Renewable and Sustainable Energy Reviews xxx (xxxx) 116679

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The role of renewable energy in achieving the Sustainable Development Goals: A systematic review and conceptual framework

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ARTICLE INFO

Keywords:
Renewable energy
Sustainable development goals
Climate action
Energy transition
Social acceptance
Energy policy

ABSTRACT

This systematic review examines the critical role of renewable energy in advancing the United Nations Sustainable Development Goals (SDGs). Despite the growing interest in the nexus between renewable energy and sustainable development, comprehensive analyses remain limited. To address this gap, the present study analyzes peer-reviewed articles to assess the scope, depth, and pathways through which renewable energy contributes to the SDGs. The 17 goals are categorized into three relevant tiers: direct, indirect, and broader development linkages; based on their level of relevance to renewable energy. The findings highlight the central role of renewable energy in ensuring access to affordable, reliable, and modern energy (SDG 7), while also facilitating progress in climate action (SDG 13), economic development (SDG 8), public health (SDG 3), urban sustainability (SDG 11), and social equity (SDG 10). Renewable energy offers a sustainable alternative to fossil fuels, reducing greenhouse gas (GHG) emissions, and improving access to clean energy, especially in underserved and off-grid areas. However, its widespread deployment is hindered by high capital costs, technological challenges, regulatory fragmentation, and social acceptance barriers. The review emphasizes the need for integrative policy frameworks, inclusive governance, technological innovation, and multi-stakeholder partnerships to effectively integrate renewable energy with broader sustainable development strategies.

1. Introduction

The adoption of the 2030 Agenda for Sustainable Development by the United Nations in 2015 marked a global commitment to eradicating poverty, reducing inequalities, improving access to essential services, and safeguarding the planet [1]. Central to this Agenda are 17 interlined and mutually reinforcing Sustainable Development Goals (SDGs) and their associated targets, which aim to address the interconnected dimensions of human well-being, economic growth, and environmental protection [2]. Achieving these ambitious goals requires integrated and cross-sectoral strategies that reflect the complex interplay among social, economic, and environmental systems [3,4].

Renewable energy has emerged as a critical enabler of sustainable development, which has attracted increasing attention as the world grapples with intensifying challenges of climate change, energy poverty, and rapid urbanization [5,6]. Renewable energy technologies such as solar, wind, hydro power, and bioenergy are crucial for decarbonizing energy systems and reducing global dependence on fossil fuels, thereby addressing the world's most pressing sustainability issues outlined in the SDGs. These technologies are instrumental for achieving SDG 7 (universal access to affordable, reliable, sustainable, and modern energy), as well as advancing SDG 13 (combating climate change and its impacts), and SDG 11 (inclusive, secure, resilient, and sustainable cities and human settlements). This interdependence has sparked growing academic interest in understanding the multifaceted contributions of renewable energy to sustainable development [7–10].

Recent studies have explored the potential role of renewable energy in improving energy security, particularly in regions lacking access to conventional energy sources. By harnessing local renewable resources, countries can reduce fossil fuels dependency, enhance energy resilience, and support environmental sustainability [11,12]. As global urbanization intensifies, renewable energy integration helps in lowering carbon footprints of cities, enhancing energy efficiency, supporting sustainable infrastructure, and improving human quality of life [13,14]. Renewable energy technologies also decrease energy cost and improve environmental quality, while generating green jobs and stimu-

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https://doi.org/10.1016/j.rser.2025.116679
Received 23 July 2025; Received in revised form 10 December 2025; Accepted 26 December 2025
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lating local economies [15,16]. Furthermore, the transition to renewable energy plays a vital role in reducing GHG emissions, in line with the target of the Paris Agreement to limit global warming to below 1.5 °C [17].

However, several studies raise concerns about many persistent challenges to large-scale deployment of renewable energy and its contribution to sustainable development. These include high upfront investment costs, technological limitations, weak policy and regulatory environments, and limited public awareness and social acceptability [14,15,18]. The intermittent nature of wind and solar energy undermines grid stability and energy reliability [19]. Moreover, infrastructure deficits and financial constraints in low-income regions further complicate energy transitions. Addressing these challenges necessitates robust policy frameworks, targeted financial mechanisms, community engagement, and inclusive governance models [20].

Nevertheless, there remains a significant gap in understanding how renewable energy technologies advance the SDGs. While substantial research has examined the direct contributions of renewable energy to SDGs 7 and 13, there is a lack of holistic analysis exploring its broader and more indirect influences on the full spectrum of SDGs. Much of the existing literature remains fragmented, focusing on individual goals or localized case studies, and lacks integrated perspectives that cut across thematic, regional, and disciplinary boundaries [6–9,12]. Several recent studies highlight the implications of not achieving the SDGs and calls for expanded inquiry into the role of renewable energy [21,22], digital technologies [23], and circular economy practices [24] in enhancing environmental performance and advancing sustainability targets of the SDGs. This fragmented coverage suggests a need for a more comprehensive and integrated analysis of how renewable energy promotes the realization of all 17 SDGs.

The study addresses this gap by conducting a systematic review of peer-reviewed literature to assess, map, and synthesize the multidimensional pathways through which renewable energy contributes to the full spectrum of SDGs. The specific objectives are fourfold: (1) To synthesize how renewable energy technologies contribute to the SDGs, and classify the goals based on their degree of relevance; (2) to examine regional and thematic patterns in the current literature on renewable energy contributions to the SDGs; (3) to identify key barriers and enabling conditions affecting renewable energy deployment in pursuit of the SDGs; and (4) to offer actionable, research-based policy recommendations for harnessing the potential of renewable energy in achieving the SDGs. This review is justified by the fragmented nature of previous studies, their lack of integration of environmental, economic, and social perspectives, and little focus on the barriers and enabling factors affecting the deployment of renewable energy in support of the SDGs.

By adopting a holistic perspective and using thematic analyses, this review contributes to closing a critical knowledge gap. Unlike previous studies that often focus on individual goals or case-specific evidence, this paper offers a holistic perspective to map interlinkages across multiple SDGs. It moves beyond narrowly focused studies by synthesizing technological, environmental, and socio-economic impacts of renewable energy adoption within the SDG framework. It adds to the growing body of literature at the intersection of renewable energy and sustainable development by providing a systematic and integrative analysis of how renewable energy technologies influence, and are influenced by, the SDGs, and offers actionable recommendations for policymakers, practitioners, and researchers seeking to align renewable energy programs with broader sustainable development agenda.

This study contributes to the developing field of sustainability science by providing comprehensive, systematic analysis and synthesis of how renewable energy contributes to SDGs, moving beyond the commonly studied direct linkages to exploring indirect and supportive relationships. This novel classification framework enables scholars to examine the integrated impacts of energy systems on development goals from interdisciplinary perspectives, including environmental science, energy policy, urban planning, economics, and social equity. Additionally, the paper identifies key research gaps such as regional disparities, technological limitations, and governance challenges to renewable energy deployment and proposes more nuanced, context-sensitive, policy recommendations. In doing so, it serves as a valuable resource for researchers, policymakers, and development practitioners aiming to leverage renewable energy in achieving sustainable development.

This study makes threefold contributions to knowledge, policy, and practice. From a knowledge perspective, it advances scholarly understanding by systematically mapping the interlinkages between renewable energy and the SDGs using thematic analyses. These insights provide an evidence-based foundation for future interdisciplinary research on clean energy transitions. From a policy standpoint, the study offers targeted recommendations to guide governments and regulatory institutions in designing inclusive, long-term frameworks that support renewable energy investment, infrastructure, and social acceptance. In terms of practice, the findings guide energy planners, development practitioners, and urban stakeholders on implementing actionable strategies for scaling renewable energy deployment, enhancing public trust, and integrating clean energy into broader development planning. Together, these contributions help bridge the gap between research and real-world implementation, supporting a more equitable and effective global energy transition.

2. Methodology

To systematically explore the relationships between renewable energy and the SDGs, this review adopted a structured and transparent methodological approach grounded in PRISMA guidelines [25]. The review adhered to these guidelines to ensure a comprehensive, reproducible, and unbiased synthesis of literature, while enhancing the validity and reliability of the findings. Scopus and Web of Science were selected as the principal databases for this review because of their extensive and multidisciplinary coverage of peer-reviewed literature, while Google Scholar was used for conducting preliminary searches, providing grey literature and other supporting contextual and background literature. Scopus and Web of Science indexed journal articles, and reviews across fields such as social sciences, economics, energy studies, and environmental sciences. [26]. The search framework was set in such a way that it would identify studies that investigate the interaction of renewable energy and the SDGs on broad themes within these disciplines. The search was limited to English-language journal articles and review papers published between 2015 and 2025 to ensure a focus on contemporary and policy-relevant research. The temporal scope of the review was limited to the period 2015–2025. This timeframe was selected because 2015 marks the official adoption of the 2030 Agenda for Sustainable Development by the United Nations, including the establishment of the SDGs. The year 2025 represents the mid-to-late implementation phase of this agenda, providing a meaningful ten-year window to assess how renewable energy has been linked to the SDGs during the first decade of their execution. This timeframe ensures that the reviewed studies are aligned with the global policy context and contemporary discourse on sustainable development. The following search queries were used.

2.1. Scopus

TITLE-ABS-KEY (("renewable energy" OR "green energy" OR "clean energy" OR "sustainable energy") AND ("SDGs" OR "sustainable development Goals") AND ("economic" OR "social" OR "environmental" OR "pathways" OR "integration" OR "challenges" OR "barriers" OR "policy recommendations")) AND (LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))

2.2. Web of Science

TS = (("Renewable energy" OR "Clean energy" OR "Green energy" OR "Sustainable energy") AND ("Sustainable Development Goals" OR "SDGs") AND ("Economic" OR "Social" OR "Environmental" OR "Pathways" OR "Integration" OR "Challenges" OR "Barriers" OR "Policy Recommendations")) AND LA = (English) AND (DT = Article OR DT = Review)

This search queries were designed to ensure that the retrieved articles are at the intersection between renewable energy and sustainable development. The keywords were carefully selected to reflect the various dimensions of the interactions between SDGs and renewable energy, including economic, environmental, and social dimensions [27,28]. Strict inclusion and exclusion criteria were used to guarantee that the studies included in the review were high-quality, wide-coverage, and pertinent. First, to ensure that the chosen studies fulfilled the highest academic standards, peer-reviewed original and review papers were included [28]. Second, only articles published in English were included, to make them consistent and convenient to extract data. In addition, this review included grey literature such as government reports, policy papers, theses, and dissertations, where relevant and credible, sourced from Google Scholar and websites of international development agencies and organizations. Exclusion criteria ensured that non-English publications, studies conducted outside of the 2015–2025 timeframe or that did not directly examine the association between SDGs and renewable energy were excluded. These inclusion and exclusion criteria are summarized in Table 1.

Table 1

Table 1. Inclusion and exclusion criteria for the systematic review

Category	Inclusion Criteria	Exclusion Criteria
Publication year	Studies published between 2015 and 2025	Studies published before 2015 or after 2025
Language	Articles written in English	Articles in languages other than English
Study type	Peer-reviewed articles, review papers, and credible grey literature (such as government reports, policy briefs, theses, and dissertations).	Non-reviewed sources such as blogs, informal websites, newspaper articles, or opinion pieces
Content focus	Articles that explicitly examine the relationship between renewable energy and one or more SDGs	Articles that do not directly address the link between renewable energy and the SDGs (e.g., generic energy studies or SDG studies unrelated to energy).
Database coverage	Indexed in Scopus or Web of Science	Studies not indexed in Scopus or WoS, unless included as credible grey literature
Geographic scope	Global; no regional limitations	–

The search initially yielded 6,654 studies. After removing duplicates, the remaining articles were screened by title, abstract, and keywords for relevance. Full texts of potentially relevant studies were reviewed against the inclusion criteria. A total of 57 studies that survived the eligibility process were ultimately included in the final synthesis. Fig. 1 presents the PRISMA flow diagram illustrating the entire study selection process, ensuring transparency and easy replication.

