Indian Journal of Information Sources and Services
ISSN: 2231-6094 (P) Vol.4 No.1, 2014, pp.51-58

DOI: https://doi.org/10.51983/ijiss.2014.4.1.397

Performance of Research Productivity on Green Energy in India: A Scientometric Study

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(Received on 18 January 2014 and accepted on 25 March 2014)

Abstract - **The study examines Green Energy Research in India as revealed by the scholarly publication indexed in web of science (WoS) for a period of fifteen years from 1999 to 2013. It was seen that the analyses included research growth, author productivity, authorship pattern, geographical distribution of the literature, citation analysis rank, global publications'share, citation impact, share of international collaborative papers and major collaborative partner countries and patterns of research communication in most productive journals. It also analyses the characteristics of most productive institutions, authors and high-cited papers.**

Keyword: **Green Energy, Scientometric, Citation, India**

I. Introduction

Green energies have a huge potential and can, theoretically, provide an unlimited supply of relatively clean and mostly local energy. In absolute terms, renewable energy supply has been growing strongly; albeit from a very low base. Green energy is closely associated with the concept of sustainable development introduced to the broad public in the report "Our Common Future" published in 1987 by the World Commission on Environment and Development chaired by Gro-Harlem Brundtland. The concept is defined in the report as: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Green is a term used for forms of energy which are not exhausted by use over time. It means that the renewable resources can be regenerated or renewed in a relatively short time. This Handbook focuses on the following leading renewable resources: biomass, wind, geothermal, solar and hydro. Industrial heat recovery power (IHRP) is a fairly novel approach to improving industrial energy efficiency by means of power generation, and in the US it is now included in the Renewable Energy Portfolio Standards. The sources of renewable energy can be divided, according to their origin, into natural renewable resources (wind, geothermal, solar, hydro, etc.) and renewable resources resulting from human activity (biomass, including landfill gas and industrial heat recovery power).

The scientometric studies play a vital role in the process of information research. Scientometric studies have shown that all the pieces of published information do not have equal importance. Present study focuses attention on the growth of literature, authorship pattern, journal coverage, institutions involved in active research etc. Citation studies are recognized as an indicator of influence of published work on the scientific community. This study attempts to analysis the performance of Green Energy research output in terms of its content and coverage, growth rates, areas of research concentration, author productivity, and authorship pattern, journals and articles and other means of assisting the peer review procedure. Performance of research institutions in promotion of Green Energy research is also given due emphasis.

II. Objectives of The Study

The main objective of this study is to examine the current status of Indian Green Energy, as reflected in the country research output during 1999-2013.The researcher has framed the following objectives for the purpose of present research.

1. To identify and analyse the rate of growth of research productivity;
2. To examine the Year-wise distribution of publications;
3. To identify the Document-wise distribution of publications output;
4. To analyse the authorship pattern and examine the extent of research collaboration and ranking of authors based on publications output;
5. To identify journal-wise distribution of publications output;
6. To identify word-wise distribution of publications output;
7. To assess the Institution-wise research concentration;
8. To identify Country-wise Collaborative Distribution of Publications.

III. Methodology

The study entitled "Research Activities on Green Energy in India: A Scientometric Analysis" is a study encompassing records output on Science from Science Citation Index (SCI) available on online (Web of Science). The present study aims at analysing the research output of Researchers in the field of Green Energy. The growth rates of output in terms of research productivity is analysed from 1999 to 2013. The authorship pattern and author productivity are examined to identify the pattern of research contribution in the field of Green Energy.The data has classified into Histcite Software. The data so retrieved were downloaded and later imported into a database management system for data cleaning and coding. In data cleaning, all duplicate records as well records pertaining to publication years not under the purview of our study, were eliminated. It is also analytical in nature in strengthening the empirical validity due to application of suitable statistical tools.

