



# Trends and Insights in Wind Energy Research: A Bibliometric Analysis

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## Abstract

Wind energy has emerged as a leading renewable energy source globally, offering a promising solution to the current energy crisis and a pathway to sustainable development. This study provides an in-depth examination of wind energy research publications, focusing on sustainable development, and socio-economic challenges. Using bibliometric techniques, the research analyzed published wind energy studies from 1996 to 2024, examining publication year, authorship, affiliation, publication title, country of origin, and alignment with the United Nations' Sustainable Development Goals (SDGs). The findings reveal a significant surge in total research publications, with a marked increase around 2018 and a dramatic acceleration in 2020. Research from 166 countries is represented, with China, the USA, and India leading the way in research publications. The majority of publications fall under "Energy Fuels and Green Sustainable Science Technology", with SDG 7 (Clean and Affordable Energy) being the primary focus. To support the growing demand for wind energy research, libraries at institutions specializing in wind energy research may use this analysis to review their collections, identify areas for expansion or enhancement. Particular attention should be given to resources addressing community acceptance, a critical socio-economic factor in wind energy adoption.

*Keywords: Wind energy, Bibliometrics, Scientific productivity, Alternative energy, Renewable and sustainable energy, Sustainable Development Goals*

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## Introduction

Scientific productivity and research in the field of wind energy have surged over the last decade. The growth in scientific productivity for wind energy research can be attributed to the increasing interest in wind energy technologies ([Karmakar & Chattopadhyay, 2025](#)). Wind energy has been used for thousands of years, powering sailing boats, wind pumps for irrigation, and windmills for grinding grain ([Eldridge, 1975](#); [Hefner, 1983](#)). Wind energy, as a vital component of modern energy systems, is one of the largest renewable energy sources globally and abundant. Utilizing wind energy can alleviate the current energy crisis and promote sustainable development. The environmental impact of fossil fuels is significant, contributing to air pollution and other ecological issues. By transitioning to wind energy and other renewable sources, we can reduce our reliance on fossil fuels and create a more sustainable future ([Blanco, 2009](#); [Blaabjerg & Ma, 2017](#); [Esteban et al., 2011](#)).

Research by Jacobson et al. ([2013](#)), Jacobson et al. ([2022](#)), and Jacobson ([2023](#)) highlights wind energy's potential to provide clean energy, reduce health impacts, and lower global warming costs in the US. The development of offshore wind farms is crucial for the US transition to clean energy ([Johnson, 2014](#); [Righter, 2012](#); [Krauland et al., 2023](#); [McCoy et al., 2024](#)). According to the National Renewable Energy Laboratory's (NREL) 2024 Offshore Wind Market Report, there are over 322 operating offshore wind projects globally. As of 2024, only three offshore wind farms are operational along the eastern US seaboard: Block Island Wind in Rhode Island (30 MW), Coastal Virginia Offshore Wind in Virginia (12 MW) ([Dies et al., 2024](#)), and South Fork in New York (132 MW). Renewable energy from offshore wind farms offers numerous economic and environmental benefits including jobs creation and revenue generation ([Parton et al., 2024](#)), protection against hurricanes by reducing wind speeds ([Gavériaux et al., 2019](#)), mitigation of powerful storms and provision of an additional layer of protection for inland areas ([Poulos, 2010](#)).

## Sustainability and the United Nations' Sustainability Development Goals

Climate change poses a significant threat to sustainable development, driven by rising greenhouse gas (GHG) emissions from fossil fuel combustion. The growing global population increases energy demand, leading to environmental degradation due to fossil fuel reliance and human activities. This contributes to air pollution, intensifies extreme weather events, and poses substantial ecosystem risks. The United Nations' 2030 Agenda for Sustainable Development outlines 17 Sustainable Development Goals (SDGs) with 169 specific targets ([United Nations, 2022](#)). These goals aim to inspire individuals, organizations, and governments to take immediate and transformative action towards a sustainable future. The 17 SDGs, presented in Table 1, provide a wide-ranging framework for achieving a more equitable, peaceful, and sustainable world by 2030.

Table 1. The UN SDGs

Goal 1. End poverty in all its forms everywhere
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3. Ensure healthy lives and promote well-being for all at all ages
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5. Achieve gender equality and empower all women and girls
Goal 6. Ensure availability and sustainable management of water and sanitation for all
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10. Reduce inequality within and among countries
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12. Ensure sustainable consumption and production patterns
Goal 13. Take urgent action to combat climate change and its impacts
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The ongoing energy crisis necessitates a shift towards alternative energy resources, such as solar and wind power, to ensure a sustainable future aligned with the UN's vision. Transitioning to these sources and reducing GHG emissions are critical for a sustainable and equitable world. Climate change disproportionately affects low-income communities and minorities, exacerbating health, economic, and environmental disparities. The urgent need for collective action to address the global climate crisis is underscored by the Paris Climate Agreement, emphasizing the importance of unified efforts to mitigate its impacts.

This paper provides an examination of wind energy research, emphasizing its role in sustainable development. Through this study, readers will gain valuable insights into the emerging trends, key players, and SDG relevance of wind energy research publications. The following research questions guide this investigation:

RQ1: Scientific output: What is the annual output of wind energy research publications -globally, by country, and by institution?

