

**Research Article**

## **THE SCIENTOMETRIC STUDY OF WIND ENERGY RESEARCH OUTPUT IN INDIA**

**\*R. Kanagarasu**

*Senior Research Fellow, Literary Research & Documentation Department (Library), CCRS – Siddha Central Research Institute, Chennai – 600106, Tamil Nadu.*

*\*Author for Correspondence*

### **ABSTRACT**

Analyzed the growth and development of wind energy research productivity in India in terms of publication output as reflected in Web of Science (WoS) for the period 1993–2012. It included 6224 publications from India, including 2799 articles, 2639 Proceedings Paper, 339 reviews, and etc., from 3154 institutions. About 9.4 % of publications are contributed by Indian Institute of Technology, Kanpur followed by Bhabha Atomic Research Centre, Bombay (7.27 %). All the papers published by Indian researchers have appeared in journals with impact factors between 0.20 and 4.14. About 24.24 % of authors contributed single articles. The growth rate of publications varied from 0.50 to 14.7 % per year. The annual growth rate was highest in the year 2012 at 14.7 %. The study reveals that the output of wind energy research in India has gradually increased over the years.

**Keywords:** *Wind Energy; Wind Power; Scientometric Study; h-index; HistCite*

### **INTRODUCTION**

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is wind energy. Wind energy is quite simply the energy produced directly by the wind and collected elsewhere, normally the Earth. Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The exceptions are geothermal energy, and nuclear fission and fusion. Even fossil fuels owe their origins to the sun; they were once living plants and animals whose life was dependent upon the sun.

Scientometricians describe about input and outputs resource, in terms of organizational structure. It provides a key opportunity to the researcher to publish their publications with new strategies, innovations, new methods and new ideas. They forecast productivity of scientists, so that dynamics of scientific research and technological development can be understood. This paper an attempt has been made by the Indian research to reveal the trends towards the increase and quality of research publications in the field of wind energy.

#### **Review of Literature**

The analysis of the review of literature is the key focus of any research. It enables to be aware of the past and current trends in any particular branch of research. Research on Scientometric study is the performance on space neuroscience has attracted the attention of various scholars, researchers, information scientists and library personals throughout the world. Kanagarasu and Jeyapargash (2014) analysed the growth and development of Open Source Software (OSS) research productivity in global level. Investigators have compared the author productivity and citations by various institutions at global level. It could clearly see that during the period 1999-2012, a total of 3143 publications were published at Global level. This paper finds trend towards collaborative research was gained momentum. As every work of researchers depended mainly on the library since it provided more scholarly information and hence these kinds of studied were more relevant in identifying thrust areas of research. Surulinathi *et al.*, (2013), analysed the growth and development of Green Computing, as reflected in publication output covered by Web of Science online database during 1956-2011. Among these 42 countries, Germany has produced 270 (16.24 %) articles and it occupies the first place of European continent. France and Italy have more than 200 articles produced in this field. UK and Spain contributed more than 100 articles.

**Research Article**

North American countries contributed their output 1317 in total where the USA (33.36%) stands in the highest position among them all, and the reason may be the impact of the advancement of the new and recent technologies applied highly in the USA and followed by Canada, Mexico. Srinivasa Ragavan *et al.*, (2012) analysed the scientometric parameters for Medicinal plant research publications. Investigators have compared the author productivity and citations by various institutions at national level. It could clearly see that during the period 1973-2009, a total of 1265 publications were published at national level and the data has reflected in Web of science database.

**Objectives of the Study**

The main objectives framed for the purpose of the study are to identify and analyze the rate of growth of research literature on Wind Energy.

- To analyze the authorship pattern and examine the extent of research Collaboration.
- To assess the Institution wise research concentration
- To identify the document wise distribution of Publications.
- To identify the h-index.
- To identify the highly cited papers in the field of Wind Energy.
- To draw the Citation Map for High Cited Papers.

**Data and Analysis**

We used the Science Citation Index Expanded part of Web of Science as our source of data and the following words in the topic field: ‘wind energy’ and ‘wind power’. We made standard Scientometric analysis using the data downloaded from Web of Science and then did a HistCite analysis and citation mapping on the data. The following concepts are used in our study.

