (2019); Al Asbahi *et al.* (2020); Cai *et al.* (2022); Dai and Solangi (2023); Dioba *et al.* (2024); Ghimire and Kim (2018); Jafarzadeh Ghoushchi *et al.* (2023); Mostafaeipour *et al.* (2021); Pandey *et al.* (2025)
EFB1	High investment cost	52	Addae *et al.* (2019); Bouraima *et al.* (2024); James *et al.* (2025); Rocha *et al.* (2023); Sengar *et al.* (2020)
EFB2	Lack of funding	37	Abdul *et al.* (2023); Alizadeh *et al.* (2020); Ghimire and Kim (2018); Kutlu Gündoğdu (2022); Mostafaeipour *et al.* (2021); Pandey *et al.* (2025); Rebucas *et al.* (2024); Shah *et al.* (2019)
EFB3	Lack of subsidy	31	Addae *et al.* (2019); Ali Sadat *et al.* (2021); Al Asbahi *et al.* (2020); Das *et al.* (2023); Dokyi and Sharifi (2024); Irfan *et al.* (2022); Lalita *et al.* (2025)
EFB4	Lack of a financing mechanism and incentives	17	Akpahou *et al.* (2024); Barahmand and Eikeland (2022); Batool *et al.* (2023); Sengar *et al.* (2020); Shao *et al.* (2025); Tseng *et al.* (2021)
EFB5	Long payback period	14	Akusta *et al.* (2025); Bouraima *et al.* (2024); Chen *et al.* (2022); Jahangoshai Rezaee *et al.* (2019); Oryani *et al.* (2021); Shahzad *et al.* (2023)
Technical/ Technological		*56*	Addae *et al.* (2019); Ali Sadat *et al.* (2021); Al Asbahi *et al.* (2020); Ghimire and Kim (2018); Mahmud and Roy (2021); Mohseni and Brent (2025); Numata *et al.* (2020); Rocha *et al.* (2023); Wu *et al.* (2022)
TB1	Lack of skilled labour	36	Akpahou *et al.* (2024); Al Asbahi *et al.* (2020); Jafarzadeh Ghoushchi *et al.* (2023); Kutlu Gündoğdu (2022); Pandey *et al.* (2025); Shah *et al.* (2019); Sun *et al.* (2021)
TB2	Inadequate technology	33	Addae *et al.* (2019); Akusta *et al.* (2025); Aparisi-Cerdá *et al.* (2024); Al Asbahi *et al.* (2020); Batool *et al.* (2023); Firoozi and Eghtesadifard (2022); Tseng *et al.* (2021); Vallecha *et al.* (2021)
TB3	Lack of R&D facilities	26	Cai *et al.* (2022); Chisale and Lee (2023); Dokyi and Sharifi (2024); Jafarzadeh Ghoushchi *et al.* (2023); Mehmood *et al.* (2022); Pandey *et al.* (2025); Shah *et al.* (2019); Sun *et al.* (2021)
TB4	Challenges of grid connection	19	Abdel-Basset *et al.* (2023); Alyamani *et al.* (2024); Dhingra *et al.* (2022); Ghimire and Kim (2018); Numata *et al.* (2020); Shao *et al.* (2025); Solangi *et al.* (2021); Wu *et al.* (2022)
T5B	Intermittent/ Unreliable supply of RE	18	Abdel-Basset *et al.* (2023); Alyamani *et al.* (2024); Asante *et al.* (2020, 2022); Bouraima *et al.* (2024); Chisale and Lee (2023); Das *et al.* (2023); Mostafaeipour *et al.* (2021); Solangi *et al.* (2025); Tseng *et al.* (2021)
TB6	Lack of infrastructure	17	Abdul and Wenqi (2024); Addae *et al.* (2019); Akusta *et al.* (2025); Baumli and Jamasb (2020); Mehmood *et al.* (2022); Oryani *et al.* (2021); Shah and Longsheng (2022); Shahzad *et al.* (2023)
TB7	Lack of servicing and maintenance facilities	17	Abdul and Wenqi (2024); Akpahou *et al.* (2024); Akusta *et al.* (2025); Alyamani *et al.* (2024); Asante *et al.* (2020, 2022); Bouraima *et al.* (2024); Dhingra *et al.* (2022); Govindan (2023); James *et al.* (2025); Mekonnen *et al.* (2022); Mustafa *et al.* (2024); Numata *et al.* (2020); Pandey *et al.* (2025); Shah *et al.* (2019); Sun *et al.* (2021); Tseng *et al.* (2021)

(*continued*)