RQ2: Key contributors: Who are the most prolific authors, institutions, and major journals in wind energy research?

RQ3: SDG alignment: What are the subject categories of wind energy research, and how do they align with the UN's SDGs?

## Literature Review

Recent review articles employing bibliometric techniques reveal a significant surge in wind energy research. These analyses drew from leading literature databases, including Scopus and Web of Science (WoS). This growing body of research has contributed to the field of wind energy, demonstrating increasing interest in this area. Several studies have used bibliometric methods to provide valuable insights. For example, Khan and Nasir (2023) examined the application of Artificial Intelligence in wind and solar energy resources from 1991 to 2022. Gao et al. (2016) analyzed wind power prices, Santos Marques et al. (2020) examined wind power competitiveness, and Ceballos-Sandoval et al. (2024) uncovered global trends in wind-power generation projects. Furthermore, Ye et al. (2020) and Chen and Su (2022) contributed to the field with bibliometric analyses of offshore wind power and wind farm research, respectively. Yilmaz (2022) conducted an extensive analysis of wind energy literature spanning from 1980 to 2021, focusing solely on studies indexed in the Social Science Citation Index (SSCI) of WoS. This bibliometric analysis provides a deeper understanding of the interdisciplinary nature of wind energy research, with a specific focus on how it intersects with societal impacts. Gaede and Rowland (2018) also explored community acceptance of wind power. These studies highlight the growing interest in wind energy research, showcasing its diverse aspects. Key trends include a surge in research publications, with an increasing number of studies dedicated to wind energy, and China's prominent leadership in the field, driven by multiple prominent research affiliations.

A small number of studies have explored alternative energy concepts from the perspective of science librarianship. For example, Lowe-Wincentsen (2010) compiled a webliography of renewable energy sources, highlighting specific types of renewable energy, including solar, wind, hydro, and geothermal energy. Aytac and Tran (2022) examined the concept of "net zero energy" and highlighted the importance of clean energy consumption in library buildings to a sustainable future. Aytac (2023) examined the concepts of "carbon footprint" and "carbon footprint calculator", highlighting the need to abandon fossil fuels and adopt renewable energy sources.

This study analyzes emerging wind energy research trends, bibliometric indicators, and sustainability impacts, with the aim of examining these areas from the perspective of science and technology librarians. It highlights global research trends, prolific researchers, most productive countries, affiliations, and the contributions of wind energy to the UN SDGs. These insights have the potential to greatly inform and empower science and technology librarians in their efforts to navigate and support advancements in wind energy research. This study also expands the breadth of bibliometric analysis of wind energy research. For instance, Yilmaz (2022) analyzed only publications indexed in the WoS SSCI, yielding a modest 2,531 publications - just 10% of the dataset considered in the current study. It also brings bibliometric analysis of wind energy research up to date. This is particularly critical given that previous studies indicate a substantial surge in wind energy research since 2020.

## Methods

For this analysis, data were collected from Clarivate's WoS Core Collection, Science Citation Index (SCI), SSCI, and Arts & Humanities Citation Index (A&HCI). The search query specifically targeted the keywords “wind energy” with quotation marks within the title, abstract, “keyword plus” (words or phrases that frequently appear in the titles of an article's references, but do not appear in the title of the article itself), and author-selected keywords fields. No other search terms or filters were applied. WoS was used for this bibliometric study on wind energy research with the expectation that it would provide a robust and reliable framework for analyzing trends and patterns in this field. The WoS Core Collection is a premier research database, offering comprehensive and interdisciplinary coverage across science, social science, arts, and humanities, making it an ideal source for this analysis.

This search conducted in December 2024 yielded a total of 25,842 publications across all document types. Another search was conducted in March 2025 to provide a benchmark for comparison in engineering. The collected datasets were exported and statistically analyzed to extract the following bibliometric indicators:

- Number of wind energy publications by year
- Number of publications by country
- Number of publications by institution
- Number of publications by journal, including publisher names, Journal Impact Factor (JIF) for 2023, and 5-Year JIF
- Number of publications by journal quartile - Journal Citation Reports (JCR) categorizes journals into four quartiles (Q1-Q4) based on their impact factor within a specific field
- Subject categories of wind energy research (based on WoS categories)
- SDGs for each paper, as assigned by WoS
- The top 10 most prolific wind energy researchers and their publications in WoS. (Gathered from the database on January 7, 2025.)

WoS has an SDG scheme that maps SDGs to “Micro Citation Topics”, enabling users to refine search results and analyze research publications according to the 17 SDGs. By associating publications with SDGs, this scheme provides a powerful tool for analyzing trends in how research publications are aligning with the UN's SDGs.