- *H-index*: A Scientist has index h if h of [his/her] Np papers have at least h citations each, and the other (Np-h) papers have at most h citations each.
- *GCS* - Global Citation Score shows the total number of citations to a paper in Web of Science.
- *LCR* - Local Cited References shows the number of citations in a paper's reference list to other papers within the collection.
- *LCS* - Local Citation Score shows the count of citations to a paper within the collection.
- *CR* - Number of Cited References shows the number of cited references in the paper's bibliography.

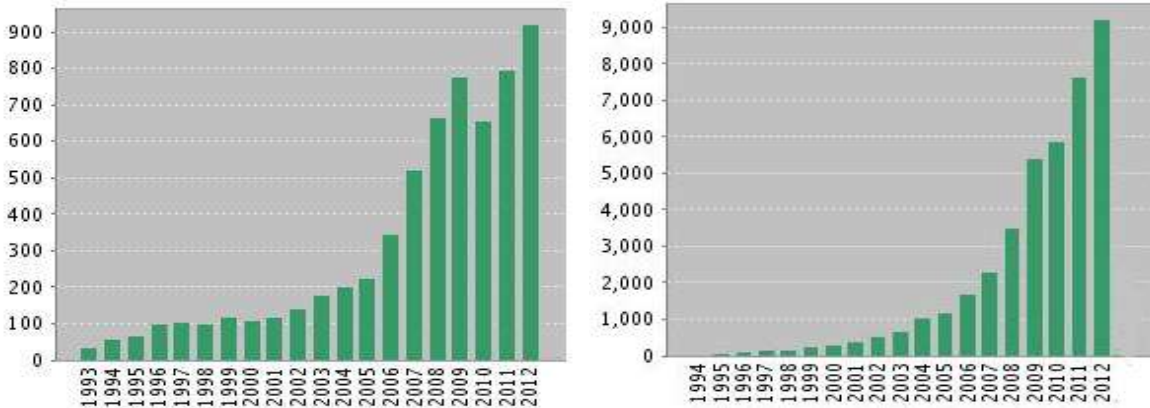
**Year wise distribution of documents**

Growth of Literature during the 20 years period (1993-2012) India has produced a total of 6224 publications. The highest number of publications was 916 in 2012. The average number of publications per year 311.2

**Table 1: Year wise distribution of documents**

#	Publication Year	Records	%	TLCS	TGCS
1	1993	33	0.5	66	343
2	1994	60	1.0	74	466
3	1995	69	1.1	183	1343
4	1996	100	1.6	497	2204
5	1997	104	1.7	256	982
6	1998	101	1.6	168	980
7	1999	117	1.9	406	1126
8	2000	109	1.8	532	1932
9	2001	118	1.9	408	1365
10	2002	142	2.3	463	2211
11	2003	178	2.9	671	2480
12	2004	200	3.2	1023	3161
13	2005	225	3.6	645	3127
14	2006	345	5.5	926	3603
15	2007	523	8.4	1125	4322
16	2008	665	10.7	1005	4713
17	2009	779	12.5	1010	3691
18	2010	649	10.4	638	2702
19	2011	791	12.7	356	1713
20	2012	916	14.7	120	555

**Research Article**



**Figure 1: Published Item in each year Figure 2: Citation in each year**

**Calculation of h-index**

The h-index is based on a list of publications ranked in descending order by the Times Cited. The value of h is equal to the number of papers (N) in the list that have N or more citations. This metric is useful because it discounts the disproportionate weight of highly cited papers or papers that have not yet been cited. In the h-index example below, the h-index is 76 because there are 76 articles with 76 or more citations in the file of wind energy.

