

A Scientometric Assessment of Wind Energy Research Productivity: A Scientometric Study



Library Science

KEYWORDS : Renewable Energy, Wind Energy, Scientometrics, Mapping of Research, India, citation.

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ABSTRACT

Wind energy research is one among the emerging and thrust areas all over the world as the wind power is becoming an alternate energy source to meet the energy demand and also provides solution to climate change and other environmental issues. This paper attempts to highlight quantitatively the growth and development of research on wind energy across the globe in terms of publication output as per Science Citation Index (1970–2011). The corresponding literatures were analysed by Scientometric methods and research landscape was established. The study also discusses detailed quantitative analysis of Indian contributions on wind energy research. Measuring the research productivity, identifying the human resource and organizational potentials in the wind energy and applied areas in different geographical regions enable the core researchers to identify the opportunities for academic and scientific research in this domain. Wind energy keywords are used in Web of Science database to study the research landscape and citation index. During 1970 to 2011 a total of 16, 407 research articles have been published by the scientists in the field of 'wind energy'. There were only five publications in 1970. Thereafter, a steady growth was observed up to 1990 and then rapid growth was observed, mainly due to serious oil crisis. It is studied that maximum number of papers (1874) were published in the year 2010. USA with 4446 (27.1 %) and UK with 1485 (9.1%) publications were the top two countries who published work on wind energy. India has contributed 468 papers (2.9%). Authorship and collaboration trend has been towards multi-authored papers, as 79.32 per cent of the papers were collaborative. The journals most preferred by the scientists for publication of papers were: Journal of Renewable energy with 840 papers, followed by the Energy Policy with 426 papers and Journal of wind engineering and industrial aerodynamics with 398 papers. English was the most predominant language (97%) used by the scientists for communication. The same study was also done in Indian context and the results were discussed. Further, an attempt is made to measure the performance of researchers and their research concentration in the field of wind energy research.

Introduction

Wind energy has historically been used directly to propel sailing ships or converted into mechanical energy for pumping water or grinding grain. Wind energy today ranks as one of the most promising renewable sources of energy for electricity generation. The system which converts energy available in the wind into electricity is called wind turbine. Wind power is being adapted the world over as the most efficient power generation source that does not cause greenhouse gas emissions. With the raising concerns on climate change, countries are under pressure to move towards renewable energy sources and reduce CO₂ emissions. Amongst renewable energy sources, Wind energy proved more successful energy option next to hydro and about 175 GW has been installed worldwide. Earth's commercially viable wind power potential is estimated 72 TW which is five times more than world's total energy demand. The use of wind power is increasing rapidly and currently wind turbines generate about 1.5% of the global electricity demand. Wind energy is used in more than 70 countries. To highlight, India holds fifth position with installed capacity of about 13, 100 MW after China, USA, Germany and Spain. Based on scientific study, India's potential for power generation from wind energy has been assessed as 49, 130 MW (with 2% potential land availability for wind power harvesting) and it may increase with increasing land availability.

Scientometrics is the branch of science that describes the output traits in terms of organizational research structure, resource inputs and outputs, develops benchmarks to evaluate the quality of information output. Scientometric studies characterize the disciplines using the growth pattern and other attributes. These studies have potential qualities particularly in assessing the emerging disciplines. The researcher being working in the field of wind energy for more than 8 years has taken the research "A Scientometric Assessment of Wind Energy Research Productiv-

ity: A global perspective" to map the global research on wind energy and to highlight Indian scenario.

Objectives of the study

The main objective of the study is to present the growth of literature on wind energy across the globe highlighting Indian contributions and make quantitative and qualitative assessment of the research by analysing the research outputs towards identifying the following facts:

- Annual growth of publications
- Geographical distribution of research output
- Most prolific authors in the field
- Authorship pattern
- Prominent institutions on wind energy research
- Highly productive Indian authors and institutions
- Document types used by the scientists
- Journals preferred by the researchers
- Language-wise distribution of publications

Methodology

Data was collected from the Science Citation Index of Web of Science published by the Institute for Scientific Information, Philadelphia. Science Citation Index is one of the very comprehensive databases that cover all aspects of science which has 9000 journal database and covers almost all major journals having high impact factor. Database was searched with the keyword algorithm "wind AND (energy OR turbine OR power)", the search has been made on the online version of Science Citation Index. Accordingly records on the subject 'wind energy and wind energy research' were downloaded for the years 1970–2011. A total of 16,407 records were downloaded and analysed in detail as per the objectives. The study is mainly exploratory in nature in identifying research output on wind energy and it is also analytical in nature in strengthening the empirical validity due to

application of the suitable statistical tools.