As shown in Fig. 1, a total of 6,654 records were initially identified from Scopus (n = 3,619) and Web of Science (n = 3,035). After removing duplicates (n = 4,368), 2,286 unique records remained for abstract screening. Of these, 1,380 records (60.4 %) were excluded based on the inclusion and exclusion criteria applied to abstracts, leaving 906 articles for full-text retrieval. Fourteen articles (1.5 %) could not be retrieved, and 835 full texts (93.6 %) were excluded after full-text assessment. Ultimately, 57 studies were included in the final review. This out-

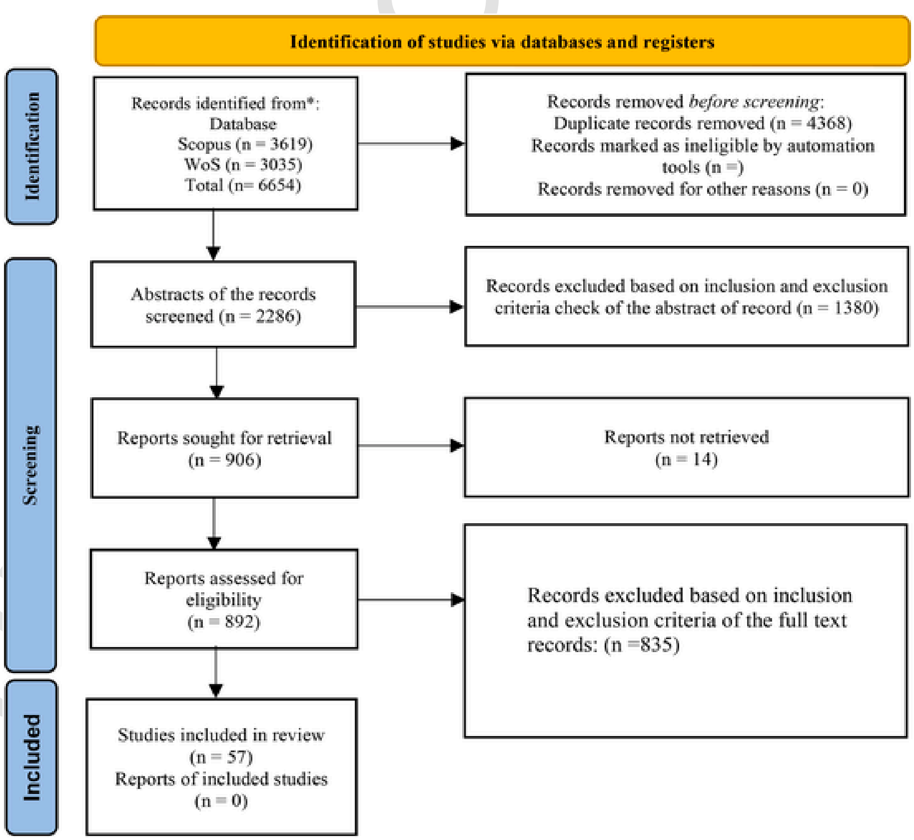


Fig. 1. PRISMA flow diagram.

come reflects the application of strict inclusion criteria focused on studies that directly address the relationship between renewable energy and the SDGs during the 2015–2025 period.

A deductive content analysis method was employed to extract and organize data systematically, using pre-established categories derived from the objectives of the present study, as suggested in the literature [29,30]. The categories were drawn from the literature review guideline, more specifically the nexus between renewable energy and the SDGs. Through the application of this deductive approach, the analysis ensured consistency in the types of data that were extracted, allowing direct comparison across studies. A standardized data extraction form was used to obtain the following information from each study: author (s), year of publication, study design, SDGs addressed, and important findings, as adopted in prior similar studies [31,32]. Studies were also categorized by methodology, including systematic reviews, econometric analysis, case studies, and modeling, allowing for thematic comparisons across approaches and drawing insights on how each study contributes to the knowledge regarding the impact of renewable energy on the SDGs. Data were managed and coded using MS Excel, and themes such as economic impacts, barriers to adoption, policy recommendations, and integration pathways were identified. Thematic coding facilitated the systematic synthesis of the results, which acted to highlight commonalities, trends, and lacunas among the studies [33–35]. Synthesis in this study was primarily grounded on a thorough content screening of the selected literature for the determination of key findings [36]. This was performed following a clearly defined protocol, as described in this section, for ensuring methodological soundness.

Several limitations were encountered during this review process. One of the potential limitations was publication bias, wherein only positive or significant findings were published and therefore may distort the results [37]. Another limitation was the language limit, whereby only English-language articles were included, potentially excluding valuable research published in other languages. Besides, problems were encountered with the extraction of data, particularly for studies with data in formats difficult to synthesize or compare. These were dealt with by having as standardized as possible the extraction of data and excluding studies without sufficient data to synthesize. Notwithstanding these drawbacks, this systematic review offers a reliable, transparent, rigorous, and thorough summary of the literature on how renewable energy contributes to the SDGs, as well as setting a solid foundation for future research and policymaking.

3. Results and analysis

This section provides a comprehensive synthesis of existing literature, identifying prevailing trends, dominant research themes, and gaps in knowledge. This contextual groundwork informs an in-depth analysis of studies on the interconnections between renewable energy and the SDGs. The reviewed studies utilize a wide range of methodologies, including econometric analysis, case studies, and bibliometric analyses, with a focus on different regions such as the G20, ASEAN, BRICS, and Sub-Saharan Africa. The key findings emphasize the key role of renewable energy in achieving SDGs, particularly SDGs 7 (Affordable and Clean Energy), 13 (Climate Action), and 8 (Decent Work and Economic Growth). Several studies also explore the challenges and opportunities in the adoption of renewable energy technologies, examining economic, environmental, and social impacts. Furthermore, these studies propose policy recommendations for enhancing energy sustainability (see Table 2).

Figs. 2 and 3 illustrate the temporal and geographical trends in scholarly research on renewable energy and its contribution to the SDGs. As shown in Fig. 2, research on renewable energy and the SDGs has grown substantially over the past decade. From a relatively modest output of less than five papers per annum between 2017 and 2020, the number of publications has risen steadily from 2021 onward, peaking in 2024 and 2025, with 16 and 15 articles, respectively. This increase suggests a significant surge in academic and policy interest in renewable energy's contribution to sustainable development, likely driven by global sustainability agendas, technological innovation, and international climate commitments.

As shown in Fig. 3, research activity related to renewable energy and the SDGs is geographically concentrated in specific regions. China, India, and several European countries (including Germany, the United Kingdom, and Italy) demonstrate the highest publication frequencies, highlighting their strong engagement in sustainable energy research. Significant contributions also emerge from the United States, Australia, and parts of the Middle East, reflecting growing global collaboration in sustainability-oriented studies. In contrast, many regions in Africa and South America exhibit limited representation, suggesting disparities in research capacity, funding, and data availability across developing economies. As a result, these trends offer a comprehensive view of the field's evolution both temporally and geographically, highlighting key centers of research activities and shifting global interests.

As shown in Fig. 4, the coverage of SDGs among the reviewed publications is highly uneven. The goals most frequently addressed are SDG 7 and SDG 13, which appear in 57 and 47 studies respectively, reflecting a strong research emphasis on energy transition and climate mitigation. Moderate attention was given to SDG 9, SDG 8, and SDG 12, while the remaining goals were less represented, often appearing in only two or three studies. This distribution suggests that the research landscape is primarily concentrated on environmental and technological sustainability dimensions, with comparatively limited focus on social equity and institutional development aspects (e.g., SDGs 1, 2, 5, 10, and 16). The findings highlight both the dominant themes within current sustainability research and the underexplored areas that require further scholarly attention.

Finally, based on the systematic review and thematic synthesis of the selected studies, we identified four key thematic domains that frequently emerge in literature linking renewable energy and the SDGs. These domains form the basis for categorizing the 17 SDGs into three levels of relevance: direct, indirect, and broader development support. The first domain centers on policy and planning for sustainable development. This cluster aligns directly with SDG 7 (all five targets) and SDG 9 (9.1, 9.2, 9.4, 9.5, and 9.a) and supports SDG 8 (8.2, 8.3, 8.4, 8.5, and 8.9) and SDG 11 (11.1, 11.2, 11.6, and 11.b) through its indirect influence. The second domain focuses on clean energy technologies and transitions, underscoring innovation and system-wide decarbonization. It directly supports SDGs 7, SDG12 (12.2, 12.5, 12.a, and 12.c), and SDG 13 (all five targets), while indirectly contributing to education and sustainable city initiatives. The third domain highlights environmental impact and climate policy efforts, reinforcing links to SDG 13 and extending to SDGs 3 (3.8, 3.9, and 3.d), SDG 6 (6.1, 6.2, 6.3, 6.4, 6.a, and 6.b), SDG 14 (14.1, 14.2, 14.a, and 14.c), and SDG 15 (15.1, 15.2, 15.3, 15.5, 15.a, and 1.b) through its emphasis on ecosystem protection and environmental equity. Lastly, the fourth domain examines energy consumption and utilization, reflecting the operational dimensions of renewable energy deployment. This cluster is directly related to SDGs 7 and 9, with additional links to SDG 2 and broader efforts toward inclusive economic growth. Collectively, these domains demonstrate the interconnectedness of renewable energy research with the SDG framework. The visual network not only reveals overlapping priorities but also validates the study's proposed classification of SDGs into direct relevance (SDGs 7, 9, 12, 13), indirect relevance (SDGs 3, 4, 6, 8, 11, 14, 15), and broader development support (SDGs 1, 2, 5, 10, 16, 17). Additionally, the recurring thematic intersections observed across the reviewed studies underscore the deeply interconnected nature of renewable energy and sustainable development. These insights strengthen the analytical framework of this review and provide a more comprehensive understanding of the multifaceted contributions of renewable energy to global sustainability goals.

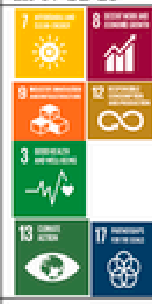
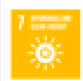
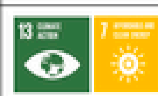
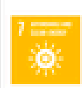
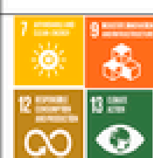
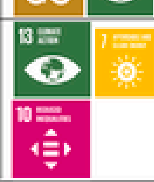
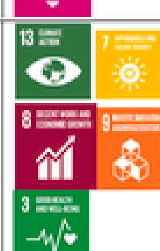
Table 2
Summary of the studies included in the review.

Author(s)	Journal Name	Methodology	Region	SDGs Addressed	Key Findings
[16]	Environmental Impact Assessment Review	Econometric Analysis	OECD Countries	7, 13	Explores the role of energy transition, green technovation and eco-policy stringency for mitigating CO_2 emissions, focusing on policy frameworks for SDGs.
[87]	Renewable and Sustainable Energy Reviews	Econometric Analysis	Global	7, 13	Analyzes the efficacy of green innovations and clean energy adoption across 42 countries, highlighting their impact on SDG 7 and 13.
[88]	Energy & Environment	Empirical Analysis	ASEAN Countries	4, 7, 13	Investigates how education and renewable energy affect CO_2 emissions in ASEAN nations, showing that using renewable energy lowers CO_2 emissions by 0.46%.
[13]	Sustainability	Quantitative Analysis	EU	7, 11	Evaluates the connection between sustainable energy and urban development in EU nations, illustrating the evolution of the relationship between SDGs 7 and 11.
[89]	Environmental Research Letters	Case Study	Global	7, 13	Focuses on policy implementation and energy transition strategies to meet renewable energy goals, emphasizing renewable energy's role in reducing GHG emissions.
[14]	Energy Strategy Reviews	Bibliometric Analysis	Global	7, 8, 9, 11, 12	Analyzes the contribution of Concentrated Solar Power to SDG 7, highlighting its role in sustainable energy and its links to economic and social SDGs.

[11]	Energy Research & Social Science	Qualitative Case Study	Global	7, 13	Develops a framework for assessing energy projects' impact on SDGs using case studies of GERD and Hinkley Point C Nuclear Power Station.
[90]	Frontiers in Energy Research	Econometric Analysis	Asia	7, 13	Examines the outcome of renewable energy on economic expansion and recommends green power and economic reform measures to lower CO_2 levels.
[12]	Renewable Energy	Econometric Analysis	G7 Countries	7, 12, 13	Analyzes renewable energy's role in reducing CO_2 emissions in the G7, highlighting the effect of research and development costs, globalization, and energy intensity.
[9]	Renewable and Sustainable Energy Reviews	Case Study	Sub-Saharan Africa	7, 13	Investigates how Power Africa and the SE4All initiative can create synergies for achieving SDG 7 in sub-Saharan Africa.
[91]	Resources, Conservation & Recycling	Life Cycle Sustainability Assessment	Global	7, 13	Examines renewable energy production systems using life cycle sustainability assessments to achieve SDG 7.
[7]	Applied Energy	SWOT-AHP Hybrid Analysis	Global	7, 13	Analyzes energy sustainability in the post-COVID-19 world, focusing on the renewable energy transition and SDG 7.
[92]	Technological Forecasting & Social Change	Panel Data Analysis	Eurozone	7, 13	Examines the role of renewable energy on economic growth, concentrating on energy sources and SDG 7.
[93]	Sustainable Development	Econometric Analysis	Global	7, 8, 13	Investigates how energy, economic expansion, and environmental quality relate to one another and how they help achieve SDGs 7, 8, and 13.
[5]	Sustainable Development	Causal Analysis	BRICS Nations	7, 13, 8	Examines the causal relationships between the BRICS countries' usage of renewable energy, financial development, environmental sustainability, and economic progress.
[94]	Sustainable Development	Econometric Analysis	Sub-Saharan Africa	7, 9, 13	Examines how renewable energy and good governance might help reduce energy poverty in Sub-Saharan Africa.
[95]	Renewable and Sustainable Energy Reviews	Agent-based Modeling	Developing Countries	7, 13	Focuses on the energy-related behaviors of household occupants in developing countries and their role in achieving SDG 7 and SDG 13.
[96]	Renewable Energy	Social Network Analysis	Belt and Road Countries	7, 8, 13	Investigates the impact of renewable energy product trade on SDG achievement across Belt and Road countries, highlighting trade patterns' effect on energy access.
[8]	Applied Energy	Econometric Analysis	Global	7, 13	Assesses the renewable energy footprint of nations and how countries can achieve SDG 7 by 2030 through energy consumption and policy.
[97]	Sustainability	Systemic Analysis	Regional and City Levels	7, 13	Analyzes the need for harmonized indicators to track SDG and sustainable energy progress at the regional and city level, facilitating more effective monitoring.
[98]	Sustainable Energy Technologies and Assessments	Case Study	Global	7, 13	Investigates challenges in achieving SDG 7 with emerging technologies and cross-border electricity trade for sustainable energy access.