Total No of Publications: 6242

Sum of the Times Cited: 43020

Times Cited without self-citations: 32279

Citing Articles: 23802

Citing Articles without self-citations:20792

Average Citations per Item: 6.89

H-index: 76

**Authorship pattern**

Table 2 explicates the authorship pattern of contributions. Out of 11554 contributors, a single author has contributed 15.94 per cent of the total articles. 29.10 per cent of the contributions were published with two authors, 26.27 per cent of the contributions were contributed by three authors.15.9 % of the contributions were published by four authors, 7.25 per cent of the contributions were published by five authors, 3.02 per cent of the contributions were published by six authors and 1.46 per cent of the contributions were published by seven authors. A significant note of the study is that the majority of the articles are contributed by multiple authors

**Table 2: Authorship pattern**

#	Authorship Pattern	Records	%
1	Single Author	992	15.94
2	Double Authors	1811	29.10
3	Three Authors	1635	26.27
4	Four Authors	938	15.09
5	Five Authors	451	07.25
6	Six Authors	188	03.02
7	Seven Authors	91	01.46
8	Eight Authors	45	00.72
9	Nine Authors	27	00.43
10	Ten and Above Authors	45	00.72
	Total	6242	100

**Research Article**

**Shows single Vs Multi Authors**

It is found from the study that multiple authors' research is ensured between the authors research as 94.06% of publications made by multiple authors.

**Table 3: Shows single Vs Multi Authors**

	Authorship Pattern	Records	%	Cum %
1	Single Author	992	15.94	-
2	Multiple Authors	5232	94.06	100
Total		6224	100	

**Ranking of Authors**

Table 4 indicates ranking of authors by number of publications. Authors "Billinton R " published highest number of articles for the study period with 44 records with 801 Global Citation Scores, next author Singh B has published next highest number of articles for the study period with 39 records with 64 Global Citation Scores and followed by others. Pena R having 35 Publications for 1230 highest Global Citation Scores followed by Publications having 44 Publications 801 Global Citation Score.

**Table: 4 Ranking of Authors (Top 15 Authors)**

#	Author	Records	%	TLCS	TLCS/t	TLCSx	TGCS	TGCS/t	TLCR
1	Billinton R	44	0.7	329	36.43	220	801	96.91	134
2	Singh B	39	0.6	33	8.21	13	64	18.67	96
3	Pena R	35	0.6	363	36.35	307	1230	125.70	70
4	Cardenas R	33	0.5	173	25.16	129	547	85.45	68
5	Chen Z	31	0.5	166	24.27	126	773	111.99	77
6	Senjyu T	31	0.5	28	4.13	23	111	21.05	37
7	Clare J	30	0.5	133	20.61	103	469	77.30	68
8	Joos G	29	0.5	64	11.65	46	172	33.17	51
9	Kaldellis JK	29	0.5	176	30.53	80	427	86.08	185
10	Funabashi T	24	0.4	25	3.65	21	108	20.57	22
11	Muljadi E	24	0.4	55	4.49	52	181	15.46	8
12	Abbey C	23	0.4	54	9.25	40	144	26.23	39
13	Asher G	23	0.4	114	16.15	85	419	66.07	44
14	Barthelmie RJ	23	0.4	93	13.36	67	334	52.22	48
15	Sourkounis C	22	0.4	1	0.33	1	10	2.91	0

**Citation map of R. Pena and A. Bejan (Highly Cited Papers)**

Pena, R. *et al.*, (University Nottingham, Dept. Electrical & Electronic Engineering, University PK, Nottingham Ng7 2rd, England) has published only 35 papers in the field of wind energy and the single paper has received 596 citations, Bejan, A, (Duke University, Dept Mechanical Engineering & Material Science, Durham, NC 27708, USA) paper having 489 citations and followed by other researchers.

Astrophysical magnetic fields and nonlinear dynamo theory Doubly fed induction generator using back-to-back PWM converters and its application to variable-speed wind-energy generation Author(s):, Pena R; Clare JC; Asher GM Source: IEE PROCEEDINGS-ELECTRIC POWER APPLICATIONS Volume: 143 Issue: 3 Pages: 231-241 Published : 1996 MAY Times Cited:596 Entropy generation minimization: The new thermodynamics of finite-size devices and finite-time processes Author: Bejan, A, Source: JOURNAL OF APPLIED PHYSICS 79 (3): Volume: 73 Issue: 3 Pages: 1191-1218 Published:1 FEB 1996 Times Cited:489