Table 1. Continued

Barrier category	Barrier	Frequency	Reference
TB8	Lack of standards and codes	10	Abdul and Wenqi (2024); Ali Sadat *et al.* (2021); Bouraima *et al.* (2024); Chen *et al.* (2022); Dhingra *et al.* (2022); Mostafaeipour *et al.* (2021); Numata *et al.* (2020); Sengar *et al.* (2020); Shah and Longsheng (2022); Thakur *et al.* (2023)
T9B	Shortage of training institutes	7	Dokyi and Sharifi (2024); Ferdoush *et al.* (2024); Mekonnen *et al.* (2022); Pathak *et al.* (2022); Rebucas *et al.* (2024); Rocha *et al.* (2023); Shah and Longsheng (2022)
Sociocultural		*46*	Akpahou *et al.* (2024); Aparisi-Cerdá *et al.* (2024); Batool *et al.* (2023); Dioba *et al.* (2024); Pandey *et al.* (2025); Pathak *et al.* (2022); Rocha *et al.* (2023); Thakur *et al.* (2023); Vallecha *et al.* (2021)
SB1	Limited public awareness	42	Addae *et al.* (2019); Ali Sadat *et al.* (2021); Barahmand and Eikeland (2022); Dhingra *et al.* (2022); Gangadhari *et al.* (2023); Mahmud and Roy (2021); Pandey *et al.* (2025); Shah *et al.* (2019); Shao *et al.* (2025)
SB2	Lack of public acceptance	39	Abdel-Basset *et al.* (2023); Akpahou *et al.* (2024); Asante *et al.* (2022); Dokyi and Sharifi (2024); Jafarzadeh Ghoushchi *et al.* (2023); Kamdar and Liu (2025); Mekonnen *et al.* (2022); Mohseni and Brent (2025); Oryani *et al.* (2021); Rekik and El Alimi (2024)
SB3	Lack of customer paying capacity	11	Abdul and Wenqi (2024); Akpahou *et al.* (2024); Asante *et al.* (2020, 2022); Barahmand and Eikeland (2022); Ghimire and Kim (2018); Irfan *et al.* (2022); Pandey *et al.* (2025); Shah *et al.* (2019); Shahzad *et al.* (2023); Solangi *et al.* (2021)
SB4	Lack of public interest	6	Addae *et al.* (2019); Kutlu Gündoğdu (2022); Pandey *et al.* (2025); Rebucas *et al.* (2024); Rekik and El Alimi (2024); Solangi *et al.* (2021)
Policy and regulatory		*36*	Asante *et al.* (2022); Das *et al.* (2023); Dioba *et al.* (2024); Kamdar and Liu (2025); Mekonnen *et al.* (2022); Numata *et al.* (2020); Rebucas *et al.* (2024); Rocha *et al.* (2023); Shah *et al.* (2019)
PRB1	Lack of coherent renewable energy policy	35	Al Asbahi *et al.* (2020); Baumli and Jamasb (2020); Govindan (2023); Jafarzadeh Ghoushchi *et al.* (2023); Kamdar and Liu (2025); Mekonnen *et al.* (2022); Rebucas *et al.* (2024); Rekik and El Alimi (2024); Rocha *et al.* (2023); Shah *et al.* (2019)
PRB2	Lack of regulatory framework	22	Alyamani *et al.* (2024); Asante *et al.* (2022); Bouraima *et al.* (2024); Cai *et al.* (2022); Dhingra *et al.* (2022); Kutlu Gündoğdu (2022); Numata *et al.* (2020); Rebucas *et al.* (2024); Shahzad *et al.* (2023); Shao *et al.* (2025); Thakur *et al.* (2023)
PRB3	Ineffective bureaucratic permit procedures	18	Abdel-Basset *et al.* (2023); Ali Sadat *et al.* (2021); Asante *et al.* (2022); Chen *et al.* (2022); Dhingra *et al.* (2022); Mahmud and Roy (2021); Shah *et al.* (2019); Solangi *et al.* (2025)
PRB4	Lack of transparency in decision-making processes	10	Abdul and Wenqi (2024); Akusta *et al.* (2025); Asante *et al.* (2020, 2022); Das *et al.* (2023); Ghimire and Kim (2018); Kutlu Gündoğdu (2022); Pathak *et al.* (2022); Rocha *et al.* (2023); Solangi *et al.* (2021)

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Table 1. Continued

Barrier category	Barrier	Frequency	Reference
Institutional		*25*	Abdel-Basset *et al.* (2023); Asante *et al.* (2022); Batool *et al.* (2023); Ramesh *et al.* (2022); Rekik and El Alimi (2024); Shah *et al.* (2019); Sun *et al.* (2021); Tseng *et al.* (2021)
IB1	Lack of coordination between key institutions	25	Akusta *et al.* (2025); Asante *et al.* (2020, 2022); Dhingra *et al.* (2022); Pathak *et al.* (2022); Ramesh *et al.* (2022); Rekik and El Alimi (2024); Solangi *et al.* (2021); Sun *et al.* (2021); Tseng *et al.* (2021)
IB2	Lack of institutional capacity	14	Asante *et al.* (2020, 2022); Ghimire and Kim (2018); James *et al.* (2025); Numata *et al.* (2020); Rocha *et al.* (2023); Shah *et al.* (2019); Shah and Longsheng (2022); Tseng *et al.* (2021)
IB3	Lack of skilled human resources	11	Abdul and Wenqi (2024); Asante *et al.* (2020, 2022); Dhingra *et al.* (2022); Ghimire and Kim (2018); Sengar *et al.* (2020); Solangi *et al.* (2021); Tseng *et al.* (2021)
IB4	Lack of infrastructure	6	Addae *et al.* (2019); Dhingra *et al.* (2022); James *et al.* (2025); Kutlu Gündoğdu (2022); Shah and Longsheng (2022)
Political		*26*	Asante *et al.* (2020); Barahmand and Eikeland (2022); Dhingra *et al.* (2022); James *et al.* (2025); Mehmood *et al.* (2022); Oryani *et al.* (2021); Shah *et al.* (2019); Vallecha *et al.* (2021)
PB1	Political instability	21	Abdul *et al.* (2023); Abdul and Wenqi (2024); Pathak *et al.* (2022); Rekik and El Alimi (2024); Shah *et al.* (2019); Shahzad *et al.* (2023); Vallecha *et al.* (2021)
PB2	Corruption and nepotism	15	Abdul and Wenqi (2024); Addae *et al.* (2019); Asante *et al.* (2020, 2022); Ghimire and Kim (2018); Pathak *et al.* (2022); Rocha *et al.* (2023); Shah *et al.* (2019); Shah and Longsheng (2022); Solangi *et al.* (2021)
PB3	Lack of political commitment and consensus	11	Abdul and Wenqi (2024); Akusta *et al.* (2025); Ali Sadat *et al.* (2021); Asante *et al.* (2020, 2022); Chisale and Lee (2023); Dhingra *et al.* (2022); Shah and Longsheng (2022)
Market		*18*	Kutlu Gündoğdu (2022); Pathak *et al.* (2022); Rocha *et al.* (2023); Shah *et al.* (2019); Shao *et al.* (2025); Solangi *et al.* (2021); Vallecha *et al.* (2021)
MB1	Small market	15	Abdul and Wenqi (2024); Addae *et al.* (2019); Alyamani *et al.* (2024); Barahmand and Eikeland (2022); Numata *et al.* (2020); Rocha *et al.* (2023); Solangi *et al.* (2021)
MB2	Market uncertainties	9	Addae *et al.* (2019); Barahmand and Eikeland (2022); Kutlu Gündoğdu (2022); Mahmud and Roy (2021); Shao *et al.* (2025); Vallecha *et al.* (2021)
MB3	Lack of market competition	8	Alyamani *et al.* (2024); Dai and Solangi (2023); Pathak *et al.* (2022); Shao *et al.* (2025); Sun *et al.* (2021)
MB4	Underdeveloped supply chain and logistics	5	Addae *et al.* (2019); Alyamani *et al.* (2024); Kutlu Gündoğdu (2022); Sengar *et al.* (2020); Shao *et al.* (2025)
Environmental		*12*	Alyamani *et al.* (2024); Batool *et al.* (2023); Baumli and Jamasb (2020); Firoozi and Eghtesadifard (2022); Mehmood *et al.* (2022); Pathak *et al.* (2022); Rocha *et al.* (2023); Thakur *et al.* (2023); Tseng *et al.* (2021); Vallecha *et al.* (2021)