[99]	Renewable Energy	Nonparametric Regression	Global	7, 13	Analyzes the role of cross-border electricity trade in promoting renewable energy, addressing intermittency and reliability issues.
[100]	Sustainable Development	Policy Analysis	Emerging Countries	7, 13	Analyzes the role of energy, environment, and economy-related policies in achieving SDG 13, with a focus on emerging economies and their environmental policies.
[101]	Renewable and Sustainable Energy Reviews	Portfolio Selection	Mexico	7, 9	Assesses the renewable energy portfolio for Industry 5.0 in Mexico, focusing on hydrogen, wind, and solar energy solutions.
[102]	Sustainable Energy Technologies and Assessments	Clustering Approach	G11 Countries	7	Uses clustering analysis to assess energy market progress toward SDG 7 across G11 countries, highlighting disparities in energy access and sustainability.
[103]	Environmental Research Letters	Systematic Review	Global	7, 13	Reviews energy-related interactions between SDGs, emphasizing positive and negative synergies in achieving SDG 7 and 13.
[104]	Renewable Energy	Empirical Analysis	G11 Countries	7, 13	Examines how education, renewable energy, and other elements affect CO2 emissions and SDG 7 in G11 nations.
[6]	Renewable and Sustainable Energy Reviews	Case Study	Africa, Asia, Latin America	7, 13	Reviews the impact of energy access projects in the Global South, highlighting SDG 7 contributions and challenges in rural-urban energy disparity.
[105]	Energy Research & Social Science	Systematic Literature Review	Africa	7, 13	Examines renewable energy business models in Africa, assessing their social, economic, and environmental value for energy access.
[106]	Energy Strategy Reviews	Systematic Review	Global	7, 13	Comprehensive review of SDG progress, emphasizing energy and environmental perspectives and assessing the role of energy in achieving SDGs.
[107]	Renewable and Sustainable Energy Reviews	Review and analysis of SDG progress	South Asia	6, 11, 13, 7, 14, 15	Identifies challenges and progress towards SDGs in South Asia, especially energy access.
[108]	Renewable Energy	Empirical analysis	BRICS countries	7, 9, 13	Human capital, hydropower, and ICT contribute to SDGs, while solar and wind energy have limited impact. Emphasizes investment in ICT and human capital for better SDG outcomes.
[109]	Energy for Sustainable Development	Long-range Energy Alternatives Planning modeling approach	Pacific Island Countries	7, 8, 9	This paper examines how nationally determined Contributions of Pacific Island Countries align with SDGs, with emphasis on synergies and trade-offs in mitigation and adaptation strategies. Identifies gaps and provides policy recommendations for achieving SDGs.
[3]	Sustainable Energy Technologies and Assessments	mixed scientometric and topic modeling approach	Global	7, 9, 12, 13	Sustainable Energy Technologies and Assessments research focuses on renewable energy, energy efficiency, and technological advancements that support SDGs 7, 13, 12, and 9. Highlights the importance of interdisciplinary collaboration and policy adaptation.
[4]	Sustainable Development	System dynamics modeling for SDG progress	Global (focus on energy)	7, 13	Models progress toward SDGs 7 and 13 under various energy transition scenarios.

[110]	Energy for Sustainable Development	Policy analysis and review	Indonesia	7	Assesses Indonesia's energy policy effectiveness for SDG 7, highlighting access challenges.
[111]	Energy & Environment	Econometric modeling	Europe (multiple nations)	7, 12, 13	Analyzes green energy's impact on ecological footprints and economic factors in Europe.
[112]	Renewable and Sustainable Energy Reviews	Policy analysis and financial modeling	Africa	7, 13	Discusses renewable energy financing challenges in Africa for SDG 7 and climate action.
[113]	Renewable and Sustainable Energy Reviews	Fuzzy-based multi-criteria decision-making	China	7, 13	Evaluates financial strategies for renewable energy in China for SDG 7 and 13.
[114]	Sustainability	Critical review and literature analysis	Lithuania	7, 9, 13	Examines how Lithuania's energy policy relates to SDGs 7 and 13.
[115]	World development	Econometric Analysis	Southeast Asia	7, 13	Analyzes the role of government policies in achieving SDG 7 in Southeast Asia, focusing on renewable energy adoption and challenges.
[15]	Sustainable Development	LDA topic modeling and bibliometric analysis	Global	7, 13	Investigates the connection between renewable energy and SDGs, revealing themes like policy uncertainty, ecological footprint, and environmental Kuznets curve. Emphasizes the need for interdisciplinary collaboration to promote sustainable development.
[116]	Energy Strategy Reviews	Panel data econometric analysis	Asian countries	7	Renewable energy usage significantly contributes to economic success in Asian countries. Recommends fiscal policies to enhance the use of renewable energy.
[117]	Renewable Energy	Empirical quantitative approach	China	7	With an importance on the detrimental effects of short-term loans and the significance of digital finance and transparency, the financial investment choices of renewable energy companies impede their sustainable development.
[118]	Frontiers in Environmental Science	Bibliometric Analysis	Global	13, 7	Analyzes global research trends in energy conservation and emission reduction, highlighting China's role and the significant rise in renewable energy research.
[119]	Renewable Energy	Econometric Analysis	G7 Countries	13, 7, 8	Examines the impact of climate technologies and renewable energy on G7 economies, emphasizing their contribution to social, economic, and environmental goals.
[120]	Journal of Cleaner Production	Systematic Mapping	Global	7, 12, 13	Identifies the interlinkages between SDGs and energy system models, highlighting SDG 7, SDG 12, and SDG 13 as central in energy system modeling.
[10]	Sustainable Development	Quantitative Analysis	G20 Countries	13, 7	Investigates the role of green digital finance and climate change adaptation technologies in achieving SDG 13 and 7 in G20 economies.

[121]	Sustainable Energy Technologies and Assessments	Systematic Literature Review	Global	 The paper examines all 17 SDGs	The study finds that renewable energy technologies advance SDGs by providing clean, affordable energy and fostering economic growth, while addressing challenges of access, affordability, and sustainability.
[122]	International Journal of Engineering Business Management	Econometric Analysis	ASEAN		The study finds that green economic growth, clean energy use, and green finance are key drivers of ESG practices in ASEAN countries, significantly supporting the achievement of SDGs.
[123]	Renewable Energy	Econometric Analysis	OECD countries		The total renewable energy sources, solar, wind, and biomass energy have a positive impact on sustainable development in the long-run, while hydroelectricity and geothermal energy have a negative impact.
[124]	Environmental Development	systematic literature review	Global		The study identifies sustainable energy development, resource policy, and sustainability as key research priorities, highlighting future work on rural energy access, ecosystem services, and renewable energy performance, with policy implications for poverty alleviation and sustainable development.
[125]	Sustainable Development	Econometric Analysis	China		The study finds that technological innovation and renewable energy reduce carbon emissions in China, contradicting the EKC hypothesis, while urbanization shows a small positive effect.
[126]	Renewable Energy	Econometric Analysis	China		The study finds significant regional disparities in China's energy security, with the western region leading and the central region lagging; overall energy security remains low but improving, driven by renewable energy and influenced by factors such as population size.
[127]	Renewable Energy	Econometric Analysis	Global		The study finds that renewable energy mutual funds enhance corporate sustainable energy and environmental performance and promote sustainable development, but have little effect on social and governance outcomes.
[128]	Journal of Cleaner Production	Econometric Analysis	Italy		The main findings of the study are that income inequality significantly and negatively affects renewable energy consumption in Italy, while economic growth positively influences it.
[129]	Environmental Science and Pollution Research	Econometric and Quantitative Analysis	BRICS countries		The study finds that in BRICS countries, access to clean energy and technological innovation rather than renewable energy alone are the main drivers of environmental sustainability, economic growth, and human development.

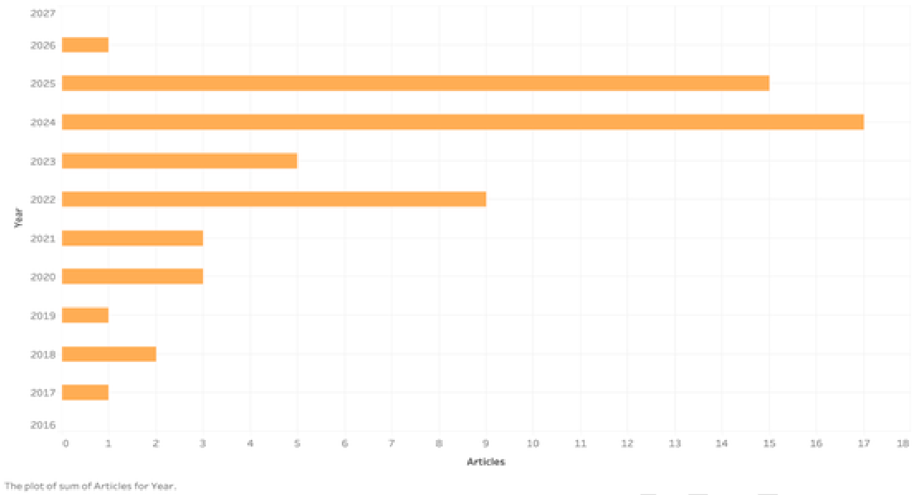


Fig. 2. Annual distribution of reviewed publications, 2016–2025.

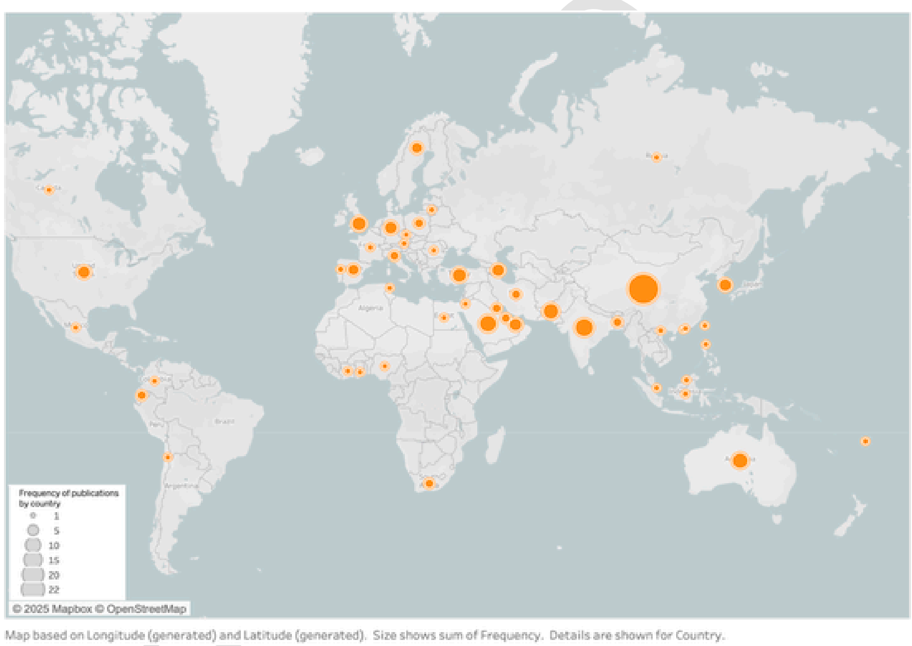


Fig. 3. Geographical distribution of reviewed publications.

3.1. Overview of renewable energy and global adoption

Renewable energy has emerged as an important solution to global challenges such as climate change, energy security, and sustainable development [38]. The accelerated deployment of technologies, such as solar photovoltaic (PV), wind power, hydropower, and bioenergy, reflects a global transition towards cleaner energy systems [39]. The principal drivers of this shift include decreasing costs of renewable technologies, supportive policy environments, and increasing public awareness of environmental issues. Globally, renewable energy sources accounted for approximately 29 % of electricity generation in 2020, with solar and wind energy registering the highest growth rates [40]. According to the International Renewable Energy Agency, solar PV capacity grew by more than 22 % on average annually over the past decade, with the wind sector following closely with massive investments, particularly in offshore wind farms [41]. Despite this significant progress, the use of renewable energy remains uneven across regions. In Europe, countries like Denmark, Germany, and Spain have achieved high levels of renewable integration through policy instruments such as feed-in tariffs, carbon pricing, and renewable energy targets. Denmark, for instance, generated over 50 % of its electricity from wind energy as of 2022 [42,43], while Germany remains a global leader in solar and wind installation, supported by its long-established policy frameworks such as the Energiewende [44].