A. Data Collection

The basic publication data used in this study is derived from the Expanded Version of Science Citation Index (SCI) database, available in Web of Science. The raw publications data along with their citations has been downloaded from the Web of Science in May 2013. Publications data for 15 years from 1999 to 2013 were used for analyzing the growth and impact of Green Energy research.

IV. Data Analysis

The table I depicts the Green Energy research output in the Indian level. From the below table, we could clearly see that during the period 1999 - 2013 a total of 1105 publications were published. In the present study the research output on Green Energy publication is taken as a tool to evaluate the performance at various levels.

Table I Shows Year Wise Distribution of Publication and Citation Scores

Sl.No.	Year	No. of Papers	% of Papers	TLCS	TGCS
1	1999	18	1.6	4	83
2	2000	27	2.4	11	461
3	2001	27	2.4	13	1170
4	2002	22	2.0	14	329
5	2003	27	2.4	11	895
6	2004	38	3.4	19	964
7	2005	52	4.7	26	896
8	2006	46	4.2	26	767
9	2007	77	7.0	45	1295
10	2008	88	8.0	34	1275
11	2009	116	10.5	57	1439
12	2010	123	11.1	49	1241
13	2011	166	15.0	41	719
14	2012	189	17.1	9	170
15	2013	89	8.1	1	13
	Total	1105	100		

Table I shows that a chronological histogram of citations, demonstrating that citation frequency grew steadily from 1999; it reached a maximum GCS of 1439 in 2009 and LCS of 57 in 2009. The highest publication is 189 in 2012 with 170 Global Citation Scores followed by 166 papers in 2011 with 719 Global Citation Score and 123 papers in 2010 with 1241 Global Citation Scores. The lowest publication is 18 in 1999 with 83 Global Citation Scores. It shows that even minimum numbers of records were scored higher global citations. The study also reveals all these 1105 publications

have 34493 cited references it shows that there is a healthy trend in citing reference is found among the Indian Scientists belongs to Green Energy.

A study of data in table II indicates the Document-wise distribution of research output in Green Energy. This study has observed a total of 1105 publications in Green Energy during the period of fifteen years from 1999 to 2013. Out of various sources of publications in Green Chemistry, journal articles that appeared in the journals have shown a predominant contribution (91.9%) with Global citation score is 10076 and this source occupies the first position. The source of review comes second in order (4.5%) of sharing total research output in Green Energy during the period of analysis. The source of proceeding papers comes in the third position (3.2%) with respect to total output in Green Energy research during the study period.

Table II Shows Document-Wise Distribution of Publications

Sl.No.	Document Type	Recs	Cum	%	%Cum	TLCS	TGCS
1	Article	1016	-	91.9	-	349	10076
2	Review	50	1066	4.5	96.47	8	1417
3	Article; Proceedings Paper	35	1101	3.2	99.63	3	220
4	Editorial Material	2	1103	0.2	99.81	0	1
5	Meeting Abstract	1	1104	0.1	99.90	0	0
6	Review; Book Chapter	1	1105	0.1	100	0	3
	Total	1105		100		360	11717

The authorship pattern in green energy literature reveals the following facts. The present study brings papers under analysis contributed by one author to ten authors.Table III indicates that the three author's papers rank first in order (27.76%), where as two authors papers obtain the second order of priority (25.70%) and four authors papers obtain the third order of priority (18.64%). The single author papers record the seventh order of priority (5.33%). The present study brings papers under analysis contributed by one author to ten authors. It is noticed that from four author papers to ten authors' papers, the trend in number of publications has reduced. It is noticed that from five authors to ten authors papers, the trend in number of publication has reduce.