**Research Article**

**Table 5: Journal wise Distribution of Publications Top (20 Journals)**

#	Journal	Records	%	TLCS	TLCS/t	TGCS	TGCS/t	TLCR
1	Renewable Energy	442	7.1	1996	305.65	4873	823.76	905
2	Renewable & Sustainable Energy Reviews	249	4.0	961	216.80	3183	755.87	1340
3	Energy Policy	194	3.1	527	97.10	2397	445.62	404
4	IEEE Transactions on Energy Conversion	179	2.9	1528	203.72	4559	620.61	394
5	Energy	104	1.7	298	70.41	1058	252.41	467
6	Wind Energy	98	1.6	138	29.35	698	135.14	182
7	Energy Conversion and Management	95	1.5	565	80.79	1149	177.94	461
8	Applied energy	79	1.3	362	95.52	917	268.35	500
9	IEEE Transactions on Power Systems	74	1.2	315	50.88	1274	201.35	185
10	Journal of Wind Engineering and Industrial Aerodynamics	65	1.0	293	29.00	690	86.09	81
11	International Journal of Hydrogen Energy	60	1.0	103	24.39	547	117.59	128
12	2011 IEEE Power and Energy Society General Meeting	57	0.9	0	0.00	0	0.00	47
13	2012 IEEE Power and Energy Society General Meeting	46	0.7	0	0.00	0	0.00	60
14	Electric Power Systems Research	46	0.7	73	15.20	348	73.19	105
15	IEEE Transactions on Industrial Electronics	42	0.7	197	42.29	1091	269.70	156
16	2008 IEEE Power & Energy Society General Meeting, vols 1-11	39	0.6	0	0.00	1	0.20	34
17	Journal of Geophysical Research-Space Physics	39	0.6	21	1.38	986	102.90	22
18	Desalination	37	0.6	121	14.84	502	67.76	96
19	IEEE Power and Energy Society General Meeting 2010	35	0.6	0	0.00	0	0.00	27
20	Journal of Solar Energy Engineering-Transactions of the ASME	35	0.6	49	4.17	182	22.27	14

***Institution wise Distribution of Publications***

Table 6 gives the leading institutions researching on pheromones. Indian Institute of Technology, Delhi ranks first with 91 contributions (1.5 %) followed by Chinese Academic Science, National Renewable Energy Lab and so on. In all 3154 institutions have contributed the 6224 publications during the period of 1993–2012.

**Table 6: Institutions wise Distribution of Publications (Top 15 Institutions)**

#	Institutions	Records	%	TLCS	TGCS
1	Indian Inst Technological	91	1.5	154	482
2	Chinese Academic Science	57	0.9	22	448
3	National Renewable Energy Lab	55	0.9	145	715
4	Delft University Technological	49	0.8	78	280
5	University Aalborg	46	0.7	144	753
6	University Saskatchewan	42	0.7	249	660
7	Istanbul Tech University	40	0.6	294	488
8	Riso Natl Lab	37	0.6	148	572
9	King Fahd University Petr & Minerals	36	0.6	238	480
10	University New Brunswick	34	0.5	77	168
11	McGill University	32	0.5	82	662
12	National Tech University Athens	32	0.5	88	299
13	University Carlos III Madrid	32	0.5	117	644
14	University Ryukyus	32	0.5	28	111
15	Leibniz University Hannover	30	0.5	10	36