Asia presents a diverse renewable energy landscape. China, which holds the world's largest installed renewable energy capacity, has made significant investments in wind and solar energy, accounting for over one-third of the world's total renewable energy capacity [45]. India is rapidly expanding its solar capacity under the National Solar Mission, although challenges such as grid integration and limited finance persist [46]. In contrast many Southeast Asian countries remain heavily dependent on fossil fuels, with renewable uptake in its initial stages owing to

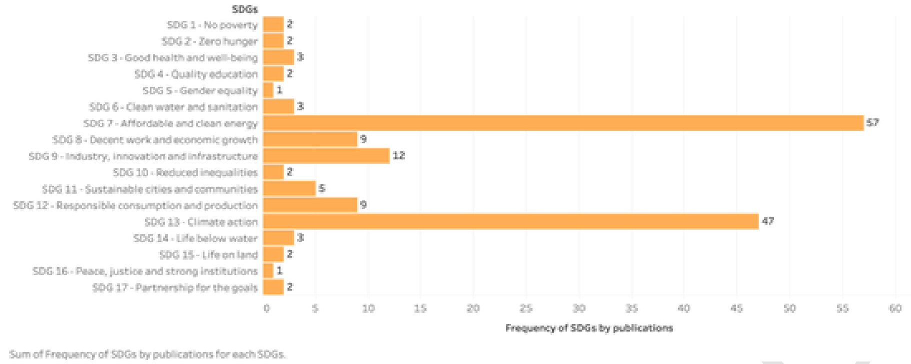


Fig. 4. Distribution of SDG coverage across publications.

weak policy framework and scarce financing instruments [47]. Sub-Saharan Africa remains underreported in global renewable energy statistics, despite its vast solar potential. Infrastructure deficit, inadequate access to capital, and political instability hinder renewable energy deployment in most countries [48]. Nevertheless, off-grid solar systems and mini-grids are being increasingly being implemented in rural areas, particularly in Kenya, Rwanda, and Ethiopia [49]. In Latin America, countries such as Brazil and Chile have made significant progress, primarily in hydroelectric and solar power, respectively [50]. Brazil generates more than 60 % of its electricity from hydropower, while Chile has emerged as a solar energy giant, due to its geographical advantage and falling technology costs [51]. The Middle East and North Africa region, traditionally reliant on fossil fuels, has recently accelerated investment in solar energy, with countries like the UAE and Morocco leading high-ticket solar initiatives, including Noor Ouarzazate and the Mohammed bin Rashid Al Maktoum Solar Park [52–54].

Despite global progress, the pace of renewable energy is influenced by geographical, economic, and political factors. Industrialized and high-income countries tend to benefit from advanced infrastructure, stable policy environment, and greater access to capital, while low- and middle-income economies face challenges such as regulatory uncertainties and limited access to capital [23]. Bridging this gap will require enhanced international cooperation, technology transfer, and finance instruments to accelerate renewable energy penetration globally. Generally, while the global trajectory of renewable energy adoption is promising, equitable and widespread access hinges on overcoming regional variation and augmenting deployment capacities worldwide.

3.2. *Classification of SDGs by relevance to renewable energy*

This classification of SDG linkages into direct, indirect, and broader supportive categories is informed by the conceptual framing of multiple impacts of renewable energy proposed by Makešová and Valentová [130], emphasizing the interconnected economic, social, environmental, and technical dimensions of renewable energy deployment. It also builds on the systemic mapping approach developed by Grace et al. [131], who used a Fuzzy Cognitive Mapping methodology to examine how EU renewable energy policies and technologies influence both biodiversity and the SDGs. Although their study primarily focused on biodiversity, their conceptual model revealed complex and multi-level pathways through which renewable energy contributes to SDG outcomes. These insights reinforce the need for a layered and structured classification of renewable energy contributions across the SDG framework.

Renewable energy plays a pivotal role in the advancement of SDGs by tackling key environmental, economic, and social challenges [55]. Based on the synthesis of the reviewed literature, the 17 SDGs were classified into three categories according to their relevance to renewable energy: The SDGs that are directly addressed or significantly influenced by renewable energy deployment and climate mitigation efforts are crucial for improving energy access, reducing emissions, and promoting sustainable production (SDGs 7, 9, 12, 13). In addition, there are SDGs that are indirectly impacted by renewable energy and climate policies. Although these goals are not primarily centered on energy, they benefit from the positive externalities of clean energy transitions and environmental protection, leading to improvements in areas such as health, economic development, and social equity (SDGs 3, 4, 6, 8, 11, 14, 15). While indirect SDGs involve measurable sectoral benefits from renewable energy transitions (such as improvements in health and education), broader development SDGs reflect systemic and institutional impacts that are less immediate but critical for long-term resilience and inclusion.

Lastly, there are SDGs that are broadly supported by the economic, social, and institutional benefits of sustainable energy transitions. Although these impacts are more indirect, they contribute to the development of inclusive and resilient societies, fostering long-term societal and economic well-being (SDGs 1, 2, 5, 10, 16, 17). While similar discussions on energy–SDG interlinkages have appeared in policy reports by organizations such as IRENA and UNDESA, these typically address selected goals or present general linkages without a structured classification. This study contributes a novel synthesis by systematically categorizing all 17 SDGs based on their degree of interconnection to renewable energy, supported by a literature-driven framework and conceptual mapping.

Fig. 5 demonstrates that most research efforts are concentrated within the 'Directly' category (77.2 %), which includes SDGs closely

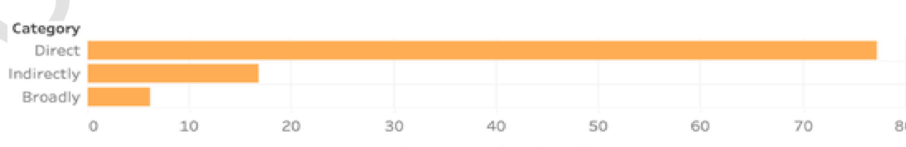


Fig. 5. Percentage of total reviewed studies by SDG category.

tied to energy, innovation, production, and climate (SDGs 7, 9, 12, and 13). These goals dominate the thematic focus of the reviewed studies, reflecting strong scholarly attention toward technological and environmental sustainability. The 'Indirectly' category (16.7 %) covering SDGs related to health, education, water, work, and ecosystems represents a moderate portion of the research landscape, indicating secondary emphasis on social-environmental linkages. Meanwhile, the 'Broadly' category (6.2 %), encompassing foundational social and institutional goals (e.g., poverty, inequality, gender, peace, and partnerships), remains significantly underrepresented. Overall, this pattern underscores the predominance of research on climate and energy-oriented SDGs, with relatively limited engagement in broader socio-economic and governance dimensions of sustainable development.

As illustrated in Fig. 6, this classification underpins the conceptual framework developed in this study, clarifying how renewable energy supports the SDG agenda through both targeted and systemic contributions.

3.2.1. SDGs directly connected to renewable energy

SDG 7 (Affordable and Clean Energy) is leading the global transition towards renewable energy. Renewable technologies such as solar, wind, small hydro, and modern bioenergy are expanding energy access in cities and rural areas, contributing to ensuring universal access to modern energy services (7.1) [7,9,56]. With declining costs and scalable deployment, renewables present a viable and cost-effective substitute to fossil fuels, thereby increasing their share in the global energy mix (7.2), especially in low-income and off-grid communities. These technologies reduce energy poverty, enhance energy independence, and facilitate inclusive economic growth by electrifying homes, schools, health centers, and businesses [57].

SDG 12 (Responsible Consumption and Production) is directly connected with renewable energy since it focuses on minimizing the negative impacts of consumption and production patterns on the environment (12.1). By promoting sustainable energy systems that reduce reliance on fossil fuels, renewables support the conservation and efficiency in the use of energy resources (12.2). Similarly, this goal facilitates the transition towards cleaner and renewable sources of supply such as bioenergy and waste-to-energy, that minimize waste (12.5), reduce depletion of resources, and limit GHG emissions. Renewables also enable the development of circular economies, where energy resources are efficiently used, and waste is minimized, and ultimately contributing to more sustainable consumption and production behavior promoting long-term environmental sustainability [58].

SDG 13 (Climate Action) is heavily dependent on the transition from fossil fuel to renewable energy, which is crucial for enhancing energy security and curbing GHG to strengthen the adaptive capacity to climate-related hazards (13.1) [10,59]. The energy industry is one of the major GHG-emitting sectors, and its reduction through renewables is necessary in order to achieve Paris Agreement targets and national energy policies, strategies and planning (13.2) [60]. Clean energy technologies lower the carbon intensity of electricity generation, reduce air pollution levels, and enhance climate resilience via diversified and decentralized energy systems [61].

SDG 9 (Industry, Innovation and Infrastructure) benefits from the inherent innovation nature of renewable energy systems [62]. Investments in renewables drive infrastructure development smart grids expansion, energy storage, and decentralized power generation, which

Fig. 6. Conceptual framework of renewable energy integration with the SDGs. Source: Authors.

support economic development (9.1). It further increases industrial innovation by encouraging R&D (9.5), green technologies, manufacturing, and digital energy solutions (9.4). Besides, investment in renewable energy infrastructure also generates jobs, improves technology, and regional economic diversification [58,63,64].

3.2.2. SDGs indirectly related to renewable energy

While the most immediate and self-evident impacts of renewable energy on SDGs are related to SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation, and Infrastructure), there are significant indirect impacts on other goals as well. SDG 11 (Sustainable Cities and Communities) in which urban areas can become sustainable with the utilization of renewable energy to provide basic services like off-grid power, improving energy-efficiency in building (11.1), mitigating urban heat islands, and providing cleaner transport systems such as electric vehicles and light rails powered by renewables (11.2). Apart from reducing environmental footprint, integrating renewable energy into urban planning supports sustainable energy infrastructure to foster sustainable urbanization (11.3) and improve quality of life [65,66]. Also, renewable energy reduces the adverse environmental impacts of cities by reducing pollution caused by using fossil fuels for power generation and transport (11.6)

SDG 6 (Clean Water and Sanitation) integrates renewable energy into water treatment plants, such as solar-powered pumps, water purification systems, desalination facilities, and wastewater treatment plants, can increase access to clean water (6.1) and sanitation (6.2), particularly in remote and off-grid locations, towards improving water quality (6.3), achieving water-use efficiency (6.4) and sustainable water resource management [67,68].

SDG 3 (Good Health and Well-being) is also indirectly related to renewable energy. Renewables contribute to achieving universal health coverage by powering rural clinics and hospitals, enabling healthcare services such as surgeries, diagnosis, imaging, and the refrigeration of drugs (3.1). They also lower air pollution and GHG emissions resulting from energy generation and transportation. Improved air quality decreases the incidence of respiratory diseases, cardiovascular conditions, and other diseases caused by fossil fuel-based energy production, thereby contributing to reducing the number of death from air pollution (3.2) and health risks (3.d) [69,70].

SDG 8 (Economic Growth and Decent Work) centers on decent work, innovation, and resource efficiency for enhancing economic productivity. The renewable energy sector is a key driver of green innovation (8.2) and provides decent employment in manufacturing and installation to maintenance and research (8.3). This results in job creation in local and marginalized communities (8.5), especially in those areas that are transitioning away from the use of fossil fuels, towards inclusive economic growth [71,72]. Similarly, transitioning to renewable energy helps decouple economic growth from fossil fuel dependence and environmental harm (8.4).

SDG 4 (Quality Education) can be enhanced through access to affordable and clean energy. Renewables can contribute to improved educational opportunities through stable electricity supply in primary and secondary schools (4.1) to promote basic, technical and vocation education (4.3), digital learning and entrepreneurial skills in the installation and maintenance of renewable energy technologies (4.4). It also supports capacity building and awareness about renewable energy technologies [73,74].

SDG 14 (Life below Water) is also indirectly supported by renewables. A shift to renewable energy reduces the extraction, processing, and use of fossil fuels that contaminate oceans and waterways (14.1) and minimizes their adverse impacts on marine and coastal ecosystems (14.2). Green energy technologies like wind farms off coasts also benefit marine life by powering without harming as traditional power generation does [75,76].

SDG 15 (Life on Land) is supported by renewables when they reduce the pressure on ecosystems caused by fossil-fuel extraction (15.1). Solar, wind, and biomass, which are modern energy technologies with minimal land and forest footprint compared to traditional fossil fuels extraction (15.2), help conserve natural ecosystems and biodiversity [77,78]. Further, promoting sustainable energy generation can reduce land degradation and deforestation caused by energy-intensive production practices (15.3). All these SDGs are indirectly supported by renewable energy through environmental improvement, enhanced service delivery, economic opportunities, and contribute towards building a sustainable future.