Results and Discussions

Annual growth of publications

The year wise research productivity reveals very poor publications during 1970 to 1990 which signifies less focus on wind energy research due to large availability of fossil fuels. After 1990, rapid growth was observed till now. This was mainly due to the depletion & cost escalation of fossil fuels and associated environmental issues. After 1990, due to increased awareness and increasing energy demand, people have focussed research on wind energy and other renewable energy sources. About 40 % of the publications were during the period 2007 to 2010 and this may be the reason not only due to the energy demand but the larger global concerns towards the environmental issues. The maximum (1874) publications were published in 2010.

Graph 1. Year wise research productivity*



(*the results were upto June 2011 only)

Geographical distribution of research output

It is revealed from the data that USA is the top most country that encourage wind energy research in various subject by contributing 27.1% of the total literature output, while UK, Canada and

China were the next major contributors with 1485 (9.1%), 922 (5.6%) and 821 (5%) research publication respectively. The total number of countries involved in wind energy research is 130.

Table. 1 Geographical distribution of research

Country	Recs	Percent	TLCS	TGCS
USA	4446	27.1	9625	71336
UK	1485	9.1	4659	18568
Canada	922	5.6	2514	12058
China	821	5.0	871	3433
Japan	816	5.0	1151	6780
Germany	740	4.5	1195	7707
France	619	3.8	1284	7814
Spain	491	3.0	1619	4104
India	468	2.9	787	2717
Denmark	466	2.8	2043	4680

Among the Asian countries China is the major contributor of wind energy research, which is followed by Japan with 816 (~5%) and India with 468 (2.9%) research publications respectively with regard to wind energy research. The top 5 countries in the wind energy installed capacity as on June 2011 is China, USA, Germany, Spain and India. These countries are among the top 15 countries in producing wind energy publications. This validates the accuracy of the results and this correlates the growth of any sector with the amount of research work.

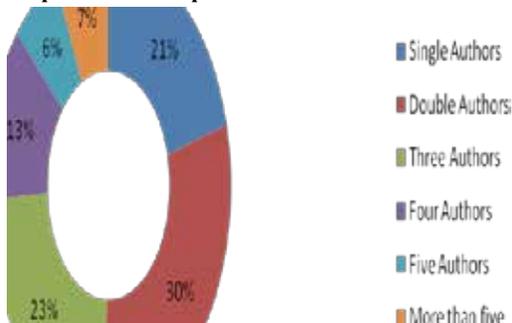
Authorship Pattern

The study revealed that 29979 authors have done research on wind energy. The top 25 authors contributed 728 research papers i.e., merely a 2.4 per cent of the total research output. Among the high productivity authors Senjyu T, Funabashi T, Billinton R, Chen Z and Kaldellis JK were in top 5 positions respectively with 52, 41, 40, 39 and 39 records.

Table 2. Author wise Research productivity

Author	Recs	Percent	TLCS	TLCS/t	TLCSx	TGCS	TGCS/t	TLCR	TLCSb	TLCS _e
Senjyu T	52	0.3	118	19.18	78	281	44.06	233	22	15
Funabashi T	41	0.2	98	16.18	67	221	35.63	193	16	11
Billinton R	40	0.2	335	33.44	218	585	57.11	215	23	107
Chen Z	39	0.2	208	32.09	157	616	82.00	195	22	15
Kaldellis JK	39	0.2	293	38.60	150	383	51.58	313	61	53
Davies AM	35	0.2	129	10.40	22	499	40.34	171	49	0
Lund H	33	0.2	444	77.16	221	677	124.04	342	69	87
Jenkins N	31	0.2	335	38.38	298	674	75.17	103	51	100
Tamura J	27	0.2	46	9.40	21	79	16.09	160	9	0
Yona A	27	0.2	33	6.43	16	68	13.07	117	8	0