Table III Shows Distribution of Authorship Patten

Authorship Patten	Publications	Cum. output	%	Cum %
Single Author	59	59	5.33	5.33
Double Author	284	343	25.70	31.04
Three Authors	307	650	27.78	58.82
Four Authors	206	856	18.64	77.46
Five Authors	110	966	9.95	87.42
Six Authors	64	1030	5.79	93.21
Seven Authors	28	1058	2.53	95.74
Eight Authors	18	1076	1.62	97.37
Nine Authors	14	1090	1.26	98.64
Ten & above	15	1105	1.35	100
Total	1105		100	

TABLE IV SHOWS RANKING OF AUTHORS PRODUCTIVITY

S.No.	Author	Recs	%	Cum	TLCS	TLCS/t	TLCSx	TGCS	TGCS/t	TLCR
1	Rai SB	29	2.6	-	15	2.53	4	269	53.84	12
2	Kumar R	23	2.1	52	15	2.96	4	147	26.52	7
3	Kumar A	18	1.6	70	2	0.31	1	112	17.95	4
4	Maiti SK	15	1.4	85	6	1.20	0	106	21.62	6
5	Buddhudu S	14	1.3	99	4	0.49	0	165	20.33	4
6	Kanoria M	14	1.3	113	18	3.27	0	61	11.70	20
7	Rout GC	14	1.3	127	10	1.46	0	41	7.38	10
8	Singh A	12	1.1	139	10	3.00	4	71	17.32	8
9	Tyagi AK	12	1.1	161	1	0.33	0	45	11.92	1
10	Ajay	11	1.0	172	5	0.57	0	21	1.95	5
11	Karmakar B	11	1.0	183	19	2.81	1	162	28.61	19
12	Ahmed J	10	0.9	193	26	2.03	9	229	19.44	16
13	Chowdhury S	10	0.9	203	27	7.67	0	203	58.67	36
14	Rai DK	10	0.9	213	8	1.20	2	134	22.25	3
15	Shivhare US	10	0.9	223	21	1.61	7	201	17.35	16
16	Yadav GD	10	0.9	233	4	0.92	0	68	11.85	4
17	Behera SN	9	0.8	242	8	1.11	0	28	4.40	4
18	Ghosh S	9	0.8	251	0	0.00	0	22	4.21	2
19	Kakani SL	9	0.8	260	4	0.70	0	7	1.23	4
20	Mukhopadhyay S	9	0.8	269	7	1.03	5	41	6.99	2
21	Das S	8	0.7	277	1	0.11	0	104	17.69	1
22	Dwivedi Y	8	0.7	285	4	0.98	0	55	12.55	4
23	Kumar S	8	0.7	293	1	0.20	1	48	10.70	0
24	Mittal A	8	0.7	301	21	3.08	12	389	64.35	11
25	Saha P	8	0.7	309	26	7.25	1	196	55.33	19
26	Singh SK	8	0.7	317	3	0.45	1	65	12.07	2
27	Som T	8	0.7	325	9	1.77	0	118	23.82	17
28	Dhar A	7	0.6	332	1	0.17	0	217	37.74	1
29	Giri NK	7	0.6	339	3	0.58	2	92	17.28	2
30	Gupta N	7	0.6	346	1	0.25	0	66	10.67	8
31	Jayasankar CK	7	0.6	353	3	0.54	2	47	8.98	4
32	Kumar K	7	0.6	360	2	0.48	1	67	14.95	2
33	Ningthoujam RS	7	0.6	367	3	0.75	0	55	14.75	4
34	Quraishi MA	7	0.6	374	7	2.25	1	44	11.00	6
35	Rai A	7	0.6	381	3	0.53	1	65	12.62	2
36	Singh P	7	0.6	388	2	0.60	1	31	5.60	6
37	Adhikari AV	6	0.5	394	8	1.05	0	65	9.65	7
38	Annapurna K	6	0.5	400	3	0.60	2	37	5.51	2
39	Das D	6	0.5	406	3	0.49	3	736	63.56	0
40	Dutta DP	6	0.5	412	0	0.00	0	20	4.83	0
41	Joshi SK	6	0.5	418	3	0.26	1	35	2.68	0
42	Karmakar SN	6	0.5	424	0	0.00	0	15	4.07	2
43	Kumar M	6	0.5	430	3	1.00	3	21	6.92	1
44	Kumar P	6	0.5	436	0	0.00	0	36	8.50	1
45	Mittal J	6	0.5	442	12	1.95	5	292	46.10	7
46	Rai VK	6	0.5	448	2	0.25	0	52	9.26	2
47	Sharma RK	6	0.5	454	1	0.25	0	14	4.66	2
48	Singh AK	6	0.5	460	11	1.99	4	87	16.03	0
49	Singh K	6	0.5	466	3	0.34	0	39	6.14	5
50	Singh S	6	0.5	472	0	0.00	0	15	3.33	0