3.2.3. Broader SDGs enabled by general development

More broadly, renewable energy contributes to SDG 1 (No Poverty) [79], SDG 2 (Zero Hunger) [80], SDG 10 (Reduced Inequalities) [81], SDG 5 (Gender Equality), SDG 16 (Peace, Justice and Strong Institutions) [82], and SDG 17 (Part strengthening institutional frameworks [83]. Access to renewable energy improves livelihoods by enabling income-generating activities (SDG 1.1) and reducing energy poverty (SDG 1.2). Renewable energy also reduces time burdens of gathering fuel especially for children and women (SDG 5.a) and creates opportunities for greater participation in economic and civil life (SDG 5.1) [84]. By providing power for essential services like health care, education, and communication, renewable energy promotes socioeconomic and political inclusion of all (SDG 10.2), ensures equal opportunities and energy access (SDG 10.3), and assists in creating stronger communities and governance structures (SDG 16.3) [85]. Furthermore, renewable energy encourages international collaboration, public-private partnership, and technology transfer, which are central to SDG 17, closing gaps among nations and accelerating global advances toward sustainability [86]. This review recognizes that renewable energy serves as a foundational lever for achieving the entire SDG framework. Its deployment catalyzes sustainable development, positioning it as a cornerstone of a sustainable, inclusive, and climate-resilient future.

4. Challenges and barriers to integrating renewable energy for SDGs

Achieving the SDGs through renewable energy integration faces numerous challenges across economic, technological, policy, social, and environmental domains. These barriers are especially pronounced in developing countries, where financial, institutional, and infrastructural limitations hinder the widespread deployment of renewable energy solutions [111,120–123]. Furthermore, large-scale renewable energy developments such as hydropower and wind farms involve environmental compromises such as ecosystem disturbance and wildlife damage [101,123[134]. Overcoming these barriers is fundamental to the attainment of SDGs related to clean energy, climate action, and sustainable development.

One of the foremost challenges to integrating renewable energy for SDGs is the economic and financial constraint that many countries, particularly those in the developing world. Renewable energy projects, such as wind turbine and solar panel infrastructure, typically demand a large initial costs, which discourages investment [88,[135]. Although the long-term benefits of renewables are reduced operation costs, raising the initial cost usually necessitates reliance on unaffordable subsidies or loans that may not be sustainable in the long run [136]. Many low-income countries also cannot access finances since they rely on proceeds from fossil fuel exports. The financial limitations inhibit the scalability of renewable energy, hindering the realization of SDGs in affordable and clean energy [18,95].

Technological and infrastructural limitations also undermine the use of renewable energy. The intermittency of renewable energy sources such as solar and wind causes grid integration challenges, requiring advanced storage solutions and flexible infrastructure, which are typically costly and underdeveloped [8,20,132]. Also, matching supply and demand for smart grids and energy storage systems is difficult [137]. Most existing energy infrastructures are built for centralized fossil fuel systems and are ill-suited to accommodate the distributed nature of renewable energy [96,100]. This infrastructure deficit delays the acceptance and scalability of renewable energy technologies, thus slowing the achievement of SDG 7 (Affordable and Clean Energy).

The lack of coherent, stable, and supportive policies and regulatory framework is another hindrance to the development of renewables. Policy and regulatory hurdles such as inconsistent energy policy and a lack of incentives also impede the transition process, especially in nations with highly developed fossil fuel sectors [93,133]. In many countries, energy policies remain skewed towards fossil fuel sectors, thus making it difficult to transition towards renewables [89,138]. Bureaucratic lags, uncertain regulatory regimes, and inadequate incentives for investors and developers discourage private sector investment [139]. In the absence of clear, long-term policy commitments and regulations, renewable energy transition remains slow [114]. Furthermore, policies still subsidizing fossil fuels or failing to include carbon externality costs also make renewables uncompetitive [140]. Overcoming these barriers is vital for reaching SDGs related to clean and affordable energy.

Social acceptance and behavioral challenges are significant issues undermining renewable energy deployment [133]. Public resistance to renewable energy projects often stem from, typically due to cost, reliability new technologies, and lack of familiarity about the long-term benefits of renewables [59,87]. Fossil fuel-based societies may resist change on grounds of job loss and economic insecurity [132]. Misinformation and traditional attachment to fossil fuels also contribute to resistance [141]. Addressing such challenges requires inclusive public education, awareness campaigns, and policies for mitigating the socioeconomic impacts of energy transitions, such as retraining programs for displaced workers [91,142].

While renewable energy is essential to sustainable development, large-scale installations can pose environmental risks. Hydroelectric power plants may destabilize marine ecosystems, displace indigenous people, and degrade water quality [101,143]. Similarly, wind and solar farms may harm wildlife biodiversity and lead to land degradation, especially in ecologically sensitive areas. The extraction and processing of raw materials such as lithium and rare earth elements, critical for batteries and wind turbines, have adverse environmental impacts [134,144]. While renewable energy offers long-term benefits, these environmental costs need to be accounted for in project planning and implementation to prevent adverse effects and ensure that projects align with broader SDGs, including biodiversity conservation and community resilience [103,110]. Some of the SDGs are illustrated in Table 3.

In summary, some of these challenges are economic and finance-related such as high initial capital costs and inadequate financing, while others are technology and infrastructure-related challenges such as inadequate grid infrastructure and energy storage capacity. Policy and regulatory barriers such as lack of consistent policy support and blurred frameworks also impede progress. Other barriers are social acceptance and design problems, such as public protest and unawareness of the benefits of renewables. In addition, large-scale renewable energy projects can induce environmental trade-offs, such as land use changes and loss of biodiversity. Grid integration and intermittency are problems created by the variability of renewable energy resources, whereas geopolitical and market barriers, such as political resistance and market uncertainty, complicated international cooperation. Lack of trained workforce and cultural resistance to new technologies also inhibit the transition to renewable energy. Finally, supply chain and resource bottlenecks, including material availability and logistics constraints, hinder the effective implementation of renewable energy technologies. These bottlenecks must be addressed holistically to enable successful mainstreaming of renewable energy and its contribution towards achieving the SDGs. Table 3 summarizes these barriers, the affected SDGs, and illustrative examples.

5. Discussion

The latest research trends on the integration of renewable energy into the SDGs landscape show an overriding concentration on technological innovation, policy framework, and cost-effectiveness. Advances in technologies such as solar PV, wind turbines, and energy storage systems have significantly lowered the cost of renewable energy significantly, making it increasingly competitive with fossil fuels [150]. This study findings classify the 17 (SDGs) into three levels of relevance to renewable energy: direct, indirect, and broadly supported through general development goals.

A growing body of research now focuses on optimizing energy storage technologies and devices, particularly batteries, and enhancing grid integration through smart grids and decentralized energy systems [151]. These advancements are designed to address the intermittency challenge of renewable energy sources like wind and solar, which are central to meeting reliable energy demands. Other research works have increasingly examined the impacts of policy mechanisms such as carbon pricing, subsidies, and regulatory incentives on accelerating the global transition to renewable energy [152]. The role of governance and regulatory frameworks has also gain prominence in facilitating the transition to clean energy [106,148].

Nonetheless significant knowledge gaps remain. One of the most notable is limited understanding of the socioeconomic impacts of renewable energy on local populations, especially in the developing world where energy access remains is uneven [90,116]. While environmental benefits of renewables are frequently studied, the long-term economic implications for workers in fossil fuel industries and the overall transition to green jobs remain underexplored [153]. Moreover, interrelationship between renewable energy and energy security, particularly in regions vulnerable to geopolitical instability or infrastructural vulnerabilities, is largely an uncharted territory [116,119]. More studies are also on the potential of decentralized renewable energy systems in rural communities, focusing on their roles in fostering local capacity, creating employment opportunities, and building community-level resilience [154]. In Sub-Saharan Africa, renewable energy and good governance are instrumental to energy poverty reduction [94]. Another study of 10 selected Asian countries corroborates the significant contribution of renewable energy towards economic growth, indicating that a 1 % increase in renewable energy consumption, raises GDP by 0.14 % [116].

In comparing this research objectives with findings from the reviewed studies, several consistent themes have emerged. These include the need for investing in renewable energy infrastructure, supporting policy environment and utilizing technological innovations to reduce system costs. For example, in the G7, OECD, and ASEAN countries, as well as elsewhere [16,87,88,118,119], renewable technologies and policy support have significantly contributed to lowering CO_2 emissions and attaining other environmental goals. While renewable energy is central to achieving SDG 7 (Affordable and Clean Energy), many studies highlight persistent barriers to large-scale deployment in Asia and Latin America such as financing difficulties, grid integration issues, and limited social acceptance [15,88,100,112,138]. Similarly, in several African communities, renewable energy access is hampered by unaffordability, unfamiliarity with the business model, and low electricity demand [105].

Additionally, there are pronounced disparities in how various nations and regions have embraced the adoption of renewable energy. Developed countries benefit from advanced technological capabilities and stable policy environments, whereas developing countries often struggle with financing and infrastructural limitations that hamper their adoption of renewable energy [155]. This stark disparity aligns with re-

Table 3
Challenges and barriers to renewable energy integration for SDGs.

Challenge/Barrier	Description	SDGs affected	Key factors/examples	References
Economic and financial constraints	Limited financial resources and high initial capital costs hinder renewable energy developments.	7, 8	High capital costs, limited financing, and poor financial incentives for renewable energy.	[9, 16, 92,142]
Technological and infrastructure limitations	Lack of advanced technologies, storage, and infrastructure impede renewable energy integration.	7, 9	Inadequate grid infrastructure, energy storage limitations, intermittency, and outdated technology.	[56]
Policy and regulatory barriers	Insufficient or inconsistent energy policies slow the development of renewable energy.	7, 13	Lack of clear regulatory frameworks, carbon pricing, and inconsistent policy support.	[10, 59]
Social acceptance and behavioral challenges	Public resistance and lack of awareness about the benefits of renewable energy hinder its adoption.	7, 10	Public opposition, job loss fears, misinformation, lack of awareness about the benefits of renewables.	[133-145]
Environmental trade-offs of large-scale projects	Negative environmental impacts on biodiversity and land use from large-scale renewable energy projects.	7, 13, 15	Land use changes and degradation, biodiversity loss, displacement, ecosystem disruption from large-scale hydroelectric dams, solar and wind farms.	[146]
Grid integration and intermittency issues	Challenges in integrating renewable energy into existing grids due to intermittency and variable generation.	7, 9	Intermittency of wind and solar power, difficulty in balancing grid supply and demand.	[138]
Geopolitical and market barriers	International and regional barriers, including market instability, lack of cooperation, and political resistance hinder global energy transition	7, 16	Market instability, national sovereignty concerns, lack of cross-border cooperation and frameworks.	[147]
Lack of skilled workforce	Insufficient skilled workforce to support renewable energy deployment.	7, 8	Shortage of trained technicians, engineers, and other skilled professionals.	[148]
Cultural and behavioral resistance	Cultural factors and local behaviors that oppose renewable energy projects.	7, 10	Cultural beliefs, traditional energy practices, and local resistance to new technologies.	[148,149]
Supply chain and resource limitations	Shortages of materials, logistical barriers and manufacturing capacity affect the adoption of renewable energy technologies.	7, 12	Lack of raw materials, difficulties in logistics and manufacturing renewable technologies.	[58]

cent findings indicating that renewable energy deployment in the Global South faces numerous structural and operational challenges [23]. These include high capital and operational expenditures, intense competition with fossil fuel-based energy sources, low levels of public acceptance, weak institutional and policy frameworks, limited technical expertise, inadequate grid capacity, and insufficient energy storage infrastructure. In addition to these socio-economic and institutional barriers, environmental concerns have also been raised regarding the ecological impacts of renewable energy infrastructure. This divergence highlights the necessity for context-specific strategies that incorporate financial instruments, technology transfer mechanisms, and capacity-building programs [112].

Controversies also emerge regarding environmental trade-offs associated with large-scale renewable energy initiatives [156]. Although renewable energy is environment-friendly alternative, initiatives like hydropower, wind farms, and large-scale solar farms can adversely affect ecosystems, biodiversity, and local communities [99,147]. The utilization of enormous tracts of land for renewable infrastructure, especially in ecologically fragile regions, raises valid concerns. The construction and operation of renewable energy facilities have been associated with the destruction of plant and animal habitats. For instance, one study reported wildlife mortality and species displacement resulting from land degradation and habitat loss during site preparation for renewable energy installations [146].

Other documented barriers include the disorientation of flying birds due to light reflections from PV panels (commonly referred to as the "lake effect"), bird mortality from collisions with wind turbines constructed along migratory pathways, and disturbances to aquatic fauna caused by seismic surveys and pile-driving activities during the development of offshore wind power infrastructure [116]. In the Middle East, barriers to renewable energy deployment include high implementation cost, lack of public awareness about the benefits of renewables, grid integration, and cheap fossil fuels [157]. Similarly, in Turkey, a recent study identified regulatory, financial, and institutional barriers as major constraints to investments in renewables, due to lack of policy coherence and institutional capacity, which indirectly hampers progress on achieving SDG targets [158]. Another challenge is balancing environmental benefits of renewable energy with its potential ecological impacts, which is crucial to ensuring sustainability and trade-off between renewable energy production and biodiversity protection [11]. Some studies conclude that attaining sustainable energy requires national policies and strategies on renewable energy sources that integrate with and contribute to the SDGs [159,160].

