



Scientometric profile of solar energy research in India

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Abstract

An analysis of the Indian literature output scanned in Web of Science during 1999–2011 on solar energy research indicates that the growth of the literature. The area of solar fuels and Material sciences multidisciplinary has received maximum attention. Publication output of literature by different countries collaboration follows the trend in basic sciences with USA and South Korea being the major producers with India. The contribution of Indian Institutions and Global Citation Scores, h-index, g-index and gh-index has been analysed.

Keywords: Solar Energy; Citation Map; h-index; g-index; gh-index

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 solar energy. Solar energy is quite simply the energy produced directly by the sun 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 solar energy.

Objectives of the Study

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

- To analyse 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, g-index and gh-index

- To identify the highly cited papers in the field of Solar 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: 'solar energy'. 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] N_p papers have at least h citations each, and the other (N_p-h) papers have at most h citations each.

- **G-index:** The index is calculated based on the distribution of citations received by a given researcher's Publications.

$$\sqrt{hg}$$

- **Gh-index:**
- **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.

Growth of Literature

During the 13 years period (1999–2011) India has produced a total of 1422 publications. The highest number of publications was 237 in 2010. The average number of publications per year was 5.4%.

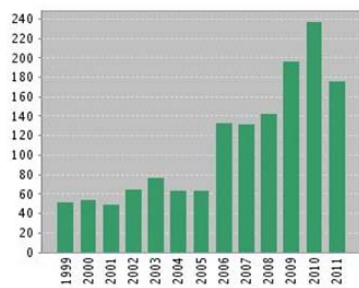
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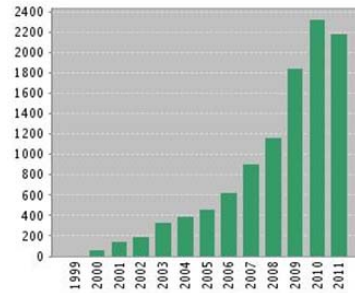
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Table 1 shows Growth of solar energy research and Citation Scores

#	Year	Records	%	Total LCS	Total GCS
1	1999	52	3.7	0	861
2	2000	54	3.8	0	868
3	2001	50	3.5	0	556
4	2002	65	4.6	0	734
5	2003	77	5.4	0	1035
6	2004	64	4.5	1	838
7	2005	64	4.5	0	1019
8	2006	130	9.1	5	1205
9	2007	130	9.1	0	1149
10	2008	140	9.8	2	1004
11	2009	183	12.9	0	902
12	2010	237	16.7	1	474
13	2011	176	12.4	0	48
Total		1422	100.00	9	10,693



Published Item in each year



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 41 because there are 41 articles with 41 or more citations in the file of solar energy.

Total No of Publications: 1422
 Sum of the Times Cited: 10675
 Times Cited without self-citations: 9601

Citing Articles: 8575
 Average Citations per Item: 7.55
H-index: 41

Document wise Distribution of Publications

During the 13 years period (1999–2011) Indian researchers have produced a total of 1422 publications. The highest numbers of publications were 1197 (84.2%) Journal articles and other publications were 123 (8.6%) Proceedings Paper, Review 98(6.9%), and followed by other source.

Table 2. Shows document wise distribution of Publications

#	Document Type	Records	%	TLCS	TGCS
1	Article	1197	84.2	6	7696
2	Article; Proceedings Paper	123	8.6	2	753
3	Review	98	6.9	1	2219
4	Letter	2	0.1	0	25
5	Editorial Material	1	0.1	0	0
6	Meeting Abstract	1	0.1	0	0
Total		1422	100.00	9	10,693

Authorship pattern

Table 3 explicates the authorship pattern of contributions. Out of 1422 contributors, a single author has contributed 6.6 per cent of the total articles. 30 per cent of the contributions were published with two authors, 24.6 per cent of the contributions were contributed by three authors.16.1 % of the contributions were published by four

authors, 8.2 per cent of the contributions were published by five authors, 5.6 per cent of the contributions were published by six authors and 3.1 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 3. Authorship Pattern of Contributions

#	Authorship Pattern	Records	%
1	Single Author	94	6.6
2	Double Authors	428	30.0
3	Three Authors	350	24.6
4	Four Authors	229	16.10
5	Five Authors	117	8.2
6	Six Authors	80	5.6
7	Seven Authors	45	3.1
8	Eight Authors	19	1.3
9	Nine Authors	26	1.8
10	Ten and Above Authors	34	2.3
Total		1422	100