(*continued*)

Table 1. Continued

Barrier category	Barrier	Frequency	Reference
EB1	Land requirements	12	Alyamani *et al.* (2024); Mahmud and Roy (2021); Mekonnen *et al.* (2022); Pathak *et al.* (2022); Rocha *et al.* (2023); Solangi *et al.* (2025)
EB2	Need for waste disposal	7	Ferdoush *et al.* (2024); Mehmood *et al.* (2022); Pathak *et al.* (2022); Rocha *et al.* (2023); Solangi *et al.* (2025)
EB3	Ecological issues	6	Abdul and Wenqi (2024); Barahmand and Eikeland (2022); Mehmood *et al.* (2022); Solangi *et al.* (2021); Vallecha *et al.* (2021)
Geographical		*13*	Akpahou *et al.* (2024); Asante *et al.* (2020); Dhingra *et al.* (2022); Ghimire and Kim (2018); Pathak *et al.* (2022); Solangi *et al.* (2021)
GB1	Transport problems	9	Barahmand and Eikeland (2022); Chisale and Lee (2023); Das *et al.* (2023); Ghimire and Kim (2018); Solangi *et al.* (2021); Tseng *et al.* (2021)
GB2	Scattered houses	9	Abdul and Wenqi (2024); Barahmand and Eikeland (2022); Chisale and Lee (2023); Das *et al.* (2023); Ghimire and Kim (2018); Kamdar and Liu (2025); Solangi *et al.* (2021)
GB3	Geographical location	7	Asante *et al.* (2022); Barahmand and Eikeland (2022); Chisale and Lee (2023); Govindan (2023); Pathak *et al.* (2022); Rocha *et al.* (2023); Vallecha *et al.* (2021)

Source(s): Authors’ own work

barriers are the least cited categories, with ecological issues and an underdeveloped supply chain and logistics being the least cited barriers.

3.2.2 Mean score analysis. The ranking of the categorised barrier taxonomies was based on their mean citation frequency, which serves as an indicator of their relative prominence in the literature. The mean citation frequency for each barrier taxonomy was computed as per equation (1):

$$Mean\ citation\ frequency\ (\mu_j) = \frac{\sum_{j=1}^{n}(R_j)}{n} \tag{1}$$

where μ_j denotes the mean citation frequency of the barrier taxonomy, n represent the number of barriers in each taxonomy and R_j represent the citation frequency barrier in each taxonomy. The number of barriers in each taxonomy, the mean citation frequency of each taxonomy and the sum of the citation frequency for each barrier taxonomy are presented in Figure 5. According to the mean scores, the most persistent barrier categories are economic/financial ($\mu = 30.2$), sociocultural ($\mu = 24.5$), policy and regulatory ($\mu = 21.25$) and technical/technological ($\mu = 20.33$), making them the most prominent barrier taxonomies to the adoption of renewable energy globally. This underscores the need to identify and prioritise the barriers associated with these taxonomies and propose mitigation strategies to overcome them.

3.2.3 Pareto analysis of barriers. Pareto analysis is a decision-making tool widely used across various fields to identify and prioritise the most significant factors contributing to a problem or solution (Sarkar *et al.*, 2013). It ranks the data in order of frequency of

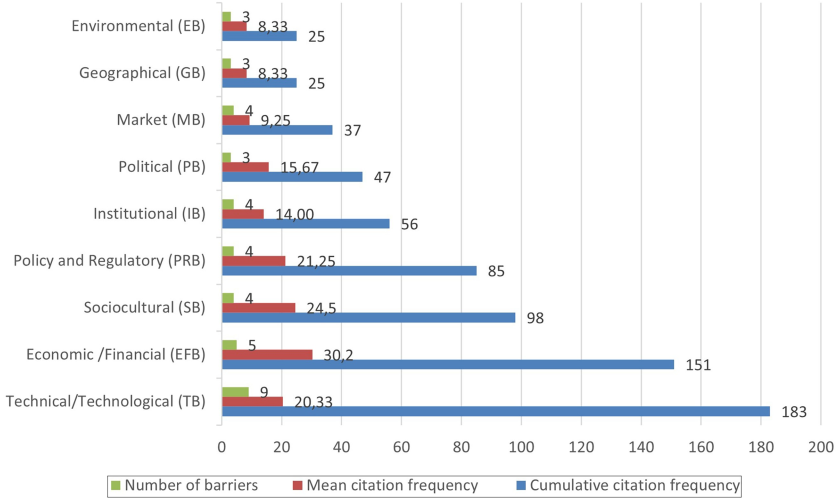


Figure 5. Mean score of the barrier taxonomies
Source: Authors' own work

occurrence, ranging from the highest to the lowest frequency (Karuppusami and Gandhinathan, 2006). Also known as "vital few, trivial many", Pareto analysis is based on the 80 / 20 rule, which suggests that 80% of effects often result from 20% of causes (Sarkar *et al.*, 2013). This methodology is widely applied in various fields, including quality management, information technology, supply chain management and finance.

In this context, Pareto analysis examined and ranked the barriers impeding the global integration of renewable energy. The findings, as illustrated in Figures 6–8, reveal the vital few, trivial many renewable energy barriers under each of the nine barrier taxonomies.

Technical/Technological Barriers (TB): A Pareto analysis chart for technical and technological barriers is presented in Figure 6(a). Technical barriers, such as lack of skilled labour (TB1), lack of adequate technology (TB2), lack of R&D facilities (TB3), challenges of grid connection (TB4), unreliable supply (TB5) and lack of infrastructure (TB6), highlight the need for technical expertise, advanced infrastructure and technological innovation. As the renewable energy industry evolves rapidly, it demands cutting-edge technology, a highly skilled workforce and ongoing research and development to stay competitive. However, many countries still lack the necessary technical expertise and infrastructure to lead the development of these projects. Their dependence on developed countries for technology and skilled labour hinders the effective advancement of renewable energy initiatives. This finding is consistent with those of Mehmood *et al.* (2022), who identified the lack of technical skills and the need for modern technology as key challenges within the technical category.