## Results

This section provides an overview of the current state of wind energy research, highlighting the dramatic changes in academic research output from 1992 to 2024. It focuses on the main producers, including countries, institutions, authors, and key journals; highly cited wind energy research; and its alignment with the UN's SDGs. Analysis of the WoS database reveals a significant surge in annual wind energy research output, with a marked increase around 2018 (1,583 records) and a dramatic acceleration in 2020 (2,191 records) (Figure 1). A separate WoS search focused on offshore wind energy revealed a similar trend (2018: 450 records; 2020: 615 records) in research publications. However, unlike the overall wind energy research, published

research in offshore wind energy appears to have stabilized from 2022 (1,027 records) onwards (2023: 1,006 records; 2024: 1,046 records). To provide a benchmark for comparison, I conducted a parallel search in WoS using the keyword “engineering” against the same database search field to examine research trends in this field alongside wind energy (See [Appendix](#)). No filters were applied to ensure a comprehensive overview. Although wind energy research appeared to grow proportionally faster, both fields exhibited consistent and accelerating growth rates in recent years (wind energy: 2022: 2,733; 2023: 2,547; 2024: 2,610). This suggests that wind energy research and engineering research are rapidly expanding fields, driven by increasing investment and interest in recent years.

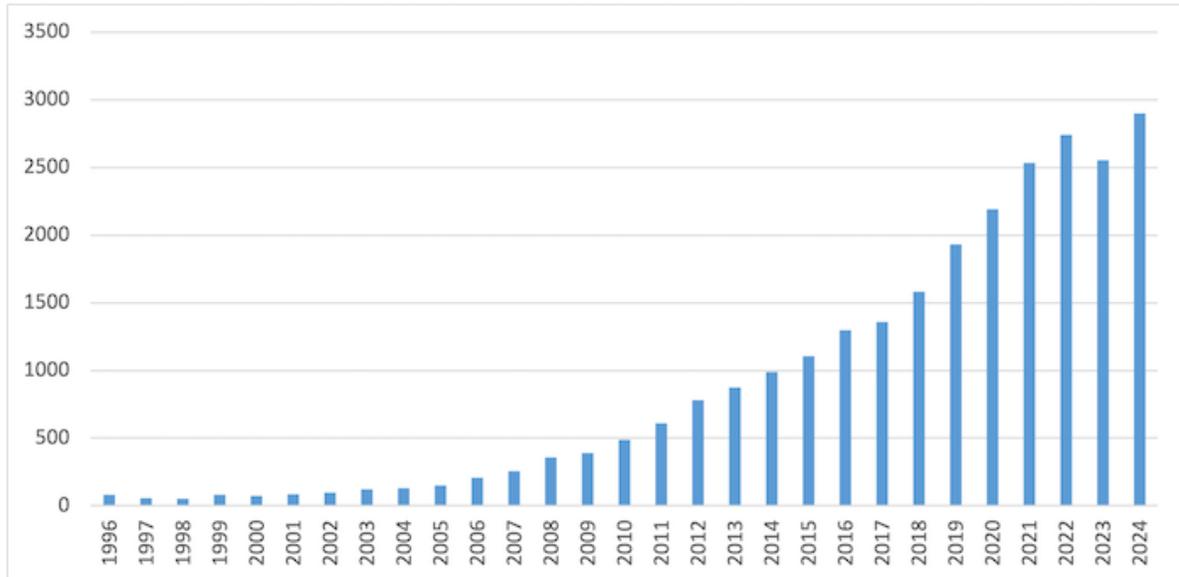


Figure 1. Wind energy research publications (1996-2024)

A careful investigation of the dataset revealed that wind energy research publications originated from a diverse geographic range of 166 countries. China, the USA, and India were the top three countries for wind energy research publications from 1996 to 2024. China was the location of the most publications with 4,861 papers (18.8%), followed by the USA with 4,093 papers (15.8%), and India with 2,162 papers (8.4%) (Figure 2). The dominance of these nations in wind energy research publications is unsurprising, given their pivotal role in advancing the field over the past three decades. Figure 2 displays the global distribution of wind energy research productivity, categorized into four tiers based on the number of countries actively contributing to wind energy research and represented by different colors:

- Tier 1: “Leading contributors” (blue): These countries have the highest volume of wind energy research publications (1,000+ research outputs).
- Tier 2: “Emerging contributors” (red): Countries in this tier have a growing presence in wind energy research but less than the output of Tier 1 nations (500-999 research publications).
- Tier 3: “Developing contributors” (yellow): These nations have some wind energy research activity but a lower scale (250-499 research publications).

- Tier 4: “Minimal contributors” (uncolored): Countries in this tier have little to no wind energy research productivity (0 to 249 research publications).