The present study deepens our understanding of the transformative potential of renewables in achieving the SDGs, improves our knowledge base, and advances theory, empirical research, and practice. Like prior studies, this review emphasized the role of solar, wind, and mini-grid solutions in expanding access to electricity, especially in off-grid and underserved areas, such as rural areas of the Global South. It also provides evidence and supports that renewables can help scale up renewable energy deployment to increase their share in the global mix. Similarly, technologies such as energy-efficient buildings and smart grids can enhance energy efficiency via reduced energy losses and optimized consumption, especially when integrated into urban infrastructure. International cooperation and public-private partnerships to remove barriers to renewable energy adoption, (such as technological limitations, lack of funding, and policy gaps), and promoting investments and innovations in renewables can contribute to achieving. Lastly, the paper specifically examined how renewables can expand energy infrastructure in the Global South, improving energy security and sustainability. It identifies the need for targeted interventions to build capacity and upgrade technology.

6. Conclusion

This systematic review has provided a comprehensive synthesis of the multifaceted role of renewable energy in advancing the United Nations SDGs. The findings reveal that renewable energy technologies, particularly solar, wind, hydropower, and bioenergy, not only play a pivotal role in ensuring access to affordable and clean energy (SDG 7), mitigating climate change (SDG 13), and fostering sustainable cities (SDG 13), but also contribute significantly to advancing progress across a broad range of social, environmental, and economic goals. The transition to renewable energy is therefore not merely a climate or energy issue; it is central to achieving an integrated vision of sustainable development, especially in the context of rapid urbanization, rising energy demands, and increasing environmental pressures.

Despite notable technological advancement and declining costs, the widespread deployment of renewable energy remains constrained by a variety of systemic barriers. Key challenges include financial limitations, infrastructural inadequacies, and issues of social acceptance, particularly in regions dependent on fossil fuels. Addressing these challenges requires more than innovation in technology and finance; it necessitates integrated policy frameworks, significant infrastructure investment, and inclusive approaches that foster public engagement and trust. Enabling conditions such as public-private partnerships, robust regulatory mechanisms, and socially inclusive policies are critical for ensuring that renewable energy transitions are equitable and context-sensitive. The sections that follow elaborate on the policy implications of the study and provide suggestions for future research.

6.1. Policy and practical implications

To advance the integration of renewable energy in support of the SDGs, the following policy recommendations are proposed for governments, urban planners, and development practitioners.

- Governments, private sectors and civil societies should collaborate to accelerate renewable energy adoption. Through partnerships, stakeholders can mobilize capital, scale-up infrastructure, deploy technology, and enhance community engagement. In low-income developing countries, such partnerships can facilitate investment in renewable energy, while raising public awareness about the benefits of clean energy, addressing public concerns, and promoting inclusive, community-driven deployment strategies.
- Policy and regulatory frameworks are also crucial in accelerating renewable energy transition. Governments should enact clear, comprehensive, and long-term policies to provide stability and direction for clean energy investments. These frameworks should support energy storage, grid modernization and integration, while providing financial incentives for producers and consumers to adopt renewable technologies. For example, feed-in tariff guarantees above-market prices for renewables, which creates investor confidence. Through consistent and forward-looking governance, policymakers can foster an environment that accelerates innovation and ensures equitable access to sustainable energy.
- Strategic and substantial investment in energy infrastructure is critical to enable the effective integration of renewable energy sources. Stakeholders should prioritize the development of smart grids, decentralized systems, and advanced energy storage systems, which are necessary to ensure grid reliability and energy security. These investments can strengthen the resilience of energy systems, reduce transmission losses, and support a more flexible and adaptive renewable energy landscape.
- Social acceptance is critical for successful renewable energy transition, particularly in communities facing economic uncertainty and potential job displacement. Policymakers should develop targeted strategies that address public concerns, promote transparent communication, and strengthen trust in energy transition processes. Socio-economic mitigation measures, such as job retraining programs for displaced fossil fuel workers, can further facilitate the transition. For example, Rwanda has active education program that raises public awareness about the benefits of off-grid solar energy. Such educational campaigns and community outreach can raise awareness about the long-term benefits of renewable technologies, while ensuring that the voices of affected populations are heard and integrated into planning and implementation.
- Financial instruments and incentives can significantly make renewable energy projects more accessible and viable, especially in low-income regions burdened by high upfront costs. Governments and financial institutions can introduce targeted mechanisms such as grants, subsidies, and concessional loans to reduce financial barriers and stimulate clean energy investment. For instance, Denmark, India, and Morocco have subsidies for developing solar plants and wind farms, these tools can empower local communities, attract private sector participation, and ensure inclusive and economically sustainable renewable energy deployment.
- Urban planners and policymakers should integrate renewable energy into spatial and development planning. Spatial plans, land

use regulations, and zoning policies should accommodate renewable energy infrastructure while minimizing environmental disruptions and ensuring equitable access. For example, Kenya's development plan integrates renewable energy into national energy planning. These directions can contribute to accelerating global transitions toward clean and inclusive energy systems.
- Finally, this study contributes to evidence-based planning and institutional learning. Policymakers, energy planners, and development practitioners can draw on the findings of this study to inform the design of multi-sectoral programs that link clean energy deployment with socioeconomic development objectives. The thematic insights and priorities identified in this study provide a foundation for monitoring and evaluation frameworks, knowledge-sharing platforms, and capacity-building initiatives that align renewable energy deployment with broader sustainable development objectives.

While the policy recommendations presented in this review are broadly applicable, it is essential to recognize that the implementation of renewable energy strategies and the achievement of the SDGs vary significantly depending on a country's level of development. In developed countries, policy agendas are often shaped by priorities such as technological innovation, improvements in energy efficiency, and commitments to carbon neutrality and net-zero emissions. These countries typically benefit from well-established infrastructure, strong institutional capacity, and better access to financial and technological resources, enabling them to pursue ambitious sustainability targets through high-tech solutions and comprehensive regulatory frameworks.

Conversely, developing countries face a different set of challenges that influence their renewable energy and SDG pathways. These include limited financial resources, underdeveloped energy infrastructure, and institutional capacity gaps. As a result, policies in developing contexts must emphasize foundational investments in clean energy infrastructure, enhanced access to international financing and technology transfer mechanisms, and the strengthening of governance systems to support SDG-aligned energy transitions.

Acknowledging these contextual differences is crucial for translating general recommendations into tailored strategies that reflect the unique developmental realities of individual countries. Differentiating policy guidance in this way enhances the practical value and relevance of the study's findings for both developed and developing settings.

6.2. Future research

Future research should consider combining qualitative content analysis with expert evaluation for enhanced understanding of the complex interactions between renewable energy and SDGs. Future studies are needed to assess the socio-economic implications of renewable energy, such as job creation, social equity, and integration into local economies and cultures. It is equally critical to explore the environmental trade-offs of large-scale renewable energy installations, especially their implications for biodiversity and land use disruptions. Moreover, research should prioritize the development of innovative technologies to improve energy storage, enhance grid flexibility, and reduce system costs. Studies should also address the needs and perspectives of diverse demographics and regions, particularly marginalized and underrepresented communities that stand to benefit the most from inclusive energy transitions. Integrating social science perspectives with technological innovation will be essential for fostering equitable and contextually appropriate pathways to renewable energy adoption and sustainable development.

Author contributions

Abdulaziz I. Almulhim: Conceptualization, Investigation, Methodology, Data Curation, Formal analysis, Validation and Writing - Original draft preparation, Writing - Review & Editing, Visualizing. Ismaila Rimi Abubakar: Investigation, Formal analysis, Validation and, Writing - Review & Editing, Resources.

Funding details

This research received no external funding.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] CEPAL NU. The 2030 agenda and the sustainable development goals: an opportunity for Latin America and the Caribbean. Goals, targets and global indicators. ECLAC; 2019.
[2] UNSDG. Sustainable development goals, United Nations. https://sdgs.un.org/goals; 2015, 2015.
[3] Raman R, Pattnaik D, Kumar C, Nedungadi P. Advancing sustainable energy systems: a decade of SETA research contribution to sustainable development goals. Sustain Energy Technol Assessments 2024;71:103978.
[4] Guang-Wen Z, Murshed M, Siddik AB, Alam MS, Balsalobre-Lorente D, Mahmood H. Achieving the objectives of the 2030 sustainable development goals agenda: causalities between economic growth, environmental sustainability, financial development, and renewable energy consumption. Sustain Dev 2023;31(2):680–97.
[5] Ruan W, Guo Z, Yang J, Gao L, Dong Y, Liu Q. Assessing the progress toward achieving energy-and climate-related sustainable development goals under four global energy transition outlooks. Sustain Dev 2024;32(4):3695–707.
[6] Minas AM, García-Freites S, Walsh C, Mukoro V, Aberilla JM, April A, et al. Advancing sustainable development goals through energy access: lessons from the global south. Renew Sustain Energy Rev 2024;199:114457.
[7] Elavarasan RM, Pugazhendhi R, Jamal T, Dyduch J, Arif MT, Kumar NM, et al. Envisioning the UN Sustainable Development Goals (SDGs) through the lens of energy sustainability (SDG 7) in the post-COVID-19 world. Appl Energy 2021;292:116665.
[8] He J, Yang Y, Liao Z, Xu A, Fang K. Linking SDG 7 to assess the renewable energy footprint of nations by 2030. Appl Energy 2022;317:119167.
[9] Chirambo D. Towards the achievement of SDG 7 in Sub-Saharan Africa: creating synergies between power Africa, Sustainable Energy for all and climate finance in-order to achieve universal energy access before 2030. Renew Sustain Energy Rev 2018;94:600–8.
[10] Zaman M, Sheraz M, Qin Q, Mumtaz MZ. Pursuing the roadmaps to SDG 13: how climate change technology moderates the nexus between digital finance and environmental sustainability. Sustain Dev 2025; 33(4). 5470–5486.
[11] Castor J, Bacha K, Nerini FF. SDGs in action: a novel framework for assessing energy projects against the sustainable development goals. Energy Res Social Sci 2020;68:101556.
[12] Chen H, Zhang L, Pinzon S, Chen H, Chen B. Decarbonizing the G7: renewable energy, economic growth, globalization, and policy pathways to sustainability. Renew Energy 2025;122671.
[13] Bąk I, Sompolska-Rzechuła A. Urban development and sustainable energy in EU countries. Sustainability 2024;16(14). 2071-1050).
[14] Yousef BA, Obaideen K, AlMallahi MN, Alajmi N, Radwan A, Al-Shihabi S, et al. On the contribution of concentrated solar power (CSP) to the sustainable development goals (SDGs): a bibliometric analysis. Energy Strategy Rev 2024;52:101356.
[15] Wang Q, Huang R, Li R. Renewable energy and sustainable development goals: insights from latent dirichlet allocation thematic and bibliometric analysis. Sustain Dev 2024;32(6):6339–59.
[16] Abbasi KR, Zhang Q, Alotaibi BS, Abuhussain MA, Alvarado R. Toward sustainable development goals 7 and 13: a comprehensive policy framework to combat climate change. Environ Impact Assess Rev 2024;105:107415.
[17] Teske S. Achieving the Paris climate agreement goals: global and regional 100% renewable energy scenarios with non-energy GHG pathways for + 1.5 C and + 2 C. Springer Nature; 2019.
[18] Sen S, Ganguly S. Opportunities, barriers and issues with renewable energy development–A discussion. Renew Sustain Energy Rev 2017;69:1170–81.