Economic/Financial Barriers (EFB): The renewable energy challenges associated with the economic taxonomy are presented in a Pareto chart in Figure 6(b). The vital few barriers include high investment cost (EFB1), lack of finance (EFB2) and lack of subsidies (EFB3). Renewable energy development is still in the early stages in various developing countries, and therefore, financial institutions are reluctant to provide funding for developing these technologies (Asante *et al.*, 2022). Renewable energy technologies development requires

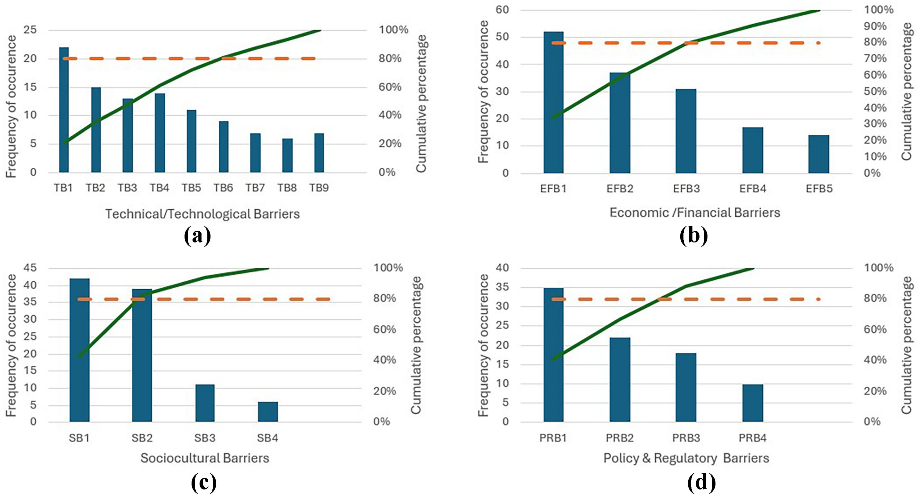


Figure 6. Pareto analysis of (a) technical/technological, (b) economic/financial, (c) sociocultural and (d) policy and regulatory
Source: Authors' own work

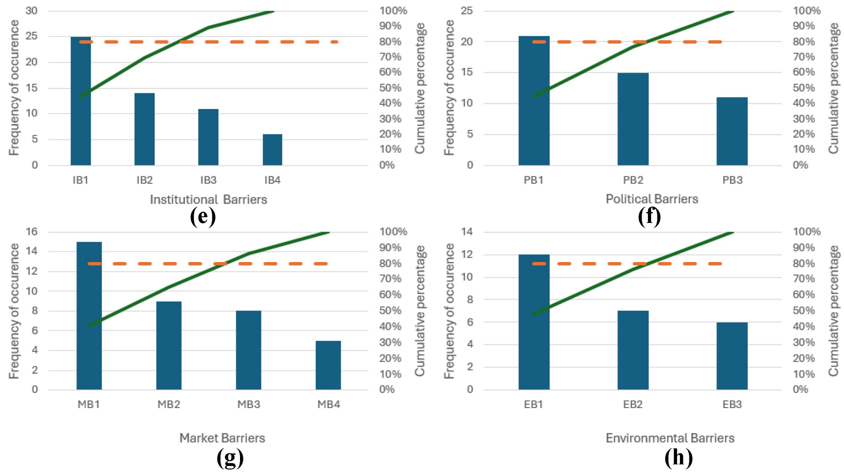
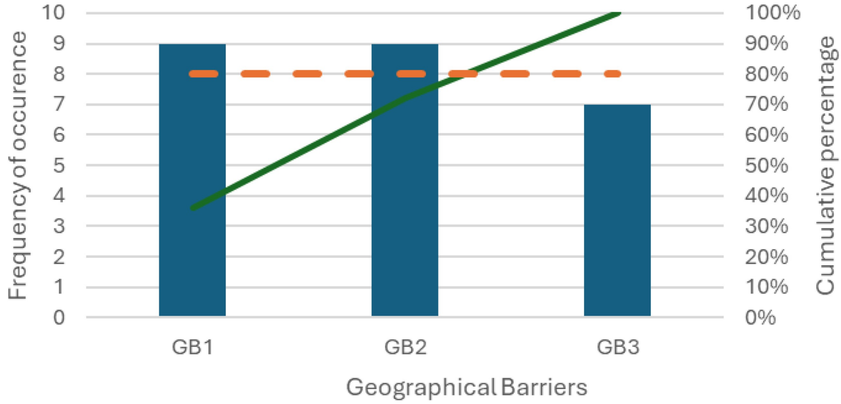


Figure 7. Pareto analysis of (e) institutional, (f) political, (g) market and (h) environmental barriers
Source: Authors' own work

high capital costs, and the payback period is longer, inhibiting financial institutions from investing in these projects. The lack of subsidies and incentives for the development of RE sources does not encourage the implementation and integration of these technologies (Sengar *et al.*, 2020).

Sociocultural Barriers (SB): A Pareto chart for sociocultural barriers is depicted in Figure 6(c). These challenges include a lack of public awareness (SB1) and a lack of



(i)

Figure 8. Pareto analysis of (i) geographical barriers
Source: Authors' own work

acceptance of renewable energy technologies (SB2). Most of the citizens in the rural and urban areas of various developing countries lack information and understanding regarding renewable energy and its benefits (Alexopoulos *et al.*, 2023). Even those with access to information have different perceptions about these technologies (Ghimire and Kim, 2018). These sociocultural factors present barriers to the adoption of these renewable energy technologies.

Policy and Regulatory Barriers (PRB): Policy and regulatory barriers include a lack of coherent RE policies (PRB1), a lack of regulatory framework (PRB2) and ineffective bureaucracy (PRB3). Detailed renewable energy policies and regulatory frameworks are vital in regulating the industry, thus ensuring compliance and effective development and integration of renewable energy sources (Shah *et al.*, 2019). However, according to the Pareto analysis in Figure 6(d), many countries still lack these policies and frameworks, which hinder the development of renewable energy projects.

Institutional Barriers (IB): The barriers associated with institutional taxonomy are presented in Figure 7(e). The lack of cooperation, communication, information sharing and alignment (IB1) amongst various key institutions responsible for the implementation of renewable energy projects results in delays in the development of RE technologies (Pathak *et al.*, 2022). Weak institutional capacity (IB2), as a result of a lack of awareness of RE benefits by policymakers in key institutions, impedes the development of renewable energy technologies in the energy system (Shah and Longsheng, 2022).

Political Barriers (PB): Barriers associated with the Political category include political instability (PB1), political commitment and nepotism (PB2) and corruption, as shown in Figure 7(f). Political instability due to a change in ministry and corruption and nepotism in awarding licences, permits and public–private partnership bids deters investors and Independent Power Producers from funding and developing these renewable energy projects (Alyamani *et al.*, 2024; Pathak *et al.*, 2022).