It is found from the study that multiple authors' research is made by multiple authors. ensured between the authors research as 93.4% of publications

Table 4. Shows single Vs Multi Authors

#	Authorship Pattern	Records	%	Cum %
1	Single Author	94	6.6	
2	Multiple Authors	1328	93.4	100.00
Total		1422	100.00	

Ranking of Authors

Table 4 indicates ranking of authors by number of publications. Authors "Twari, GN" published highest number of articles for the study period with 70 records with 431 Global Citation Scores, next author Kumar, S has published next highest number of articles for

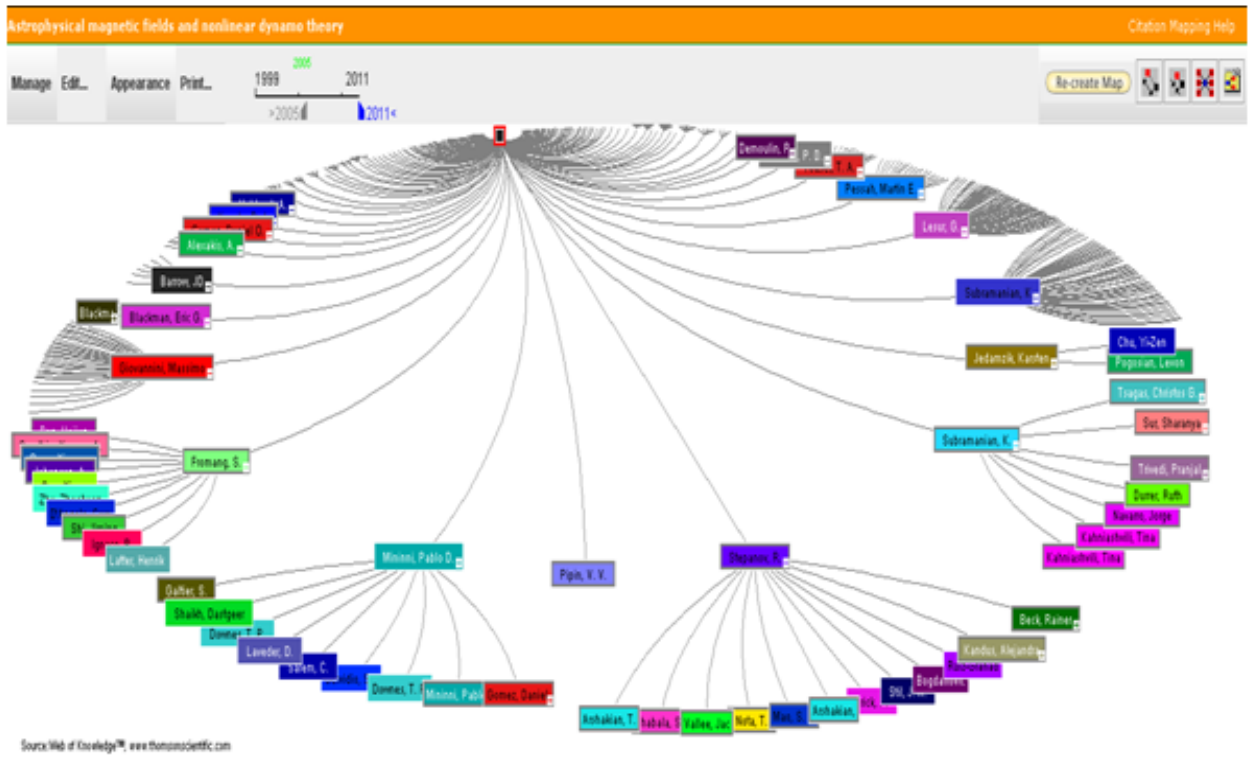
the study period with 31 records with 287 Global Citation Scores and followed by others. Twari GN having highest Global Citation Scores of 431 followed by Sharma GD having 26 Publications 105 Global Citation Score.