[19] Sovacool BK. The intermittency of wind, solar, and renewable electricity generators: technical barrier or rhetorical excuse? Util Policy 2009;17(3–4): 288–96.
[20] Cantarero MMV. Of renewable energy, energy democracy, and sustainable development: a roadmap to accelerate the energy transition in developing countries. Energy Res Social Sci 2020;70:101716.
[21] Leal Filho W, Wolf F, Lange Salvia A, Beynaghi A, Shulla K, Kovaleva M, et al. Heading towards an unsustainable world: some of the implications of not achieving the SDGs. Discover Sustainability 2020;1(1):2.
[22] Olabi AG, Elsaid K, Obaideen K, Abdelkareem MA, Rezk H, Wilberforce T, et al. Renewable energy systems: comparisons, challenges and barriers, sustainability indicators, and the contribution to UN sustainable development goals. Int J Thermofluids 2023. 2023/11/01/;20:100498.
[23] Li Y, Dai J, Cui L. The impact of digital technologies on economic and environmental performance in the context of industry 4.0: a moderated mediation model. Int J Prod Econ 2020;229:107777.
[24] Terra dos Santos LC, Frimaio A, Giannetti BF, Agostinho F, Liu G, Almeida CMVB. Integrating environmental, social, and economic dimensions to monitor sustainability in the G20 countries. Sustainability 2023;15(8):6502. https://doi.org/10.3390/su15086502. PubMed PMID:
[25] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372.
[26] Singh VK, Singh P, Karmakar M, Leta J, Mayr P. The journal coverage of Web of Science, Scopus and Dimensions: a comparative analysis. Scientometrics 2021; 126:5113–42.
[27] Aromataris E, Riitano D. Systematic reviews: constructing a search strategy and searching for evidence. AJN The American Journal of Nursing 2014;114(5): 49–56.
[28] Meline T. Selecting studies for systemic review: inclusion and exclusion criteria. Contemporary issues in communication science and disorders 2006;33:21–7. Spring.
[29] Meade MO, Richardson WS. Selecting and appraising studies for a systematic review. Ann Intern Med 1997;127(7):531–7.
[30] Bengtsson M. How to plan and perform a qualitative study using content analysis. NursingPlus Open 2016:8–14. 2016/01/01/;2.
[31] Fife S, Gossner J. Deductive qualitative analysis: evaluating, expanding, and refining theory. Int J Qual Methods 2024 03/28;23.
[32] Gøtzsche PC, Hróbjartsson A, Marić K, Tendal B. Data extraction errors in meta-analyses that use standardized mean differences. JAMA 2007;298(4):430–7.
[33] Munn Z, Tufanaru C, Aromataris E. Data extraction and synthesis: the steps following study selection in a systematic review. Am J Nurs 2014;114(7):49–54.
[34] Sharifi A, Amirzadeh M, Khavarian-Garmsir AR. The metaverse as a future form of smart cities: a systematic literature review of co-benefits and trade-offs for sustainable development goals. Cities 2025;161:105879. https://doi.org/10.1016/j.cities.2025.105879.
[35] Sharifi A. Urban sustainability assessment: an overview and bibliometric analysis. Ecol Indic 2021;121:107102.
[36] Baker FW, Moukhliss S. Concretising design thinking: a content analysis of systematic and extended literature reviews on design thinking and human-centred design. Rev Educ 2020;8(1):305–33. https://doi.org/10.1002/rev3.3186.
[37] Joober R, Schmitz N, Annable L, Boksa P. Publication bias: what are the challenges and can they be overcome? Journal of Psychiatry and Neuroscience 2012;149–52.
[38] Owusu PA, Asumadu-Sarkodie S. A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Eng 2016;3(1): 1167990.
[39] Lodhi SK, Gill AY, Hussain I. Renewable energy technologies: present patterns and upcoming paths in ecological power production. Global Journal of Universal Studies 2024;1(1):108–31.
[40] Strielkowski W, Civín L, Tarkhanova E, Tvaronavičienė M, Petrenko Y. Renewable energy in the sustainable development of electrical power sector: a review. Energies 2021;14(24):8240. https://doi.org/10.3390/en14248240.
[41] IRENA. Renewable power generation costs in 2019. International Renewable Energy Agency, Abu Dhabi 2020.
[42] Busch S, Kasdorp R, Koolen D, Mercier A, Spooner M. The development of renewable energy in the electricity market. vol. 187. European Commission Discussion Paper; 2023.
[43] Denmark.dk. Pioneers in clean energy. https://denmarkdk/innovation-and-design/clean-energy; 2022.
[44] Jacobs D. Renewable energy policy convergence in the EU: the evolution of feed-in tariffs in Germany. Spain and France: Routledge; 2016.
[45] Zhang S, Wei J, Chen X, Zhao Y. China in global wind power development: role, status and impact. Renew Sustain Energy Rev 2020;127:109881.
[46] Behuria P. The politics of late late development in renewable energy sectors: dependency and contradictory tensions in India's National Solar Mission. World Dev 2020;126:104726.
[47] Aleluia J, Tharakan P, Chikkatur A, Shrimali G, Chen X. Accelerating a clean energy transition in Southeast Asia: role of governments and public policy. Renew Sustain Energy Rev 2022;159:112226.
[48] Bishoge OK, Kombe GG, Mvile BN. Renewable energy for sustainable development in sub-saharan African countries: challenges and way forward. J Renew Sustain Energy 2020;12(5).
[49] Mugisha J, Ratemo MA, Keza BCB, Kahveci H. Assessing the opportunities and challenges facing the development of off-grid solar systems in Eastern Africa: the cases of Kenya, Ethiopia, and Rwanda. Energy Policy 2021;150:112131.
[50] González-Lorente Á, Hernández-López M, Martín-Álvarez FJ, Mendoza-Jiménez J. A comparative analysis of electricity generation in Latin America and the Caribbean using multivariate techniques. Heliyon 2024;(20):e39304. 2024/10/30/;10.
[51] Escamilla-García PE, Fernández-Rodríguez E, Jiménez-Castañeda ME, Jiménez-González CO, Morales-Castro JA. A review of the progress and potential of energy generation from renewable sources in Latin America. Lat Am Res Rev 2023;58(2): 383–402.
[52] Alnaser W, Trieb F, Knies G. Solar energy technology in the Middle East and North Africa (MENA) for sustainable energy, water and environment. Adv Sol Energy 2007;17:261.
[53] Yao Z, Xiao J, Xie X, Zhu H, Qu J. Design of optimal sand fences around a desert solar park—a case study from phase IV of the Mohammed bin Rashid Al Maktoum Solar Park. Nat Hazards 2022;113(1):673–97.
[54] SENER molten salt tower technology. Ouarzazate NOOR III case. In: Relloso S, Gutiérrez Y, editors. AIP conference proceedings. AIP Publishing; 2017.
[55] Gan KE, Taikan O, Gan TY, Weis T, Yamazaki D, Schüttrumpf H. Enhancing renewable energy systems, contributing to Sustainable Development Goals of United Nation and building resilience against climate change impacts. Energy Technol 2023;11(11):2300275.
[56] Aboulnaga M, Amer A, Al-Sayed A. Towards sustainable development: mega project's strategic environmental assessment to attain SDG 7, 9, 11, 12 and 13. Sustain Mediterr Constr 2020;101–6.
[57] Kaygusuz K. Energy services and energy poverty for sustainable rural development. Renew Sustain Energy Rev 2011;15(2):936–47.
[58] Schröder P, Antonarakis AS, Brauer J, Conteh A, Kohsaka R, Uchiyama Y, et al. SDG 12: responsible consumption and production–Potential benefits and impacts on forests and livelihoods. Sustainable development goals: their impacts on forests and people 2019;386–418.
[59] Erasmus K, Steenkamp Y. Elements of responsible leadership in driving climate action (SDG 13). Sustainable Development Goals for Society 2021;2:107–21. Food security, energy, climate action and biodiversity: Springer.
[60] Zhakata W. Governing climate change: general principles and the Paris agreement. Climate Change Law in Zimbabwe: Concepts and Insights 2019;48.
[61] Kabeyi MJB, Olanrewaju OA. Sustainable energy transition for renewable and low carbon grid electricity generation and supply. Front Energy Res 2022;9: 743114.
[62] Küfeoğlu S. SDG-9: industry, innovation and infrastructure. Emerging technologies: value creation for sustainable development. Springer; 2022. p. 349–69.
[63] Amir M, Deshmukh RG, Khalid HM, Said Z, Raza A, Muyeen SM, et al. Energy storage technologies: an integrated survey of developments, global economical/environmental effects, optimal scheduling model, and sustainable adaption policies. J Energy Storage 2023;72:108694.
[64] Kabeyi MJB, Olanrewaju OA. Smart grid technologies and application in the sustainable energy transition: a review. Int J Sustain Energy 2023;42(1):685–758.
[65] Vaidya H, Chatterji T. SDG 11 sustainable cities and communities: SDG 11 and the new urban agenda: global sustainability frameworks for local action. Actioning the global goals for local impact: towards sustainability science, policy, education and practice. Springer; 2019. p. 173–85.
[66] Küfeoğlu S. SDG-11: sustainable cities and communities. Emerging technologies: value creation for sustainable development. Springer; 2022. p. 385–408.
[67] Amezaga J, Bathurst J, Iroumé A, Jones J, Kotru R, Dutt L. SDG 6: clean water and sanitation–forest-related targets and their impacts on forests and people. Sustainable development goals: their impacts on forests and people 2019; 178–205.
[68] Küfeoğlu S. SDG-6 clean water and sanitation. Emerging technologies: value creation for sustainable development. Springer; 2022. p. 289–304.
[69] Küfeoğlu S., SDG-3 Good health and well-being. Emerging technologies: value creation for sustainable development. Springer; 2022. p. 229–53.
[70] Fernandez RM. SDG3 good health and well-being: integration and connection with other SDGs. Good health and well-being. 2020. p. 629–36.
[71] Stoian D, Monterroso I, Current D. SDG 8: decent work and economic growth–potential impacts on forests and forest-dependent livelihoods. Sustainable Development Goals: Their Impacts on Forests and People 2019;237–78.
[72] Rai SM, Brown BD, Ruwanpura KN. SDG 8: decent work and economic growth–A gendered analysis. World Dev 2019;113:368–80.
[73] Boeren E. Understanding Sustainable Development Goal (SDG) 4 on "quality education" from micro, meso and macro perspectives. Int Rev Educ 2019;65: 277–94.
[74] Unterhalter E. The many meanings of quality education: politics of targets and indicators. SDG 4 Global Policy 2019;10:39–51.
[75] Friess DA, Aung TT, Huxham M, Lovelock C, Mukherjee N, Sasmito S. SDG 14: life below water–impacts on mangroves. Sustainable Development Goals 2019; 445:445–81.
[76] Sturesson A, Weitz N, Persson Å. SDG 14: life below water. A Review of Research Needs Technical annex to the Formas report ForskningfÃ¶r Agenda. 2018;2030.
[77] Sayer J, Sheil D, Galloway G, Riggs RA, Mewett G, MacDicken KG, et al. SDG 15 life on land–the central role of forests in sustainable development. Sustainable development goals: their impacts on forest and people. Cambridge University Press; 2019. p. 482–509.
[78] Ansari NA, Agus C, Nunoo EK. Foundations of 'SDG15–LIFE on land': earth, forests and biodiversity. SDG15–life on land: towards effective biodiversity management. Emerald Publishing Limited; 2021. p. 7–48.