Market Barriers (MB): Market barriers impeding the development of renewable energy products include small markets (MB1) and market uncertainties (MB2), as shown in Figure 7(g). The uncertainty and doubts about the end-users/market of electricity generated using renewable energies slow down the development of these projects (Sengar *et al.*, 2020).

Environmental Barriers (EB): The Pareto chart shown in Figure 7(h) depicts the most persistent environmental challenges faced in the development and construction of renewable energy projects. These include challenges associated with land requirements and land use (EB1). The process of acquiring land and the pre-environmental assessment associated with rezoning the land for renewable energy generation is challenging (Solangi *et al.*, 2025). The need for waste disposal (EB2) has also emerged as a challenge faced during construction, where waste management is not well-defined and regulated (Pathak *et al.*, 2022).

Geographical Barriers (GB): The Pareto analysis of renewable energy barriers associated with the geographical conditions is presented in Figure 8(i). The vital few geographical barriers include transportation challenges (GB1) and scattered houses (GB2). Renewable energy sources are abundant in remote rural areas with poor road infrastructure (Chisale and Lee, 2023). The transportation of the components to these sites becomes costly and delayed, thus impeding the construction period of these projects (Ghimire and Kim, 2018). In turn, the electricity generated from these sites needs to be transmitted over long transmission networks to households in scattered areas. The lack of transmission and distribution infrastructure has emerged as a challenge (Asante *et al.*, 2020; Das *et al.*, 2023).

This analysis is instrumental in enabling stakeholders to focus on addressing the most impactful barriers. Technical/technological, economic/financial, sociocultural and policy & regulatory obstacles account for almost 67% of the challenges. By prioritising these barriers, targeted strategies can be developed to promote the successful adoption and integration of renewable energy resources globally.

3.2.4 Mitigation strategies to promote renewable energy adoption. Out of the sixty-one articles analysed from the systematic literature review, twenty-nine articles presented strategies for removing renewable energy barriers to advance the development and penetration of RE into the energy system. Presented in Table 2 is the list of solutions identified from the literature review analysis, ranked in order of frequency of occurrence. Mitigating barriers to renewable energy will accelerate the development and integration of renewable energy sources into the energy system.

3.2.4.1 Public awareness-raising. Governments and key stakeholders should prioritise awareness campaigns to enhance public energy literacy and support the transition to renewable energy. These campaigns should focus on educating the public about the benefits of renewable energy technologies (Chisale and Lee, 2023; Jahangoshai Rezaee *et al.*, 2019; Mahmud and Roy, 2021; Shah and Longsheng, 2022; Solangi *et al.*, 2021). Awareness initiatives can take the form of conferences, seminars, field presentations and training sessions, ensuring accessibility to all individuals (Pathak *et al.*, 2022). In addition, government and public institutions should implement pilot renewable energy projects to showcase the practical benefits and ease of integrating renewable energy into existing energy systems (Mehmood *et al.*, 2022). These efforts are expected to positively influence public perceptions of RE, fostering greater support for the government's efforts to transition towards renewable energy.

3.2.4.2 Training and capacity building. The successful development, construction, operation and maintenance of renewable energy projects require a wide range of specialised skills. However, a shortage of skilled labour at various professional levels has been identified as a significant barrier to RE development (Bouraima *et al.*, 2024). To address this challenge, vocational education and training should be integrated into university and college curricula to provide foundational and technical knowledge about renewable energy (Mahmud and Roy, 2021; Solangi *et al.*, 2021). In addition, capacity-building programs should be implemented to train employees at all levels of the workforce. These training initiatives will

Table 2. Frequency ranking of proposed strategies

Code	Solutions	Frequency	Reference
S1	Development of direct, clear, enabling and integrating policies	25	Alyamani *et al.* (2024); Dokyi and Sharifi (2024); Kamdar and Liu (2025); Mohseni and Brent (2025); Oryani *et al.* (2021); Shahzad *et al.* (2023); Solangi *et al.* (2025); Soltani and Imani (2024)
S2	Financial incentives and subsidies	24	Akpahou *et al.* (2024); Alyamani *et al.* (2024); Dai and Solangi (2023); Mahmud and Roy (2021); Mostafaeipour *et al.* (2021); Pathak *et al.* (2022); Wu *et al.* (2022)
S3	Training and capacity building	23	Al Asbahi *et al.* (2020); Mekonnen *et al.* (2022); Mostafaeipour *et al.* (2021); Solangi *et al.* (2025); Soltani and Imani (2024)
S4	Public awareness-raising	21	Alyamani *et al.* (2024); Jahangoshai Rezaee *et al.* (2019); Mekonnen *et al.* (2022); Shah *et al.* (2019); Shah and Longsheng (2022); Solangi *et al.* (2025)
S5	Improved funding mechanism	18	Cai *et al.* (2022); Dai and Solangi (2023); Jahangoshai Rezaee *et al.* (2019); Mohseni and Brent (2025); Shah and Longsheng (2022); Soltani and Imani (2024)
S6	Support research and development	17	Alyamani *et al.* (2024); Jahangoshai Rezaee *et al.* (2019); Lalita *et al.* (2025); Oryani *et al.* (2021); Pathak *et al.* (2022); Rocha *et al.* (2023); Thakur *et al.* (2023)
S7	Coordination and cooperation among key institutions	15	Al Asbahi *et al.* (2020); Dokyi and Sharifi (2024); Lalita *et al.* (2025); Shahzad *et al.* (2023); Solangi *et al.* (2025)
S8	Invest in grid infrastructure upgrade	9	Akpahou *et al.* (2024); Alyamani *et al.* (2024); Cai *et al.* (2022); Dokyi and Sharifi (2024); Kamdar and Liu (2025); Lalita *et al.* (2025); Mohseni and Brent (2025); Solangi *et al.* (2025); Soltani and Imani (2024)
S9	Renewable energy targets, quotas and mandate	8	Akpahou *et al.* (2024); Chisale and Lee (2023); Mahmud and Roy (2021); Pandey *et al.* (2025); Shah and Longsheng (2022)
S10	Promoting local production	7	Jahangoshai Rezaee *et al.* (2019); Mahmud and Roy (2021); Mekonnen *et al.* (2022); Oryani *et al.* (2021); Pathak *et al.* (2022); Thakur *et al.* (2023)
S11	Carbon pricing	4	Chisale and Lee (2023); Pandey *et al.* (2025); Shah and Longsheng (2022); Solangi *et al.* (2021)

Source(s): Authors' own work

foster a skilled workforce in the RE sector, strengthen leadership abilities and cultivate expertise in renewable energy (Solangi *et al.*, 2021).