Table 5. Shows ranking of Authors

#	Author	Records	%	TLCS	TGCS	TLCR
1	Tiwari GN	70	4.9	0	431	0
2	Kumar S	31	2.2	0	287	0
3	Sharma GD	26	1.8	1	105	1
4	Gangotri KM	24	1.7	0	145	0
5	Kumar A	20	1.4	1	98	0
6	Sodha MS	19	1.3	0	182	0
7	Lakhina GS	18	1.3	0	182	0
8	Sharma R	17	1.2	1	64	1
9	Genwa KR	15	1.1	1	59	1
10	Jain R	15	1.1	0	38	0
11	Lokhande CD	15	1.1	0	293	0
12	Mikroyannidis JA	15	1.1	1	73	1
13	Sathyamoorthy R	15	1.1	0	72	0
14	Sharma SK	14	1.0	0	75	0
15	Bhosale CH	13	0.9	1	104	0
16	Han SH	13	0.9	0	186	0
17	Mane RS	13	0.9	0	196	0
18	Kumar P	12	0.8	0	34	0
19	Reddy KTR	12	0.8	0	119	0
20	Roy MS	12	0.8	0	73	0

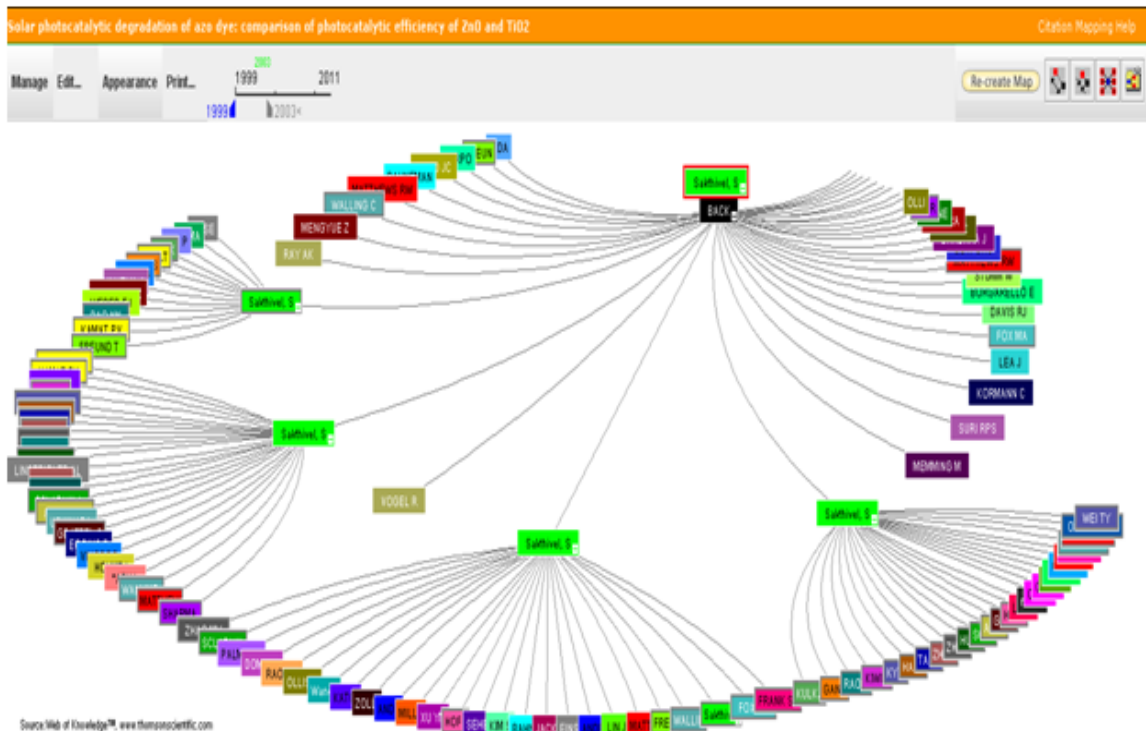
Citation map of K. Subramanian and S. Sakthivel (Highly Cited Papers)

Subramanian, K (Punjabi University, Inter University Centre Astronomy & Astrophysics, Pune- 411007, Maharashtra, India) has published only 6 papers in the field of solar energy and the single paper has received 303 citations, Sakthivel, S et al. (Anna University, Department of Chemistry, Madras 600025, Tamil Nadu, India) paper having 233 citations and followed by other researchers.