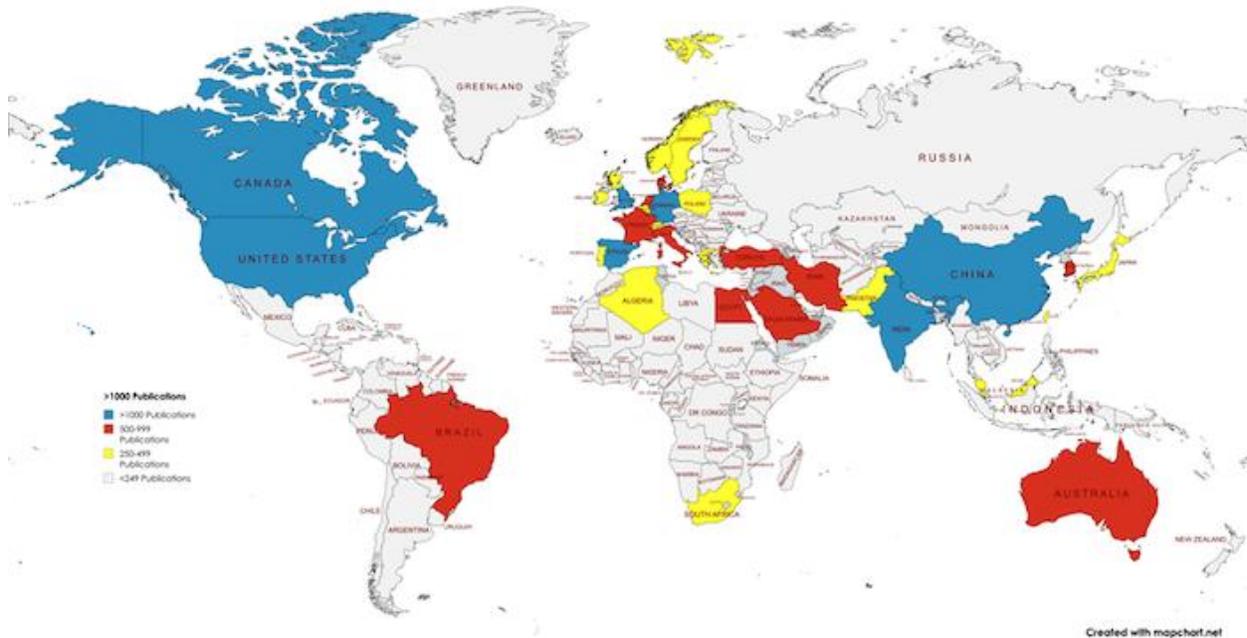


Figure 2. Geographic distribution of wind energy research publications

Fifty institutions surpassed 100 publications in wind energy research publications. The top four institutions were the Chinese Academy of Sciences (CAS) with 549 publications (2.1%), Technical University of Denmark with 466 (1.8%), United States Department of Energy (DOE) with 464 (1.8%), and Indian Institute of Technology System with 445 (1.7%). Refer to Table 2 for a list of the institutions producing the most wind energy research publications, along with their publication frequencies. During the period 1996-2004, the average number of publications was 891, reflecting the research activity in wind energy within that timeframe.

Table 2. Top wind energy research-producing institutions

Ranking	Institution	Publications	Publications as a percentage of total wind energy publications (25,842)
1	Chinese Academy of Sciences	549	2.12
2	Technical University of Denmark	466	1.80
3	United States Department of Energy	464	1.80
4	Indian Institute of Technology System IIT System	445	1.72
5	National Institute of Technology NIT System	436	1.69

6	Delft University of Technology	250	0.97
7	National Renewable Energy Laboratory USA	250	0.97
8	North China Electric Power University	249	0.96
9	Centre National de la Recherche Scientifique CNRS	239	0.93
10	Islamic Azad University	223	0.86
11	Aalborg University	216	0.84
12	University of California System	212	0.82
13	University of Chinese Academy of Sciences	210	0.81
14	Tsinghua University	208	0.81
15	Helmholtz Association	204	0.79
16	University System of Georgia	196	0.76
17	Shanghai Jiao Tong University	189	0.73
18	Chongqing University	186	0.72
19	Swiss Federal Institutes of Technology Domain	185	0.72
20	Norwegian University of Science Technology	183	0.71
21	United States Department of the Interior	172	0.67
22	University of Strathclyde	170	0.66
23	Georgia Institute of Technology	168	0.65
24	Beijing Institute of Nanoenergy Nanosystems	167	0.65
25	Universidade de Lisboa	154	0.60
26	University of Texas System	152	0.59
27	Indian Institute of Technology IIT Delhi	149	0.58
28	Zhejiang University	149	0.58
29	University of Colorado System	147	0.57
30	King Fahd University of Petroleum Minerals	139	0.54
31	United States Geological Survey	139	0.54
32	University of Colorado Boulder	136	0.53
33	University of Tehran	136	0.53
34	Texas A M University System	131	0.51
35	Xi An Jiaotong University	122	0.47

36	Huazhong University of Science Technology	120	0.46
37	Hong Kong Polytechnic University	117	0.45
38	Harbin Institute of Technology	116	0.45
39	Nanyang Technological University	115	0.45
40	Leibniz University Hannover	114	0.44
41	State University System of Florida	114	0.44
42	National Technical University of Athens	112	0.43
43	University of Massachusetts System	112	0.43
44	King Saud University	111	0.43
45	Istanbul Technical University	109	0.42
46	Aarhus University	106	0.41
47	Imperial College London	106	0.41
48	Universiti Malaya	103	0.40
49	University of London	103	0.40
50	University of Quebec	101	0.39

*Energies* was the leading journal with the highest output of papers in wind energy research (1,378 papers), followed by *Renewable Energy* (1,313), *Renewable* (915), *Sustainable Energy Reviews* (794), and *Energy* (600). Not surprisingly, out of the top 20 publication venues, 12 journals were ranked in the JCR Q1, showing that the topic is being published in high-impact venues. Elsevier, a highly influential publisher in the field, has published 10 of the top 20 journals. Descriptive data related to these top journals such as publisher, number of publications, 2023 Impact Factor, 5-Year Impact Factor, and JCR quartile is available in Table 3.