3.2.4.3 Development of direct, clear, enabling and integrating policies. A key barrier to renewable energy development is the lack of comprehensive policies, categorised under the Policy and Regulatory taxonomy. Clear and detailed policies are essential to efficiently facilitate the integration of renewable energy technologies into the energy system (Chisale and Lee, 2023). The development of such policies should involve consultation with relevant stakeholders and institutions to ensure that they are well-informed and effective (Mahmud and Roy, 2021). Finally, these policies must be comprehensive, transparent and supportive of the development and scaling of renewable energy projects (Dai and Solangi, 2023).

3.2.4.4 Improved funding mechanisms. The development and construction of renewable energy projects require substantial capital, which has been identified as a major obstacle to their advancement. To overcome this barrier, funding mechanisms need to be strengthened and financing options expanded to attract investment in these projects. Special loans and dedicated funds should be established specifically for renewable energy initiatives (Jahangoshai Rezaee *et al.*, 2019). Furthermore, these financial resources must be made accessible to small and medium-sized enterprises (SMEs), enabling them to participate in and benefit from renewable energy development (Shah and Longsheng, 2022).

3.2.4.5 Financial incentives and subsidies. To attract investment into renewable energy initiatives, the government must provide various financial incentives, such as grants, taxes and subsidies (Asante *et al.*, 2022; Chisale and Lee, 2023). The proposed subsidies can include capital subsidies and performance-based subsidies (Solangi *et al.*, 2021). Capital subsidies will make RE attractive by reducing the high initial costs associated with development (Shah and Longsheng, 2022). Performance-based subsidies will encourage the expansion and scaling of renewable energy development. All subsidies and grants allocated to conventional energy generation must be eliminated to ensure the price of electricity from these systems accurately reflects their true cost.

3.2.4.6 Renewable energy targets, quotas and mandate. Various countries are increasing their renewable energy targets to shift away from conventional power generation as the primary energy source (Mahmud and Roy, 2021). To align with this global shift, the government and key stakeholders must set and define achievable renewable energy targets and quotas in the national energy plans and policies. In addition, measures must be put in place to monitor progress and ensure that these RE targets are met; therefore, renewable energy is fed into the grid.

3.2.4.7 Support research and development. Research and development (R&D) plays an important role in every stage of renewable energy project development (Chisale and Lee, 2023). Establishing local research institutions dedicated to renewable energy can drive innovation and address region-specific challenges. To support these efforts, governments and funding entities must provide or enhance R&D financing, investment incentives and subsidies, as these are critical to building robust R&D capacity in the renewable energy sector (Pathak *et al.*, 2022). Increased investment in R&D can lead to breakthroughs in technology, improved project efficiency and cost reductions, ultimately accelerating the transition to sustainable energy systems while fostering economic growth.

3.2.4.8 Coordination and cooperation among key institutions. The involvement of relevant public and private institutions at various decision-making stages, i.e. policy formulation, setting RE targets, etc. is vital in fostering collaboration and ensuring effective implementation of these projects (Mahmud and Roy, 2021). Collaboration between different stakeholders and institutions is also important; it facilitates knowledge sharing, capacity building and skill development among the workforce involved in RE projects. This, in turn, accelerates the development and integration of renewable energy into the energy mix, ensuring a more cohesive and efficient transition to sustainable energy systems.

3.2.4.9 Promoting local production. Boosting local manufacturing and after-sales services for renewable energy equipment and components is a vital step towards fostering the renewable energy sector. According to Oryani *et al.* (2021), this can be achieved by imposing import taxes on equipment that can be manufactured or sourced locally. Such a measure encourages domestic production, reduces reliance on imports and strengthens local supply chains. In addition, implementing tax incentives to promote the exportation of locally manufactured renewable energy goods can position the country as a key player in the global renewable energy market. Promoting local production will attract RE investment and accelerate development while contributing positively to the country's economy.

3.2.4.10 Carbon pricing. Implementing a carbon pricing strategy is crucial for encouraging investment in renewable energy generation. According to Shah and

Longsheng (2022), such a strategy would foster competitiveness in the renewable energy sector while simultaneously driving the reduction of carbon emissions from conventional power generation systems. Furthermore, the funds collected through carbon pricing can be reinvested into renewable energy development, primarily through incentives and subsidies, thus accelerating the transition to cleaner energy sources. This approach supports the growth of renewable energy and helps mitigate the environmental impact of traditional energy systems.

3.2.4.11 Enhancing grid investment. In many parts of the world, the current grid infrastructure is designed for conventional thermal energy generation, making it unsuitable for the integration of fluctuating renewable energy sources (Kamdar and Liu, 2025). To address these technical challenges, it is imperative that grid stakeholders invest in advanced, flexible smart grid technologies (Solangi *et al.*, 2025). Such investments are crucial not only for accommodating the intermittently growing share of renewable energy but also for enhancing overall grid capacity and reliability (Alyamani *et al.*, 2024).

3.2.5 Evaluation of proposed strategies. A Pareto analysis was conducted to prioritise solutions for addressing the barriers to the integration of renewable energy. The Pareto chart in Figure 9 highlights the frequency of occurrence of 11 proposed strategies, where S1 to S6 contribute around 75% of the total occurrences, meaning focusing on these strategies would mitigate most of the issues.

Financial incentives and subsidies (S1) is the most frequently occurring strategy, appearing 26 times and accounting for 15% of the strategies. To improve the feasibility and attractiveness of renewable energy projects, the government must provide incentives and subsidies in the form of grants, taxes and other available forms (Lalita *et al.*, 2025). Following closely is the development of clear, inclusive and comprehensive policies (S2) that integrate the perspectives of various stakeholders across the energy sector. These findings align with the study by Soltani and Imani (2024), which highlighted the need to revise governmental policies and improve financial mechanisms to accelerate the adoption of renewable energy.