Astrophysical magnetic fields and nonlinear dynamo theory
Author(s): Brandenburg, A (Brandenburg, A); Subramanian, K (Subramanian, K) Source: PHYSICS REPORTS-REVIEW

SECTION OF PHYSICS LETTERS Volume: 417 Issue: 1-4 Pages: 1-209 Published: OCT 2005 Times Cited: 303



Solar photocatalytic degradation of azo dye: comparison of photocatalytic efficiency of ZnO and TiO₂ **Author(s):** Sakthivel, S (Sakthivel, S); Neppolian, B (Neppolian, B); Shankar, MV (Shankar, MV); Arabindoo, B (Arabindoo, B); Palanichamy, M (Palanichamy, M); Murugesan, V (Murugesan, V) **Source:** SOLAR ENERGY MATERIALS AND SOLAR CELLS Volume: 77 Issue: 1 Pages: 65-82 **Published:** APR 30 2003 **Times Cited:** 233

Journal wise Distribution of Publications

The below table-6 showed that analysis about the list of

Table 6. Journal wise Distribution of Publications

#	Journal	Records	%	TLCS	TGCS	TLCR
1	RENEWABLE ENERGY	58	4.1	0	411	0
2	SOLAR ENERGY MATERIALS AND SOLAR CELLS	56	3.9	2	823	0
3	SOLAR ENERGY	49	3.4	1	436	0
4	RENEWABLE & SUSTAINABLE ENERGY REVIEWS	46	3.2	1	582	2
5	ENERGY CONVERSION AND MANAGEMENT	44	3.1	0	334	0
6	DESALINATION	28	2.0	0	187	0
7	INTERNATIONAL JOURNAL OF ENERGY RESEARCH	27	1.9	0	124	0
8	ASTROPHYSICAL JOURNAL	25	1.8	0	603	0
9	APPLIED ENERGY	24	1.7	0	120	1
10	INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	23	1.6	0	185	0
11	SOLAR PHYSICS	22	1.5	0	170	0
12	JOURNAL OF ASTROPHYSICS AND ASTRONOMY	21	1.5	0	20	0
13	PHYSICAL REVIEW D	21	1.5	0	347	0
14	JOURNAL OF THE INDIAN CHEMICAL SOCIETY	19	1.3	1	42	0
15	ENERGY AND BUILDINGS	18	1.3	0	104	0
16	JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	18	1.3	0	196	0
17	JOURNAL OF PHYSICAL CHEMISTRY C	18	1.3	0	110	0
18	JOURNAL OF APPLIED PHYSICS	17	1.2	0	114	0
19	THIN SOLID FILMS	16	1.1	0	113	0
20	ASTRONOMY & ASTROPHYSICS	15	1.1	0	153	0

Institution wise Distribution of publications

Indian Scientists are accounts to 1422 Publications in the field of Solar Energy. The contributions of the Indian Institutions and Global Citation Scores, h-index, g-index and gh-index has been analysed and the same is shown in below table. Various institutions are contributed this specific subject research output. We have taken top 30 (twenty) productivity institution for this analysis and 10 Institutions for

journals publication of the area of solar energy search output. The researcher had taken top 20 publication journals. The "Renewable energy" journal has high publication, 411 global citation scores. The "Solar energy materials and solar cells" has 56 articles published, local citation score and 823 global citation scores. "Solar Energy" Journals are having with their publication number of article is 49 and the journal of "Solar Energy Materials and Solar Cells" is having highest (823) total global citation score among the 369 journals.

Scientometric index. By seeing the analysis, IIT's dominated the first place 218 Publications along with 1615 total global citation score based publication and citation respectively. Anna University is occupied second place with 831 total global citation score based on Citation Scores. Followed by Tata institute of fundamental research is stood the third place with 757 global citation score and followed by other Institution.