Journals could be assigned to multiple categories, and each category has its own quartile ranking. Consequently, a journal's quartile ranking can vary depending on the category. For instance, the “Wind Energy” journal is classified under both “Engineering” and “Energy & Fuels” categories (Table 3). Notably, it achieves a Q1 ranking in the “Engineering” category, whereas it is ranked Q3 in the “Energy & Fuels” category.

Table 3. Journals publishing wind energy research (JCR, 2023)

	Publication Title	Publications (n)	Publisher	IF (2023)	IF (5-year)	JCR Quartile
1	<i>Energies</i>	1,378	MDPI	3.0	3.0	Q3
2	<i>Renewable Energy</i>	1,313	Pergamon-Elsevier Science (PES)	9.0	8.1	Q1
3	<i>Renewable &amp; Sustainable Energy Reviews</i>	915	PES	16.3	16.9	Q2

4	<i>Energy</i>	794	PES	9.0	8.2	Q1
5	<i>Applied Energy</i>	600	Elsevier Science	10.1	10.4	Q1
6	<i>Energy Conversion and Management</i>	538	PES	9.9	9.8	Q1
7	<i>Energy Policy</i>	486	Elsevier Science	9.3	8.4	Q1
8	<i>Sustainability</i>	404	MDPI	3.3	3.6	Q2
9	<i>Wind Energy</i>	392	Wiley	4.0	3.9	Q3/Q1
10	<i>IEEE Access</i>	345	IEEE	3.4	3.7	Q2
11	<i>Wind Engineering</i>	335	Sage Publications	1.5	1.4	Q4
12	<i>International Journal of Hydrogen Energy</i>	305	PES	8.1	7.3	Q1
13	<i>Journal of Cleaner Production</i>	268	Elsevier Science	9.8	10.2	Q1
14	<i>Energy Reports</i>	259	Elsevier	4.7	5.0	Q2
15	<i>IEEE Transactions on Sustainable Energy</i>	258	IEEE	8.7	8.6	Q1
16	<i>International Journal of Electrical Power &amp; Energy Systems</i>	251	Elsevier Science	5.0	4.6	Q1
17	<i>International Journal of Renewable Energy Research</i>	248	<i>Int Journal Renewable Energy Research</i>	1.0	1.1	Q4
18	<i>IEEE Transactions on Energy Conversion</i>	236	IEEE	5.0	5.1	Q2/Q1
19	<i>IET Renewable Power Generation</i>	217	Institution of Engineering and Technology (IET)	2.6	2.8	Q3/Q2
20	<i>IEEE Transactions on Power Systems</i>	214	IEEE	6.5	7.4	Q1

The multidisciplinary nature of wind energy research is evident in the 183 WoS categories identified in the dataset. The top categories were Energy Fuels (42.4%), Green Sustainable Science Technology (17.6%), Engineering Electrical Electronic (17.15%), Environmental Sciences (10%), Thermodynamics (6.7%), and Environmental Studies (6.5%). Some less common WoS subject categories were Psychology, Food Science, Sports Tourism, Library Science, Social Science, Ergonomics, and Sociology. These categories reflect the breadth of disciplines contributing to wind energy research.

Table 4 shows the 10 most productive authors who published 45 or more articles based on 25, 842 publications analyzed for the study. Zhong Lin Wang of Georgia Institute of Technology was the most prolific author with 87 research articles on wind energy published in the period 2007-2024. The second most prolific author was Jianzhou Wang of Dongbei University of Finance with 73 publications, Bhim Sing of Indian Institute of Technology with 71 publications. Table 4 shows the bibliometric information of top 10 most prolific authors with their number of publications in wind energy research indexed in WoS, as well as their total publications in all fields and the total number of citations for their total publications to present a broader view of their scientific impact.

Table 4. The top 10 most prolific authors of wind energy research publications

	<b>Author</b>	<b>Publications (wind energy)</b>	<b>Affiliation</b>	<b>Country</b>	<b>Publications (all)</b>	<b>Citations (all)</b>
1	Wang, Zhong Lin	87	Georgia Institute of Technology	USA	2,346	352,134
2	Wang, Jianzhou	73	Dongbei University of Finance and Economics	China	377	16,502
3	Sing, Bhim	71	Indian Institute of Technology (IIT) - Delhi	India	2,074	27,557
4	Mostafaeipour, Ali	64	Duy Tan University Inst Res & Dev DA	Vietnam	171	6,135
5	Barthelmie, Rebecca J	54	Cornell University	USA	186	8,372
6	Dincer, Ibrahim	52	University of Ontario Institute of Technology	Canada	1,550	66,859
7	Rehman, Shafiqur	49	King Fahd University of Petroleum & Minerals	Saudi Arabia	212	10,520
8	Lundquist, Julie K.	48	University of Colorado Boulder	USA	165	7,392
9	Pryor, Sara C.	45	Cornell University	USA	251	9,329
10	Iglesias, Gregorio	45	Basque Foundation for Science	Spain	242	9,280

The analysis also identified top-cited, high-impact research papers in wind energy and their authors. Table 5 displays the top 25 most cited wind energy research papers indexed in WoS. Notably, eight of the 11 papers published in Elsevier journals were openly accessible through institutional repositories, ResearchGate, or other online platforms. Table 5 provides detailed information on each paper, including author names, affiliations, countries, journal titles, and research areas. The citation-based impact of these publications has consistently increased over time, with a significant surge in papers achieving “highly cited” status in WoS.