Table V Distribution of Green Energy in Journal Publications

Sl. No.	Journal	Recs	%	TLCS	TLCS/t	TGCS	TGCS/t	TLCR
1	Journal of Buminescence	23	2.1	11	2.24	249	47.03	10
2	Spectrochimica Acta Part A-Molecular And Biomolecular Spectroscopy	22	2.0	5	0.85	116	20.63	19
3	Journal of Applied Physics	19	1.7	0	0.00	175	34.80	3
4	Indian Journal of Animal Sciences	18	1.6	1	0.07	15	1.25	4
5	Physica B-Condensed Matter	18	1.6	15	3.04	106	18.47	9
6	Journal of Hazardous Materials	17	1.5	26	3.99	825	136.26	5
7	Materials Letters	14	1.3	3	1.17	126	20.17	2
8	Journal of Alloys And Compounds	12	1.1	4	0.53	266	46.37	2
9	Colloids and surfaces B-biointerfaces	11	1.0	6	2.42	66	21.25	8
10	Indian Journal of Pure & Applied Physics	11	1.0	2	0.27	22	3.54	2
11	Materials Chemistry And Physics	11	1.0	10	1.85	283	36.86	2
12	Asian Journal of Chemistry	10	0.9	0	0.00	0	0.00	5
13	Asian-Australasian Journal of Animal Sciences	10	0.9	6	0.56	52	4.66	1
14	Digest Journal of Nanomaterials And Biostructures	10	0.9	11	2.35	99	22.43	3
15	Journal of Chemical Physics	10	0.9	1	0.08	107	11.46	1
16	Journal of Thermal Stresses	10	0.9	10	1.86	77	10.59	14
17	Optical Materials	10	0.9	9	1.69	123	17.17	4
18	Journal of Food Science And Technology-Mysore	9	0.8	2	0.13	16	2.57	0
19	Journal of Physical Chemistry C	9	0.8	3	0.50	222	39.57	0
20	Physica C-Superconductivity And Its Applications	9	0.8	4	0.42	17	2.19	4
21	Renewable & Sustainable Energy Reviews	9	0.8	1	0.20	247	60.05	1
22	Solid State Communications	9	0.8	6	1.16	64	11.75	3
23	Current Science	8	0.7	1	0.20	44	6.80	1
24	Energy Conversion And Management	8	0.7	2	0.17	143	12.15	3
25	International Journal of Hydrogen Energy	8	0.7	3	0.30	772	67.22	2
26	Journal of Materials Chemistry	8	0.7	1	0.33	113	17.54	3
27	Journal of Superconductivity And Novel Magnetism	8	0.7	4	0.70	7	1.23	4
28	Physical Review B	8	0.7	1	0.07	68	9.30	0
29	Applied Surface Science	7	0.6	0	0.00	56	11.85	2
30	Bioresource Technology	7	0.6	1	0.33	100	31.79	0
31	Ceramics International	7	0.6	0	0.00	15	3.73	0
32	Journal of Materials Science	7	0.6	2	0.48	22	4.67	1
33	Materials Research Bulletin	7	0.6	1	0.09	66	10.27	1
34	Applied Physics B-Lasers And Optics	6	0.5	1	0.17	90	12.51	1
35	Dalton Transactions	6	0.5	1	0.33	30	8.11	3
36	Journal of Food Engineering	6	0.5	9	0.64	176	20.43	7
37	Journal of Nanoparticle Research	6	0.5	3	1.00	22	7.50	0
38	Journal of Nanoscience And Nanotechnology	6	0.5	0	0.00	8	2.20	1
39	Journal of Physical Chemistry A	6	0.5	2	0.42	35	8.16	3
40	Journal of The Electrochemical Society	6	0.5	1	0.14	97	14.09	1
41	physica e-low-dimensional systems & nanostructures	6	0.5	3	0.64	23	3.98	7
42	Pramana-Journal of Physics	6	0.5	1	0.17	19	3.23	0
43	Chemical Engineering Journal	5	0.5	11	3.00	94	25.25	9
44	Chemical Physics Letters	5	0.5	1	0.14	121	18.37	1
45	Colloids And Surfaces A-Physicochemical And Engineering Aspects	5	0.5	6	1.50	51	13.42	2
46	Crystal Growth & Design	5	0.5	0	0.00	98	15.79	0