**Research Article**

**Table 7: Geographical Collaboration wise Distribution of Publications (Top 50 Country)**

#	Country	Recs	%	TLC S	TGCS	#	Country	Recs	%	TLCS	TGCS
1	USA	949	15.2	1363	9972	26	Algeria	55	0.9	82	253
2	Unknown	701	11.3	605	2580	27	Saudi Arabia	54	0.9	247	543
3	China	602	9.7	392	1884	28	Norway	52	0.8	62	451
4	UK	394	6.3	1083	5606	29	Ireland	47	0.8	100	415
5	Canada	386	6.2	1013	4296	30	Chile	46	0.7	182	690
6	Germany	328	5.3	400	1852	31	Belgium	44	0.7	60	326
7	India	312	5.0	499	1992	32	Malaysia	41	0.7	64	171
8	Turkey	261	4.2	1550	3048	33	Mexico	40	0.6	71	227
9	Spain	257	4.1	611	2650	34	Poland	40	0.6	20	283
10	Japan	171	2.7	122	1340	35	Singapore	38	0.6	52	162
11	Denmark	157	2.5	341	1753	36	South Africa	34	0.5	33	111
12	France	151	2.4	198	1278	37	Russia	33	0.5	27	153
13	Greece	135	2.2	511	1770	38	New Zealand	30	0.5	15	119
14	Italy	134	2.2	167	866	39	Switzerland	29	0.5	21	300
15	Australia	123	2.0	235	1078	40	Finland	27	0.4	16	182
16	Netherlands	104	1.7	209	1157	41	Tunisia	26	0.4	46	100
17	Iran	88	1.4	171	384	42	Jordan	25	0.4	58	144
18	Portugal	86	1.4	88	407	43	Austria	23	0.4	17	305
19	Romania	82	1.3	35	152	44	Croatia	22	0.4	14	48
20	Taiwan	79	1.3	134	433	45	Nigeria	22	0.4	59	101
21	Brazil	76	1.2	68	645	46	Thailand	21	0.3	1	12
22	South Korea	75	1.2	60	365	47	Lithuania	19	0.3	16	50
23	Egypt	72	1.2	51	159	48	Lebanon	18	0.3	111	249
24	Argentina	67	1.1	118	478	49	Oman	17	0.3	18	73
25	Sweden	58	0.9	172	568	50	Hungary	16	0.3	26	65

**Findings and Conclusion**

The research has been undertaken to assess the research productivity of researchers on Wind Energy Literatures. The findings of the study lead to the following observations:

- The findings of the year wise distribution of research output on Wind Energy bring out the fact that the highest publication is 916 in the year 2012 with 555 Global Citation Scores, there is consistent growth in terms of research publications from 1993 to 2005. The average citation per article is 6.89 and the h-index of the medicinal plants research is 76.
- A large number of research institutions 3154 have contributed the wind energy research in India, while the top 15 institutions contribute 14.2 percent of the total research output for the study period.
- The finding of the source wise distribution of research output brings out the fact that the journal articles occupied the predominant place among the other sources of publications.
- The finding of the ranking of journals brings out the fact that the highest numbers of publications were 442 (7.1%) published in Journal of Renewable Energy. As the top 20 Journals contribute 32.4% percent of the total literature (2015 articles) among the 1572 journals, it proves the applicability of Bradford's law of scattering.
- Pena, R. *et al.*, (University Nottingham, Dept. Electrical & Electronic Engineering, University PK, Nottingham Ng7 2rd, England) has published only 35 papers in the field of wind energy and the single paper has received 596 citations, Bejan, A, (Duke University, Dept Mechanical Engineering &

### **Research Article**

Material Science, Durham, NC 27708, USA) paper having 489 citations and followed by other researchers.

This study has highlighted quantitatively the contributions made by the Indian researchers during 1993-2012 as reflected in Web of Science database. During 20 years period (1993 - 2012) Indian contributions in terms of number of publications is significant. A comparison of Indian output in relation to the world output may help in understanding the contribution in a better angle. It is to conclude that the sum of citations of the wind energy research publications and the h-index scored is good. A notable attribute of this study is that, this Collaboration really stipulates/ induces fruitful research for the researcher. Since, the database found contributions only from 1993, that the research begins during the period.

### **REFERENCES**

**Kanagarasu R and Jeyapragash (2014)**, The Global Perspective of Open Source Software Research: A Scientometric study. *International Journal of Library Science* **10**(1) 36-44.

**Poornima A, et al.**, (2011), Mapping the Indian research productivity of food science and technology: Ascienceometric analysis. *Food Biology* **1**(1)36-41

**Srinivasa Ragavan S, Surulinathi M and Neelakandan B** (2012), Indian Perspective of Medicinal Plant Research: A Scientometric Study. *International Journal of Plant, Animal and Environmental Science* **2**(3)195-203.

**Surulinathi M, Balasubramani R and Kalsdha** (2013), Continent wise Analysis of Green Computing Research: A Scientometric Study. *Journal of Advances in Library and Information Science* **2**(1) 39-44.

**Velvizhi J, et al.**, (2011), Scientometric profile of solar energy research in India. *Recent Research in Science and Technology* **3**(10) 112-117