Table7. Institution wise Distribution of publications

#	Institution	Records	%	TLCS	TGCS
1	Indian Institute of Technology	218	15.3	1	1615
2	Jai Narnia Vyas University	66	4.6	2	321
3	Shivaji University	48	3.4	3	489
4	Anna University	43	3.0	0	831
5	Phys Research Lab	40	2.8	0	315
6	Tata Inst Fundamental Research	39	2.7	0	757
7	Indian Institute of Astrophysics	37	2.6	0	261
8	Banaras Hindu University	34	2.4	0	210
9	Indian Institute of Science	31	2.2	0	178
10	Natal Inst Technology	30	2.1	0	124
11	Natal Phys Lab	27	1.9	0	175
12	University of Delhi	27	1.9	0	140
13	Indian Assoc Cultivate Science	24	1.7	0	120
14	Indian Inst Geomagnetism	23	1.6	0	193
15	Indian Inst Technology Delhi	20	1.4	0	73
16	NASA	20	1.4	0	549
17	Jadavpur University	19	1.3	0	52
18	Alagappa University	18	1.3	0	155
19	Han yang University	18	1.3	0	191
20	Cent Electrochemical Research Institute	16	1.1	0	118
21	Devi Ahilya University	16	1.1	0	477
22	Kongunadu Arts & Science College	16	1.1	0	120
23	University of Patras	16	1.1	1	74
24	Bhabha Atom Research Centre	14	1.0	0	52
25	CALTECH	14	1.0	0	157
26	CSIR	14	1.0	0	191
27	Sri Venkateswara University	14	1.0	0	128
28	Vikram Sarabhai Space Centre	14	1.0	0	129
29	Cochin University of Science & Technology	13	0.9	0	113
30	Harish Chandra Research Institute	13	0.9	0	217

Table 8. Index in Scientometrics

#	Institution	Records	TGCS	h-Index	g-Index	gh Index
1	Indian Institute of Technology	218	1615	19	40	27
2	Jai Narain Vyas University	66	321	9	17	12
3	Shivaji University	48	489	12	22	16
4	Anna University	43	831	12	28	18
5	Phys Res Lab	40	315	10	17	13
6	Tata Institute of Fundamental Research	39	757	14	27	19
7	Indian Institute Astrophysics	37	261	9	16	12
8	Banaras Hindu University	34	210	9	14	11
9	Indian Institute of Science	31	178	9	13	10
10	National Institute Technology	30	124	6	11	8

Geographical Collaboration wise Distribution of Publications

It was feasible to analyse the articles under sample according to geographical distribution of Indian collaboration research with

more than 50 countries in the file of Solar Energy. Out of 1422 articles, the highest number i.e. 95 has been contributed with US professionals that is followed 463 Publications with South Korea.

Table 9. Geographical Collaboration wise Distribution of Publications

#	Country	Records	TGCS	#	Country	Records	TGCS
1	USA	95	1219	29	Malaysia	4	20
2	South Korea	61	463	30	Argentina	3	26
3	Japan	47	466	31	Egypt	3	9
4	UK	35	270	32	Saudi Arabia	3	6
5	Germany	32	540	33	Bulgaria	2	0
6	France	25	240	34	Chile	2	8
7	Greece	17	82	35	Iran	2	12
8	Italy	17	476	36	Portugal	2	30
9	Unknown	15	64	37	Singapore	2	0
10	Russia	14	69	38	Turkey	2	6
11	Switzerland	14	53	39	Algeria	1	1
12	Mexico	13	92	40	Bangladesh	1	2
13	Taiwan	12	153	41	Cyprus	1	0
14	Netherlands	11	63	42	Czech Republic	1	0
15	Canada	10	188	43	Ethiopia	1	8
16	Sweden	10	63	44	Hungary	1	0
17	Australia	9	35	45	Ireland	1	0
18	Brazil	9	23	46	Israel	1	22
19	Peoples R China	6	35	47	Kuwait	1	2
20	Spain	6	17	48	Lithuania	1	5
21	Thailand	6	32	49	Mauritius	1	1
22	Austria	5	18	50	Nigeria	1	5
23	Belgium	5	11	51	Oman	1	2
24	Croatia	5	15	52	Romania	1	0
25	Denmark	5	82	53	Slovakia	1	19
26	Norway	5	28	54	Tunisia	1	33
27	Finland	4	28				

CONCLUSION

The publishing trend totally depends on the productivity of contributors, pattern of contributions and the quality of information. A significant note of the study is that the majority of the articles are contributed by multiple authors and that the University wise contributions were the maximum. The geographical Collaboration distributions of international level shows among the 54 countries, India gives priority for research when compared to other countries. A notable attribute of this study is that, this Collaboration really stipulates/ induces fruitful research for the researcher. Today, we see that research is done in almost all the branches of knowledge, especially in Solar Energy.

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