[79] Feliciano D. A review on the contribution of crop diversification to Sustainable Development Goal 1 "No poverty" in different world regions. Sustainable development 2019;27(4):795–808.
[80] Blesh J, Hoey L, Jones AD, Friedmann H, Perfecto I. Development pathways toward "zero hunger". World Dev 2019;118:1–14.
[81] Oestreich JE. SDG 10: reduce inequality in and among countries. Soc Altern 2018;37(1):34–41.
[82] Susan Solomon D, Singh C, Islam F. Examining the outcomes of urban adaptation interventions on gender equality using SDG 5. Clim Dev 2021;13(9): 830–41.
[83] Maltais A, Weitz N, Persson Å. SDG 17: partnerships for the goals. A review of research needs. 2018.
[84] Nelson S, Kuriakose AT. Gender and renewable energy: entry points for women' s livelihoods and employment. Climate Investment Funds 2017.
[85] Izuka U, Ojo GG, Ayodeji SA, Ndiwe TC, Ehiaguina VE. Powering rural healthcare with sustainable energy: a global review of solar solutions. Engineering Science & Technology Journal 2023;4(4). No. 1 90 208.
[86] ESCAP U. SDG 17: partnerships for the goals: strengthen the means of implementation and revitalize the global partnership for sustainable development. 2022.
[87] Alnafrah I. Evaluating efficiency of green innovations and renewables for sustainability goals. Renew Sustain Energy Rev 2025;209:115137.
[88] Amin N, Shabbir MS, Song H, Abbass K. Renewable energy consumption and its impact on environmental quality: a pathway for achieving sustainable development goals in ASEAN countries. Energy Environ 2024;35(2):644–62.
[89] Baruch-Mordo S, Kiesecker J, Kennedy C, Oakleaf J, Opperman J. From Paris to practice: sustainable implementation of renewable energy goals. Environ Res Lett 2019;14(2):024013.
[90] Chen J, Su F, Jain V, Salman A, Tabash MI, Haddad AM, et al. Does renewable energy matter to achieve sustainable development goals? The impact of renewable energy strategies on sustainable economic growth. Front Energy Res 2022;10:829252.
[91] Ee AW, Lee JT, Tian H, Lim EY, Yan M, Tong YW, et al. Current status on utilizing a life cycle system perspective to evaluate renewable energy production systems for achieving UN SDGs. Resour Conserv Recycl 2024;203:107381.
[92] Estevão J, Lopes JD. SDG7 and renewable energy consumption: the influence of energy sources. Technol Forecast Soc Change 2024;198:123004.
[93] Fahad S, Khan A, Waqas M, Luqman M. Scrutinizing the nexus: energy, economic growth, and environmental quality: an approach toward achieving the Sustainable Development Goals (7, 13, and 8). Sustain Dev 2024;32(6): 6999–7010.
[94] Haldar A, Sethi N, Jena PK, Padhan PC. Towards achieving Sustainable Development Goal 7 in sub-Saharan Africa: role of governance and renewable energy. Sustain Dev 2023;31(4):2446–63.
[95] Hamed MM, Alkhreasha A, AlShaer A, Olabi AG. Promoting sustainable development goals through energy-related behaviors of household occupants: fostering sustainable energy solutions in developing countries. Renew Sustain Energy Rev 2025;213:115511.
[96] Hao X, Li K, Li Y, Wu H. How do trade patterns of renewable energy products affect sustainable development goals? Evidence from Belt and Road countries. Renew Energy 2025;123023.
[97] Ibañez Iralde NS, Lecocq EM, Pascual J, Martí Audí N, Salom J. Harmonising indicators to report sustainable development goals and sustainable energy and climate action plan: systemic analysis of existing regional and city indicators sets. Sustainability 2024;16(18):7943.
[98] Jayachandran M, Gatla RK, Rao KP, Rao GS, Mohammed S, Milyani AH, et al. Challenges in achieving sustainable development goal 7: affordable and clean energy in light of nascent technologies. Sustain Energy Technol Assessments 2022;53:102692.
[99] Jha AP, Mahajan A, Singh SK, Kumar P. Renewable energy proliferation for sustainable development: role of cross-border electricity trade. Renew Energy 2022;201:1189–99.
[100] Kartal MT, Mukhtarov S, Depren Ö, Ayhan F, Ulussever T. How can SDG-13 be achieved by energy, environment, and economy-related policies? Evidence from five leading emerging countries. Sustain Dev 2025;4:5110–33.
[101] Khazaei M, Gholian-Jouybari F, Dolatabadi MD, Alamdari AP, Eskandari H, Hajiaghaei-Keshteli M. Renewable energy portfolio in Mexico for Industry 5.0 and SDGs: Hydrogen, wind, or solar? Renew Sustain Energy Rev 2025;213:115420.
[102] Matenga Z. Assessment of energy market's progress towards achieving Sustainable Development Goal 7: a clustering approach. Sustain Energy Technol Assessments 2022;52:102224.
[103] McCollum DL, Echeverri LG, Busch S, Pachauri S, Parkinson S, Rogelj J, et al. Connecting the sustainable development goals by their energy inter-linkages. Environ Res Lett 2018;13(3):033006.
[104] Mehmood U. Contribution of renewable energy towards environmental quality: the role of education to achieve sustainable development goals in G11 countries. Renew Energy 2021;178:600–7.
[105] Mukoro V, Sharmina M, Gallego-Schmid A. A review of business models for access to affordable and clean energy in Africa: do they deliver social, economic, and environmental value? Energy Res Social Sci 2022;88:102530.
[106] Kartal MT, Santosh M, Ulussever T, Pata UK, Depren SK. A comprehensive review of progress in sustainable development goals from energy and environment perspectives. Energy Strategy Rev 2024;56:101550.
[107] Pandey A, Asif M. Assessment of energy and environmental sustainability in South Asia in the perspective of the Sustainable Development Goals. Renew Sustain Energy Rev 2022;165:112492.
[108] Pata UK. How to progress towards sustainable development by leveraging renewable energy sources, technological advances, and human capital. Renew Energy 2025;122367.
[109] Prasad RD, Raturi A. Enhancing sustainable development through implementation of climate goals in Pacific Island Nations: a call for unified action. Energy Sustainable Development 2025;85:101677.
[110] Santika WG, Urmee T, Simsek Y, Bahri PA, Anisuzzaman M. An assessment of energy policy impacts on achieving Sustainable Development Goal 7 in Indonesia. Energy Sustain Dev 2020;59:33–48.
[111] Saqib N, Usman M, Radulescu M, Şerbu RS, Kamal M, Belascu LA. Synergizing green energy, natural resources, global integration, and environmental taxation: pioneering a sustainable development goal framework for carbon neutrality targets. Energy Environ 2023;0958305X231215319.
[112] Schwerhoff G, Sy M. Financing renewable energy in Africa–Key challenge of the sustainable development goals. Renew Sustain Energy Rev 2017;75:393–401.
[113] Solangi YA, Magazzino C. Evaluating financial implications of renewable energy for climate action and sustainable development goals. Renew Sustain Energy Rev 2025;212:115390.
[114] Alonso Soto A, Stasiškienė Ž. Exploring the interplay between energy policies and sustainable development goals within Lithuania's energy sector: a critical review. Sustainability 2024;16(22):10018.
[115] Swain RB, Karimu A. Renewable electricity and sustainable development goals in the EU. World Dev 2020;125:104693.
[116] Wang G, Sadiq M, Bashir T, Jain V, Ali SA, Shabbir MS. The dynamic association between different strategies of renewable energy sources and sustainable economic growth under SDGs. Energy Strategy Rev 2022;42:100886.
[117] Wang H. Does the financial investment preference of renewable energy firms promote their advance towards sustainable development goals? Renew Energy 2023;218:119326.
[118] Xu K, Yang M, Yang J, Nataliia B, Cai Y, Zhang H, et al. Mapping scholarly publications of energy conservation and emission reduction in support of the sustainable development goals (SDGs). Front Environ Sci 2024;12:1421990.
[119] Yin Y, Chen T, Pang J, Hussain J. The drivers of sustainable development goals in G-7 countries: navigating the role of climate technology and renewable energy transition. Renew Energy 2025;240:122251.
[120] Zaidan S, El Fadel M. Sustainable development goals in energy system models: a systematic interlinkages mapping analysis. J Clean Prod 2024;464:142638.
[121] Awogbemi O, Von Kallon DV. Assessment of the role of renewable energy in achieving sustainable development goals. Sustain Energy Technol Assessments 2025;81:104455. https://doi.org/10.1016/j.seta.2025.104455.
[122] Phan TC. Impact of green investments, green economic growth and renewable energy consumption on environmental, social, and governance practices to achieve the sustainable development goals: a sectoral analysis in the ASEAN economies. Int J Eng Bus Manag 2024;16. https://doi.org/10.1177/18479790241231725.
[123] Akusta E, Cergibozan R. The role of renewable energy sources on the path to sustainable development for OECD countries: considering the three pillars of Sustainability. Renew Energy 2025;124101. https://doi.org/10.1016/j.renene.2025.124101.
[124] Cheng X, Chen J, Jiang S, Dai Y, Zeng J, et al. Pursuing sustainable development goals: a review of renewable energy and poverty alleviation nexus. Environ Dev 2021;40:100679. https://doi.org/10.1016/j.envdev.2021.100679.
[125] Xing L, Udemba EN, Tosun M, Abdallah I, Boukhris I. Sustainable development policies of renewable energy and technological innovation toward climate and sustainable development goals. Sustain Dev 2023;31(2):1178–92. https://doi.org/10.1002/sd.2514.
[126] Shi Z, Yang X, Jin Q, Chiu Y, Zhang L. Roadmap to achieve sustainable energy development: is energy security important to the path to SDG7: affordable and Clean Energy -Sustainable Development Goals. Renew Energy 2025;251:123425. https://doi.org/10.1016/j.renene.2025.123425.
[127] Martí-Ballester C. Do renewable energy mutual funds advance towards clean energy-related sustainable development goals? Renew Energy 2022;195:1155–64. https://doi.org/10.1016/j.renene.2022.06.111.
[128] Eyuboglu K, Uzar U. The social, economic, and environmental drivers of renewable energy: is income inequality a threat to renewable energy transition? J Clean Prod 2025;144780. https://doi.org/10.1016/j.jclepro.2025.144780.
[129] Ofori EK, Hayford IS, Nyantakyi G, Tergu CT, Opoku-Mensah E. Synerging Sustainable Development Goals—can clean energy (green) deliver UN-SDG geared towards socio-economic-environment objectives in emerging BRICS? Environ Sci Pollut Control Ser 2023;30(43):98470–89. https://doi.org/10.1007/s11356-023-29209-x.
[130] Makešová M, Valentová M. The concept of multiple impacts of renewable energy sources: a critical review. Energies 2021;14(11):3183. https://doi.org/10.3390/en14113183.
[131] Grace M, Meletiou A, Pham-Truffert M, Darbi M, Locher-Krause KE, Rueff H. Using Fuzzy Cognitive Mapping to collate Expert Knowledge: diverse impacts of renewable energy on biodiversity and the UN Sustainable Development Goals. Biodiversity Information Science and Standards 2019;3. https://doi.org/10.3897/biss.3.38433.
[132] Sinsel SR, Riemke RL, Hoffmann VH. Challenges and solution technologies for the integration of variable renewable energy sources—a review. Renew Energy 2020;145:2271–85.
[133] Wüstenhagen R, Wolsink M, Bürer MJ. Social acceptance of renewable energy innovation: an introduction to the concept. Energy Policy 2007;35(5):2683–91.
[134] Arora NK, Mishra I. Responsible consumption and production: a roadmap to sustainable development. Environmental Sustainability 2023;6(1):1–6.

[135] Jaiswal KK, Chowdhury CR, Yadav D, Verma R, Dutta S, Jaiswal KS, et al. Renewable and sustainable clean energy development and impact on social, economic, and environmental health. Energy Nexus 2022;7:100118.
[136] Wiser RH, Pickle SJ. Financing investments in renewable energy: the impacts of policy design. Renew Sustain Energy Rev 1998;2(4):361–86.
[137] Zame KK, Brehm CA, Nitica AT, Richard CL, Schweitzer IIIGD. Smart grid and energy storage: policy recommendations. Renew Sustain Energy Rev 2018;82: 1646–54.
[138] Grid integration of renewable energy sources: challenges, issues and possible solutions. In: Anees AS, editor. 2012 IEEE 5th India International Conference on Power Electronics (IICPE); 2012. IEEE.
[139] Lam PT, Law AO. Financing for renewable energy projects: a decision guide by developmental stages with case studies. Renew Sustain Energy Rev 2018;90: 937–44.
[140] Matallah S, Boudaoud S, Matallah A, Ferhaoui M. The role of fossil fuel subsidies in preventing a jump-start on the transition to renewable energy: empirical evidence from Algeria. Resour Policy 2023;86:104276.
[141] Knight K. Does fossil fuel dependence influence public awareness and perception of climate change? A cross-national investigation. Int J Sociol 2018;48: 295–313.
[142] Frey DF. Economic growth, full employment and decent work: the means and ends in SDG 8. The sustainable development goals and human rights. Routledge; 2018. p. 122–42.
[143] Tortajada C. Contributions of recycled wastewater to clean water and sanitation Sustainable Development goals. npj Clean Water 2020;3(1):22.
[144] McKenna R, Lilliestam J, Heinrichs HU, Weinand J, Schmidt J, Staffell I, et al. System impacts of wind energy developments: key research challenges and opportunities. Joule 2025;9(1):101799.
[145] Stigka EK, Paravantis JA, Mihalakakou GK. Social acceptance of renewable energy sources: a review of contingent valuation applications. Renewable and sustainable energy Reviews 2014;32:100–6.
[146] Ariza-Montobbio P. Large-scale renewable energy?: a transdisciplinary view on conflicts and trade-offs in the implementation of renewable energy. Universitat Autònoma de Barcelona; 2013.
[147] Agbonifo PE. Renewable energy development: opportunities and barriers within the context of global energy politics. Int J Energy Econ Pol 2021;11(2): 141–8.
[148] Briggs C, Atherton A, Gill J, Langdon R, Rutovitz J, Nagrath K. Building a 'fair and Fast'energy transition? Renewable energy employment, skill shortages and social licence in regional areas. Renew Sustain Energy Transit 2022;2:100039.
[149] Apel H. Inequality in development: the 2030 Agenda, SDG 10 and the role of redistribution. Real-World Econ Rev 2020;92:228–37.
[150] Ebhota WS, Jen T-C. Fossil fuels environmental challenges and the role of solar photovoltaic technology advances in fast tracking hybrid renewable energy system. International Journal of Precision Engineering and Manufacturing-Green Technology 2020;7:97–117.
[151] Pandiyan P, Saravanan S, Usha K, Kannadasan R, Alsharif MH, Kim M-K. Technological advancements toward smart energy management in smart cities. Energy Rep 2023;10:648–77.
[152] Alamooti M, Alamooti M. Accelerating the energy transition: policy and regulatory frameworks for sustainable energy systems. 2024.
[153] Hanna R, Heptonstall P, Gross R. Job creation in a low carbon transition to renewables and energy efficiency: a review of international evidence. Sustain Sci 2024;19(1):125–50.
[154] Shi Z, Liang F, Pezzuolo A. Renewable energy communities in rural areas: a comprehensive overview of current development, challenges, and emerging trends. J Clean Prod 2024;484:144336.
[155] Hassan Q, Algburi S, Sameen AZ, Al-Musawi TJ, Al-Jiboory AK, Salman HM, et al. A comprehensive review of international renewable energy growth. Energy and Built Environment 2024. https://doi.org/10.1016/j.enbenv.2023.12.002.
[156] Urkidi Azkarraga L, Gurrutxaga M. Making space for environmental justice in renewable energy planning. Energy Res Social Sci 2024;118:103806.
[157] Malik K, Rahman SM, Khondaker AN, Abubakar IR, Aina YA, Hasan MA. Renewable energy utilization to promote sustainability in GCC countries: policies, drivers, and barriers. Environ Sci Pollut Control Ser 2019;26(20):20798–814.
[158] Akusta E, Ari A, Cergibozan R. Barriers to renewable energy investments in Turkiye: a fuzzy AHP approach. Renew Energy 2025;240:122161. https://doi.org/10.1016/j.renene.2024.122161.
[159] Büyüközkan G, Karabulut Y, Mukul E. A novel renewable energy selection model for United Nations' sustainable development goals. Energy 2018;165: 290–302.
[160] Li W, Allen H. From policy uncertainty to carbon neutrality: Digital pathways to renewable energy and decarbonization for achieving SDG 7 and SDG 13. Sustain Dev 2025. https://doi.org/10.1002/sd.70444.