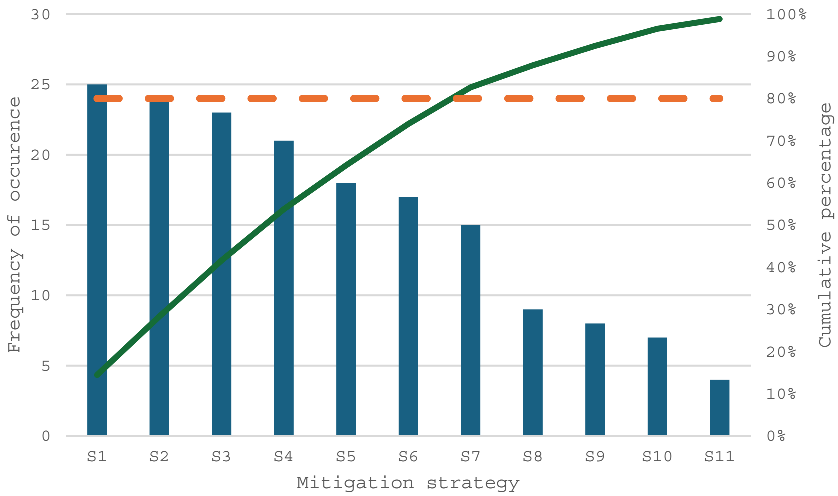


Figure 9. Pareto analysis of mitigation strategies
Source: Authors' own work

The third strategy identified in Figure 9, is public awareness-raising (S3). The significance of the sociocultural factors in the development and acceptance of renewable energy has been accentuated by Vallecha *et al.* (2021) in their evaluation of barriers to developing a sustainable energy community in India. The local community in which renewable energy projects are constructed plays a significant role in the success of these projects. Therefore, instigating awareness programs in the form of public forums, campaigns, conferences and training to educate the communities about the benefits of adopting renewable energy is vital for promoting community awareness and thus gaining support for renewable energy implementation (Alyamani *et al.*, 2024).

The implementation of renewable energy projects requires a diverse set of skills across various hierarchical levels (Shah and Longsheng, 2022). As such, capacity building and training (S4) should involve the development of targeted programs aimed at educating, training and upskilling all stakeholders engaged in the energy transition. This perspective is supported by Solangi *et al.* (2021) who emphasised the critical role of a skilled workforce in the effective planning and execution of renewable energy initiatives.

Renewable energy projects require a substantial amount of capital throughout all phases of the project lifecycle. The expansion of financing options by improving funding mechanisms (S5) for all stakeholders is vital in addressing the financial challenges associated with the implementation of renewable energy (Shah and Longsheng, 2022). Facilitating access to attractive loans will stimulate investment in renewable energy, thereby accelerating the adoption of these projects (Shah *et al.*, 2019).

Although supporting research and development (S6) is ranked lower amongst the vital few strategies, it remains crucial for driving innovation in the renewable energy sector. Strengthening R&D initiatives through increased funding, local and international collaborations and the establishment of dedicated research centres enables countries to develop innovative technologies (Rocha *et al.*, 2023). This, in turn, reduces dependence on foreign technologies and helps lower the capital and operational costs of these projects.

Collectively, these prioritised strategies provide a clear roadmap for overcoming barriers and fostering the successful integration of renewable energy sources into the energy system.

4. Discussion

4.1 Barriers to renewable energy adoption

This study identifies and categorises 39 barriers to renewable energy adoption across 9 taxonomies. Economic/financial and sociocultural barrier taxonomies ranked as the most critical barriers to renewable energy adoption. The development and construction of renewable energy projects require significant capital, and securing this funding remains a major barrier in many developing countries. These findings align with the study by Addae *et al.* (2019) and Asante *et al.* (2022) which emphasised financial constraints as primary impediments to renewable energy adoption.

Limited public awareness and lack of public acceptance are critical sociocultural issues that can slow the adoption of renewable energy technologies. These findings align with the study by Molepo *et al.* (2025) where sociocultural challenges emerged as one of the most critical barriers, highlighting the significance of public interference in hindering the development of these projects, even when technological and economic conditions are feasible.

While economic and sociocultural barriers dominate, policy and technical-related barriers are also experienced at a higher rate. These barriers suggest that, in addition to financial investments, efforts must also focus on skills development, research and technical expertise to facilitate the successful adoption of renewable energy. In addition, the absence of coherent renewable energy policies and complex bureaucratic processes impedes the efficient implementation of renewable energy projects (Kamdar and Liu, 2025). Addressing these barriers requires a multifaceted approach that combines financial, technical, social and policy-based interventions to drive the transition towards sustainable energy systems.

It is evident from this analysis that there is no single barrier to the adoption of renewable energy. The implementation and integration of these projects are faced with multidimensional barriers, coexisting with one another (Mercer *et al.*, 2017). Presented in Figure 10, is the conceptual framework depicting the interrelationship between renewable energy barrier taxonomies.

This study makes several novel contributions to the global literature on renewable energy barriers. Firstly, it presents a more detailed list of barriers, categorised into distinct barrier taxonomies, developed through a comprehensive review that captures the complexity and multidimensionality of renewable energy challenges. Secondly, the study examines the relationships between barriers, both within the same taxonomy and across different taxonomies, highlighting interdependencies that have been previously overlooked in detail.

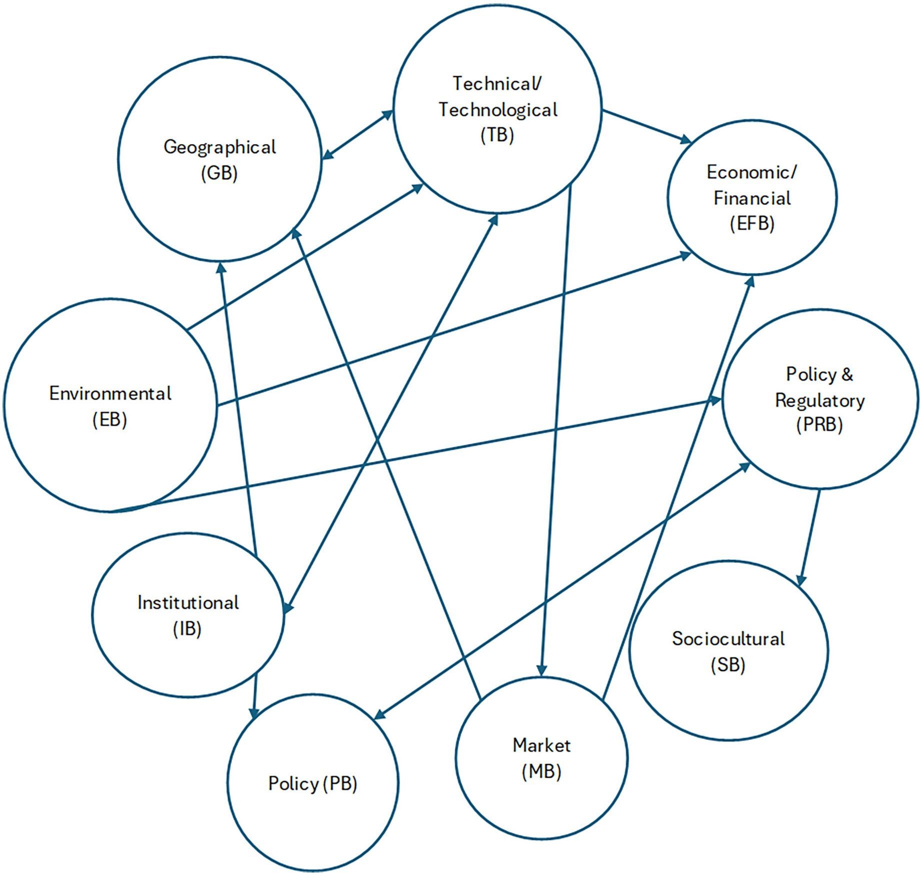


Figure 10. Framework for the interrelationship between barrier taxonomies
Source: Authors' own work