Table IV indicates ranking of authors by number of publications. Authors “Rai SB” published highest number of articles for the study period with 29 records; next consecutive authors Kumar R is published next highest number of articles for the study period with 23 records. Das Dhaving highest Global Citation Scores of 736 with just 6 publications followed by Mittal.A having Global Citation Score of 389 with just 8 publications, while Kakani SL having lowest Global Citation Score of 7 with just 9 publications. Thus the most-cited authors are distinguished from the most-published ones. It is found from the analysis that Lotka’s law may not be applicable with regard to author productivity in proliferation of research in Green Energy as the research papers equally distributed by a large number of authors.

The study found that the total research output of the Green Energy for the study period (1999 – 2013) published in 86 journals. As the major portion of the research productivity (27.8%) covered by 25 journals that is coincide with the theory of Bradford’s Law of scattering of journals in research productivity. Top ten produced mostly 15% of the research output. The journal “JOURNAL OF LUMINESCENCE” topped with 23 publications with the Global Citation Score of 249, next “SPECTROCHIMICA ACTA PART A-MOLECULAR AND BIOMOLECULAR SPECTROSCOPY” has 22 publications with the Global Citation Score of 116 and “JOURNAL OF APPLIED PHYSICS” with 19 publications with the Global Citation Score of 175 respectively. “JOURNAL OF HAZARDOUS MATERIALS” has scored the highest Global Citation Score of 825 with 17 publications while “INDIAN JOURNAL OF PHYSICS AND PROCEEDINGS OF THE INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE” has scored a Global Citation Score of 2 with just 5 records.

Key Word is one of the best indicators to understand and grasp instantaneously the thought content of the papers,

Table VI Key Word Appeared in The Publications

Sl.No.	Word	Recs	Percent	TLCS	TGCS
1	GREEN	178	16.1	132	2140
2	SYNTHESIS	128	11.6	41	1040
3	ENERGY	109	9.9	20	796
4	PROPERTIES	105	9.5	26	804
5	NANOPARTICLES	94	8.5	41	635
6	USING	91	8.2	49	887
7	EFFECT	88	8.0	15	431
8	DOPED	86	7.8	52	834
9	OPTICAL	62	5.6	17	465
10	SILVER	51	4.6	23	285
11	EMISSION	50	4.5	12	653
12	LIGHT	48	4.3	9	508
13	ZNO	47	4.3	11	929
14	CHARACTERIZATION	46	4.2	15	298
15	BASED	45	4.1	9	170
16	STRUCTURAL	44	4.0	5	223
17	PRODUCTION	43	3.9	11	1131
18	LUMINESCENCE	41	3.7	15	300
19	AQUEOUS	39	3.5	34	731
20	PHOTOLUMINESCENCE	38	3.4	8	329
21	EXTRACT	37	3.3	29	258
22	GLASS	37	3.3	22	375
23	UPCONVERSION	37	3.3	30	451
24	TEMPERATURE	36	3.3	12	179

methodologies used and areas of research addressed to the high frequency keywords were "GREEN" is topped with 178 publications with the Global Citation Score of 2140, next "SYNTHESIS" with the Global Citation Score of 1040 respectively. "GREEN" has scored the highest Global Citation Score of 2140 with 178 publications. The high frequency keywords appeared more than five times.