Table 5. Top 25 most-cited wind energy research publications

Author(s), date	Article title	Journal title	Free full text?	Times cited
Kouro et al. (2010)	Recent advances and industrial applications of multilevel converters	<i>IEEE T Ind Electron</i>	Y	2,889
Panwar et al. (2011)	Role of renewable energy sources in environmental protection: A review	<i>Renew Sust Energ Rev</i>	Y	2,444
Ellabban et al. (2014)	Renewable energy resources: Current status, future prospects and their enabling technology	<i>Renew Sust Energ Rev</i>	Y	1,851
Wuestenhagen et al. (2007)	Social acceptance of renewable energy innovation: An introduction to the concept	<i>Energ Policy</i>	N	1,795
Bejan (1996)	Entropy generation minimization: The new thermodynamics of finite-size devices and finite-time processes	<i>J Appl Phys</i>	Y	1,738
Wang et al. (2015)	Progress in triboelectric nanogenerators as a new energy technology and self-powered sensors	<i>Energ Environ Sci</i>	Y	1,722
Blaabjerg et al. (2004)	Power electronics as efficient interface in dispersed power generation systems	<i>IEEE T Power Electr</i>	Y	1,710
Pena et al. (1996)	Doubly fed induction generator using back-to-back PWM converters and its application to variable-speed wind-energy generation	<i>IEE P-Elect Pow Appl</i>	Y	1,675
Hosseini & Wahid (2016)	Hydrogen production from renewable and sustainable energy resources: Promising green energy carrier for clean development	<i>Renew Sust Energ Rev</i>	N	1,600
Qin et al. (2008)	Microfibre-nanowire hybrid structure for energy scavenging	<i>Nature</i>	Y	1,426
Zakeri & Syri (2015)	Electrical energy storage systems: A comparative life cycle cost analysis	<i>Renew Sust Energ Rev</i>	Y	1,180
Ning (2015)	Additive manufacturing of carbon fiber reinforced thermoplastic composites using fused deposition modeling	<i>Compos Part B-Eng</i>	Y	1,136
Gneiting et al. (2007)	Probabilistic forecasts, calibration and sharpness	<i>J R Stat Soc B</i>	Y	1,081
Hoffert et al. (2002)	Advanced technology paths to global climate stability: Energy for a greenhouse planet	<i>Science</i>	Y	1,057
Chen et al. (2009)	A review of the state of the art of power electronics for wind turbines	<i>IEEE T Power Electr</i>	Y	1,008
Devine-Wright (2009)	Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action	<i>J Community Appl Soc</i>	Y	992
Zhong et al. (2020)	Accelerated discovery of CO <sub>2</sub> electrocatalysts using active machine learning	<i>Nature</i>	Y	907

Nishiyama et al. (2021)	Photocatalytic solar hydrogen production from water on a 100-m <sup>2</sup> scale	<i>Nature</i>	N	892
Chinchilla et al. (2006)	Control of permanent-magnet generators applied to variable-speed wind-energy systems connected to the grid	<i>IEEE T Energy Conver</i>	Y	886
Devine-Wright (2005)	Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy	<i>Wind Energy</i>	Y	880
Lei et al. (2009)	A review on the forecasting of wind speed and generated power	<i>Renew Sust Energy Rev</i>	Y	843
Asif & Muneer (2007)	Energy supply, its demand and security issues for developed and emerging economies	<i>Renew Sust Energy Rev</i>	Y	822
Kalogirou (2005)	Seawater desalination using renewable energy sources	<i>Prog Energy Combust</i>	Y	805
Staffell & Pfenninger (2016)	Using bias-corrected reanalysis to simulate current and future wind power output	<i>Energy</i>	Y	798
Zhao et al. (2015)	Review of energy storage system for wind power integration support	<i>Appl Energy</i>	N	786

This study examined how wind energy research aligns with the UN's SDGs. An analysis of 25,842 wind energy research papers reveals that the most prevalent SDG categories were SDG 7: Clean and Affordable Energy: 15,202 papers (58.8%), SDG 13: Climate Action: 5,276 publications (20.4%), and SDG 11: Sustainable Cities and Communities: 3,646 papers (14.1%). Table 6 provides a detailed breakdown of the SDG distribution for wind energy research papers published between 1996 and 2024. Notably, 6,581 records (25.5%) lacked SDG data.