Graph 2. Authorship Pattern



Prominent institutions on wind energy research

The analysis reveals that 6710 research institutions are being engaged in wind energy research. The institutions involved in wind energy research are research institutions, universities and

industrial units. Among the institutions, NASA is in first place by contributing 262 (1.6%) of the research article while National Oceanic & Atmospheric Administration (NOAA) and Russian Academy of Science stands 2nd & 3rd positions with 229 (1.4%) and 184 (1.1%) publications. Among the Asian institutions, Chinese Academy of Sciences and Indian Institute of Technology are among the top 10 institutions involved in wind energy research with 165 and 157 publications respectively.

Table 3. Institution wise research productivity

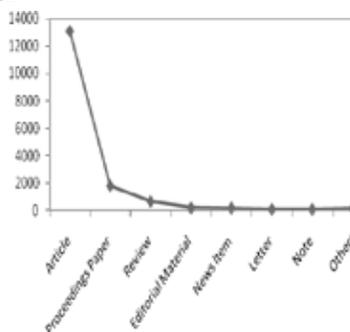
Institution	Recs	Percent	TLCS	TGCS
National Aeronautics and Space Administration (NASA)	262	1.6	445	6523
National Oceanic and Atmospheric Administration (NOAA)	229	1.4	548	4849
Russian Academy of Sciences	184	1.1	108	642
Chinese Academy of Sciences	165	1.0	62	714

National Centre for Atmospheric Research	163	1.0	603	6352
Indian Institute of Technology (IIT)	157	1.0	345	986
University of Colorado	157	1.0	453	3750
United States Navy	154	0.9	292	2818
University of Washington	147	0.9	447	3642
University of California San Diego	131	0.8	373	2658

Document types used by the scientists

Scientists communicated their papers through variety of communications channels. Graph 3 depicts the percentage of literature published in different document types. It is debited from the data, journal article forms the majority of the research output (81%) while conference proceedings (11%) and reviews (4%) are the next major form of documents in which the wind energy research has been published. As to the web of science coverage the research publishing on wind energy documented in 12 forms of publications types.

Graph 3. Document wise distribution of wind energy research



Journals preferred by the researchers

The study shows that 1749 journals were used to publish wind energy related research literature. The top 10 prominent journals that publish wind energy research literature for the study period is listed in table 4. "Renewable Energy" is the top journal that published 5.1% of the total literature output, while "Energy Policy" and "Journal of Wind Engineering and Industrial Aerodynamics" is on 2nd and 3rd position respectively with 2.6% & 2.4% of the total literature output. The top 10 journals contribute only 4033 literatures which is 24.3% of total literature output, it shows that the proliferation of wind energy research published in large number of scholarly journals as wind energy is highly multi-disciplinary field.

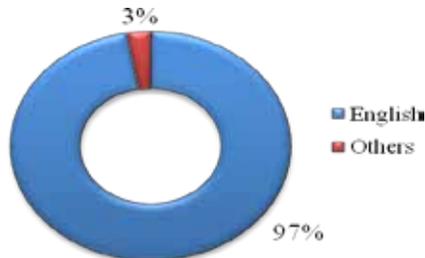
Table 4. Journal wise research productivity

Journal	Recs	Percent	TLCS	TLCS/t	TGCS	TGCS/t	TLCR
Renewable energy	840	5.1	3639	457.55	5886	758.66	2674
Energy policy	426	2.6	1864	284.11	3917	575.06	1677
Journal of wind engineering and industrial aerodynamics	398	2.4	926	83.30	2298	200.34	456
Journal of geophysical research-oceans	380	2.3	947	76.01	7901	576.89	1054
Journal of physical oceanography	378	2.3	1876	146.84	8746	662.19	1390
IEEE transactions on energy conversion	367	2.2	2956	337.10	6238	699.01	1509
Wind energy	314	1.9	1070	160.18	1634	237.91	1073
Renewable & sustainable energy reviews	304	1.9	1217	220.20	2472	435.08	1988
Journal of geophysical research-atmospheres	301	1.8	688	59.55	6043	491.30	735
Boundary-layer meteorology	295	1.8	935	77.18	5402	447.63	784