In general, institutions which are specifically meant for research activities would contribute a greater level of research publications and it is not up to the mark of desired level of expectations in other institutions.The below given table VII analysis indicates Institution-wise research productivity. It is noted that 860 institutions were contributed 1105 of the total research productivity. It is noted that Central Green Energy Research Institute contributed the highest number of research publications (116) at the same time it ranks first in terms of Global Citation Score 2031.

Table VII Institution-Wise Distribution of Publications

Sl.No.	Institution	Recs	Percent	TLCS	TGCS
1	Indian InstTechnol	116	10.5	38	2031
2	Banaras Hindu Univ	49	4.4	29	428
3	Indian InstSci	36	3.3	9	826
4	Bhabha Atom Res Ctr	34	3.1	5	140
5	Sri VenkateswaraUniv	33	3.0	10	277
6	Univ Delhi	27	2.4	7	224
7	CSIR	22	2.0	7	324
8	SahaInstNuclPhys	22	2.0	7	288
9	Indian AssocCultivatSci	20	1.8	3	326
10	Univ Calcutta	20	1.8	18	80
11	NatlPhys Lab	18	1.6	3	102
12	Anna Univ	17	1.5	3	585
13	NatlInstTechnol	17	1.5	9	161
14	GovindBallabh Pant UnivAgr&Technol	16	1.4	7	36
15	Univ Pune	16	1.4	4	87
16	Indian Vet Res Inst	15	1.4	1	35
17	Cent Glass & Ceram Res Inst	13	1.2	19	236
18	Jawaharlal Nehru CtrAdvSci Res	13	1.2	2	209
19	NarasinhaDuttColl	13	1.2	6	84
20	Guru Nanak DevUniv	12	1.1	25	179
21	Indian InstTechnol Guwahati	12	1.1	7	280

The study of Country-wise distribution of a number of research output is an important factor in highlighting the research and development in any discipline of science. In this context, the analysis of performance of Indian Green Energy scientists is quite obvious with a view to reflect their achievements in attracting the attention of foreigners in terms of published research articles in the journals of various countries.

The below table VIII indicates that among the country-wise distribution of Green Energy covered by the study tops India with 1088(98.5%) publications followed by United States of America with 44(4.0%), South Korea with 24(2.2%), Japan with 22(2.0%) and Germany with 17(1.5%) research publications respectively. First place goes to India having total Global Citation Score of 11617 with1088 publications. South Korea secured second rank in terms of GCS with 66 but with only 14 publications and also collaboration with more than 40 Countries.

TABLE VIII COUNTRY-WISE DISTRIBUTION OF PUBLICATIONS

Sl.No.	Country	Recs	Percent	TLCS	TGCS
1	India	1088	98.5	359	11617
2	USA	44	4.0	9	1294
3	South Korea	24	2.2	5	75
4	Japan	22	2.0	3	333
5	Germany	17	1.5	0	501
6	Canada	14	1.3	17	439
7	Unknown	14	1.3	1	80
8	UK	11	1.0	3	261
9	France	10	0.9	0	57
10	Taiwan	9	0.8	0	55
11	Brazil	8	0.7	0	99
12	Saudi Arabia	7	0.6	3	52
13	South Africa	7	0.6	3	73
14	Spain	6	0.5	1	38

V. CONCLUSION

It conclued quantitatively the contributions made by the Indian researchers during 1999-2013 as reflected in Web of Science database. During 15 years period (1999-2013) 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. Though the records available in the Web of Science database reveal a small number, it is important that the Web of Science covers only the peer-reviewed journals. If a broader coverage database is available, it may provide a reasonable number of papers. Researcher suggest for tracking citation record of papers so that the impact of publications in Green Energy may be visible.

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