Table 6. Distribution of SDG categories of wind energy research publications (1996-2024)

Rank	SDG	Number of Publications	Percentage
1	SDG 7: Clean and Affordable Energy	15,202	58.8%
2	SDG 13: Climate Action	5,276	20.4%
3	SDG 11: Sustainable Cities and Communities	3,646	14.1%
4	SDG 9: Industry, Innovation, and Infrastructure	2,885	11.2%
5	SDG 14: Life Below Water	1,627	6.3%
6	SDG 15: Life on Land	1,199	4.6%
7	SDG 12: Responsible Consumption and Production	708	2.7%
8	SDG 6: Clean Water and Sanitation	676	2.6%
9	SDG 8: Decent Work and Economic Growth	348	1.4%
10	SDG 3: Good Health and Well-being	344	1.3%
11	SDG 2: Zero Hunger	151	0.6%
12	SDG 1: No Poverty	65	0.3%
13	SDG 4: Quality Education	40	0.2%

14	SDG 17: Partnerships for the Goals	30	0.1%
15	SDG 16: Peace, Justice, and Strong Institutions	18	0.1%
16	SDG 10: Reduced Inequalities	14	0.1%
17	SDG 5: Gender Equality	10	0.0%

## Discussion

This paper seeks to familiarize science and technology librarians with the landscape of wind energy research, providing insights into its bibliometric indicators and sustainability impact. By bridging the existing knowledge gap, this study aims to enhance librarians' capacity to support sustainable energy research initiatives, ultimately contributing to a more informed and environmentally conscious community.

This analysis of wind energy research publications from 1996-2024 reveals China, USA and India were the three most productive countries. The Chinese Academy of Sciences, the Technical University of Denmark, the US Department of Energy (DOE), and the Indian Institute of Technology System were the institutions with the most productive researchers publishing wind energy research. *Energies* was the journal publishing the most wind energy research papers. The most prolific authors were Zhong Lin Wang, Jianzhou Wang, and Bhim Sing. Notably, most of the most-cited papers were openly accessible, highlighting the growing importance of open access research in wind energy.

The 17 SDGs are essential for achieving the 2030 UN sustainability targets. The analysis reveals that four SDGs are particularly pertinent to wind energy: SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), SDG 11 (Sustainable Cities and Communities), and SDG 9 (Industry, Innovation, and Infrastructure). These goals converge with wind energy research and development, underscoring the vital role of wind energy in achieving a sustainable future.

SDG 7 prioritizes affordable and clean energy for all, focusing on reducing GHG emissions and shifting to alternative energy sources like wind. By 2030, UN SDG 7 aims to ensure universal access to modern energy services, increase renewable energy share, double energy efficiency, enhance international cooperation, and expand sustainable energy infrastructure. Wind energy is a key clean energy option that can help achieve this goal. Transitioning to wind energy mitigates health impacts, reduces global warming costs, and supports a carbon-neutral economy. As an abundant, renewable, and non-polluting source, wind energy can alleviate the energy crisis and promote sustainable development.

Wind energy research plays a crucial role in realizing UN SDG 13, which emphasizes urgent climate action. By supporting the five targets of SDG 13, strengthening resilience, integrating climate change into national policies, enhancing climate education, and promoting climate planning in vulnerable communities, wind energy research can help mitigate climate change and promote sustainable development.

SDG 11 prioritizes sustainable cities and human settlements. Wind energy plays a vital role in achieving this goal by providing renewable energy, powering sustainable cities, reducing air pollution, enhancing energy security, and economic growth. SDG 9 focuses

on resilient infrastructure, sustainable industrialization and innovation. Wind energy supports this by fostering innovation and integrating renewable energy, generating economic benefits. The frequencies of the WoS categories for SDGs 7, 13, 11, and 9 in the dataset indicate that significant volumes of wind energy research publications are aligned with these goals.

## Challenges and Concerns

Despite its numerous benefits for sustainable development, wind energy faces significant challenges. Two major concerns surrounding wind energy are potential adverse impacts on wildlife and social acceptance.

Wind farms can harm birds and disrupt wildlife habitats. Concerns about unintended or overlooked impacts on wildlife have driven substantial research. Studies have investigated the impact of wind farms on wildlife in various regions (e.g., [Passoni et al., 2017](#); [Morris and Stumpe, 2015](#); [Villegas-Patracca et al., 2012](#)). These studies underscore the importance of careful planning, placement, and monitoring of wind farms to mitigate potential impacts on wildlife and ensure environmentally sound energy development.

While wind farms improve public health by reducing GHG emissions, they often meet with resistance from local communities due to concerns about visual impact and noise. These concerns affect community acceptance and are a significant barrier to offshore wind farm development ([Firestone, 2019](#); [Dong & Lang, 2022](#); [Devine-Wright & Wiersma, 2020](#); [Cranmer et al., 2023](#)).

Public perception and social acceptance of wind farms are crucial aspects of wind energy research. Table 5, which shows the most-cited papers on wind energy, includes three papers ([Devine-Wright, 2005](#); [Devine-Wright, 2009](#); [Wüstenhagen et al., 2007](#)) that provide a framework for understanding public perceptions of wind energy, identifying strategies to increase social acceptance, and addressing the “Not In My Backyard” (NIMBY) phenomenon. These papers emphasize that community acceptance is a significant barrier to offshore wind farm development, underscoring the need for effective strategies to promote public acceptance and support.