Language-wise distribution of publications

It is evident from the analysis that English is the major language of research communication with 97% while all other languages amount to 3% of research publishing. 19 other languages were used as medium of research communication with regard to wind energy publications. German (1%) & Russian (0.5%) were the next major languages in which the literature published other than English. Among Asian languages, Chinese (0.2%) and Japanese (0.1%) languages were the most used for wind energy research publications.

Graph 4. Language wise distribution of wind energy research



Results on Indian Context

India has contributed 468 publications during the study period which is 2.9% of the total publications. Indian Institute of Technology (IIT) is the premier Indian research institute which has published 157 research literatures and has contributed 33.5% of total Indian publications followed by Anna University with 5.6%. The annual growth trend shows the very poor research during 1970 to 1990 and then there has been ups and downs

between 1990 to 2004, thereafter there has been a staggering growth in wind energy research in India. That is the period in which India experienced the larger capacity addition with many global wind turbine manufacturing players established their foot print. The prominent authors were listed in Table 5. The table shows that most of the top authors were from IIT. There have been 1013 Indian authors who have published their work in 166 journals and 366 organizations have been involved in wind energy research. Indian scientists have contributed more predominantly in English than in any other language.

Table 5. Author wise research productivity – Indian Context

Author	Institutions	Recs	TLCS	TGCS
Bhatti T S	Indian Institute of Technology, New Delhi	17	21	114
Kothari D P	Indian Institute of Technology, New Delhi	15	14	99
Singh B	Indian Institute of Technology, New Delhi	14	9	41
Tripathy S C	Indian Institute of Technology, New Delhi	11	6	44
Bansal R C	Birla Institute of Technology & Science, Pilani	10	16	130
Bansal N K	Indian Institute of Technology, New Delhi	9	11	53
Iniyani S	Anna University, Chennai	9	5	127
Balasubramanian R	Indian Institute of Technology, New Delhi	7	6	38
Sharan M	Indian Institute of Technology, New Delhi	7	5	41
Gowda B H L	Indian Institute of Technology, Chennai	6	1	6

Graph 5. Annual Growth Pattern - Indian Context

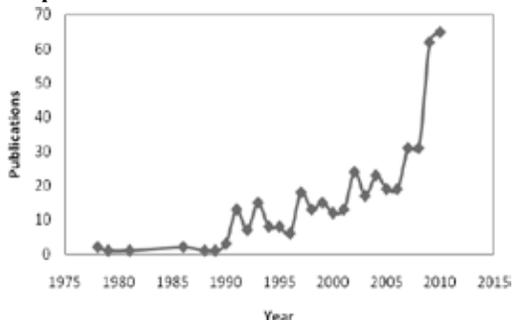


Table 6. Institutions wise research productivity of Indian authors

Institution	Recs	Percent	TLCS	TGCS
Indian Institute of Technology	157	33.5	101	986
Anna University	26	5.6	6	172
Indian Institute of Science	24	5.1	31	468
Indian Institute of Tropical Meteorology	24	5.1	2	67
National Institute of Technology	21	4.5	13	90

Summary

A currently most popular research discipline has been reviewed by Scientometric methods. The time dependent overall number of wind energy articles is given, revealing a still strongly increasing research activity in this field. The wind energy articles were analyzed with respect to the most productive authors, research organizations, countries of authors, and leading journals. The same study was also carried out in Indian context and results were discussed. Among the geographical location of research organizations the USA, UK, Canada, China and Japan were on the top and India is holding 10th position in terms of maximum research publications. Among the top research institutions there are many USA research organizations and few Indian and Chinese institutions. The time evolution of the wind energy literatures shows a similar increase in the growth of the wind energy sector. The research landscape of the wind energy research field was established using the Web of Science database and HistCite tool. The Web of Science database is used for data retrieval and HistCite is used to evaluate the productivity and analyse citations.

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