An example of this can be seen in the sociocultural category, where a lack of awareness about renewable energy projects and their benefits leads to low public interest, often resulting in community rejection of such projects. Similarly, in the policy category, the absence of comprehensive policies contributes to weak regulatory frameworks, inefficient bureaucratic permitting processes and a lack of transparency in decision-making.

The interrelationship across multiple barrier categories is evident where the lack of local infrastructure, inadequate technology and limited maintenance and service facilities necessitate the importation of renewable energy components. This reliance on imports places a strain on an already underdeveloped supply chain and transportation system, ultimately increasing the capital cost of projects. Furthermore, the lack of coordination between key institutions, training centres and research and development (R&D) facilities contributes to a shortage of skilled labour. This shortage directly affects the formulation of policies, standards and codes, which are essential for advancing renewable energy.

Thirdly, the study incorporates a mean citation frequency analysis to rank barrier taxonomies from a global perspective, rather than limiting the focus to a single country or region. This makes the results more useful for comparing different contexts and for helping both researchers and policymakers better understand where to focus their efforts.

4.2 Mitigation strategies to promote renewable energy adoption

The study identified eleven mitigation strategies to address the barriers, with the development of clear, enabling and integrated policies emerging as the most frequently recommended solution. Establishing comprehensive policy frameworks can provide regulatory certainty and encourage private sector participation in renewable energy projects. These finding echoes (Solangi *et al.*, 2021) who highlight the importance of robust policy mechanisms for fostering renewable energy growth.

The second most imperative strategy is the provision of financial incentives and subsidies. These incentives play a vital role in attracting investment, lowering costs and enhancing the financial viability of renewable energy projects. The importance of financial support is also emphasised by Dai and Solangi (2023) who advocate for a range of financial mechanisms to accelerate the adoption of renewable energy.

Other notable strategies include public awareness campaigns, capacity-building programs and improved funding mechanisms. Raising public awareness is crucial for enhancing energy literacy and fostering societal support and acceptance. Meanwhile, capacity-building programs address skill gaps and improve workforce readiness, ultimately creating a competent workforce for renewable energy projects. These strategies align with the recommendations of Mahmud and Roy (2021), who argue that public engagement and technical training are essential to overcoming social and technical barriers.

5. Conclusions and recommendations

This study investigated the barriers hindering the global development and integration of renewable energy, particularly solar and wind sources. A systematic literature review methodology was used to search, retrieve and analyse articles from the Scopus database. The findings revealed a growing interest in research aimed at addressing barriers to renewable energy between 2018 and 2022. Thirty-nine distinct barriers were identified and categorised into nine taxonomies as follows: economic/financial, technical/technological, sociocultural, political, institutional, policy and regulatory, market, environmental and geographical. The study employed mean citation frequency analysis to rank the barrier categories and Pareto analysis to prioritise the identified barriers and their corresponding mitigation strategies. According to the mean citation frequency analysis, the most significant barrier taxonomies to the adoption of renewable energy are economic/financial, sociocultural, policy and regulatory and technical/technological, highlighting their substantial impact on hindering renewable energy development. These barriers underscore the multifaceted challenges that must be addressed to ensure the successful global integration of renewable energy sources. In addition, the study analysed and prioritised the proposed solutions to address these barriers. The top key strategies include the development of clear and direct policies, provision of financial support (including incentives, subsidies and tax grants) and implementation of public awareness and training programs. Prioritising this strategy is essential to ensuring maximum impact in overcoming financial and technological barriers.

However, despite the comprehensiveness of the study, certain limitations must be acknowledged. Firstly, the barrier taxonomies were ranked based on frequency mean citation, which overlooks less frequent but highly impactful factors. Secondly, Pareto analysis does not account for the interdependencies between barriers, which limit the depth of analysis. Given the multidisciplinary nature of renewable energy barriers, the following recommendations are proposed: a theoretical framework for barrier identification must be developed to ensure a holistic and structured approach; secondly, a qualitative study should be conducted with renewable energy experts to gain a deeper understanding of the barriers and their interrelationships. Thirdly, prioritisation of the barriers and solutions must be conducted utilising a multi-criteria decision-making technique to ensure a more comprehensive and holistic approach to decision-making. Fourthly, the impact of these barriers varies from one country to another, depending on that country's political, geographical, social and economic conditions. Therefore, an in-depth analysis must be conducted, focusing on each individual country. Ultimately, it is crucial to identify and categorise the proposed mitigation strategies for each barrier within a well-defined taxonomy. This approach will ensure that every barrier is individually addressed, allowing for effective and targeted solutions.

The study concludes by offering the following theoretical and practical implications:

Theoretically, the study enhances the existing body of knowledge on renewable energy adoption barriers by providing a framework for categorising, ranking and prioritising these barriers, utilising mean citation frequency and Pareto analysis. By systematically identifying the most critical challenges and assessing their relative importance, this research deepens the contribution by providing a structured approach for future research. The categorisation of barriers into nine taxonomies provides a structured approach to assess and prioritise the barriers, allowing for the adoption of suitable mitigation strategies to address each one of them. This framework not only enriches the existing literature but also paves the way for more nuanced theoretical models that incorporate multidimensional barrier analysis.

Practically, the study provides a strategic framework to enable policymakers, researchers, decision-makers and relevant stakeholders to develop and implement more effective policies and frameworks to target the critical strategies. The prioritisation of renewable energy adoption barriers and mitigation strategies allows stakeholders to efficiently allocate resources to address the challenges. This targeted approach supports evidence-based decision-making, fostering accelerated progress towards sustainable energy transitions.

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