## Implications for Librarians

Science and technology librarians play a crucial role in advancing wind energy research and in providing expert guidance and access to specialized resources. This paper may inform collection development, such as strategic decisions on journal subscriptions and database evaluations, and research guidance. Libraries at institutions specializing in wind energy should assess and expand their collections, prioritizing top-tier journals (Table 3) and research publications. Librarians can develop targeted resources and services to support researchers, policymakers, and community members seeking to understand wind energy development. Special attention should be given to literature on community acceptance, a crucial aspect of wind energy adoption. By strengthening their collections and services in this area, libraries can better support stakeholders and promote wind energy development.

Bibliometric analysis enables librarians to identify research trends, publication patterns, and emerging topics. This may help librarians to offer authoritative advice on research projects, identifying top-producing countries, institutions, and authors. By leveraging these findings, librarians can deliver more effective support for students and faculty, driving progress in wind energy research and sustainability. Ultimately, librarians support for wind energy research may enable research and innovation that contributes to SDG 7 (Affordable and Clean Energy), SDG 9, SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

The study's findings also have significant implications for community outreach. Librarians can play a vital role in promoting sustainable practices and addressing social challenges, such as community acceptance and public awareness. By providing accessible resources, inspiring climate change awareness, fostering eco-friendly policies, and educating communities on sustainable practices, librarians can support informed decisions and advance science and technology. Libraries at institutions specializing in wind energy could consider facilitating community engagement and education by hosting events, workshops, and exhibitions.

Promoting access to authoritative publications on wind energy research is also important with regard to information literacy. In today's complex information landscape, libraries play a vital role in combatting fake news and misinformation. With the rapid evolution of information retrieval, individuals struggle to navigate credible and reliable resources. Libraries are uniquely positioned to address this challenge by providing education and resources on information literacy, guiding library patrons in navigating the complex information landscape, and empowering critical thinking. By leveraging their expertise and resources, libraries can help combat the spread of fake news and misinformation related to wind energy adoption. This enables a more informed and discerning public, equipped to make informed decisions about wind energy development.

## **Limitations**

This study has two primary limitations. First, 25.5% of WoS records lacked SDG data. Hopefully, WoS will continue to assign SDG data to indexed papers, including retrospectively. In the present and future, journal editors and librarians can encourage authors to assign relevant SDGs and promote SDG inclusion alongside keywords, enhancing article discoverability and impact. Second, the study's sample size and language bias affect generalizability. Future research should address these limitations by including non-English journals, expanding the sample size, and utilizing databases like Scopus for a more comprehensive understanding of wind energy research publications. By addressing these limitations, future studies can provide a more comprehensive understanding of wind energy research literature and its alignment with the United Nations' SDGs.

## **Conclusion**

Wind energy is key to transitioning to renewable energy, offering a clean and sustainable solution to the current energy crisis. Research in wind energy is gaining

momentum, with a growing body of studies exploring its diverse facets. Building on previous bibliometric studies, which revealed a significant increase in research publications and China's emergence as a dominant force in the field, this bibliometric study offers new and updated insights relevant to science and technology librarianship. Furthermore, it investigates the alignment of wind energy research publications with the United Nations' SDGs.

Bibliometric research is essential for science and technology librarianship, as it reveals research trends, evaluates databases, guides collection development, and assesses research impact. By analyzing publication patterns, librarians can identify emerging topics, optimize resources, and provide expert guidance, ultimately supporting informed decisions and advancing science and technology.

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## Appendix

Research output comparison: Benchmarking wind energy publications against engineering publications.

Year	Engineering publications	Wind energy publications	Ratio (engineering : wind energy)
1996	7,206	81	89.0 : 1
1997	7,318	56	130.7 : 1
1998	8,172	54	151.3 : 1
1999	8,383	81	103.4 : 1
2000	9,570	74	129.2 : 1
2001	9,369	86	109.1 : 1
2002	10,235	98	104.6 : 1
2003	11,312	121	93.6 : 1
2004	12,621	131	96.3 : 1
2005	15,109	152	99.4 : 1
2006	16,422	208	78.8 : 1
2007	17,503	254	68.9 : 1
2008	19,806	358	55.3 : 1
2009	22,482	392	57.3 : 1

2010	24,640	486	50.7 : 1
2011	28,584	611	46.8 : 1
2012	32,713	781	41.9 : 1
2013	34,570	875	39.5 : 1
2014	37,350	986	37.9 : 1
2015	41,911	1,105	37.9 : 1
2016	45,955	1,299	35.4 : 1
2017	50,636	1,360	37.2 : 1
2018	55,089	1,583	34.8 : 1
2019	61,552	1,930	31.9 : 1
2020	69,396	2,191	31.7 : 1
2021	81,652	2,533	32.2 : 1
2022	85,823	2,740	31.3 : 1
2023	83,387	2,555	32.6 : 1
2024	93,873	2,898	32.4 : 1



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