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Scientometric Trends and Impact of Solar Energy and Waste-to-Energy Research (2008-2022): Insights into Growth, Citation Patterns, and Collaboration

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Abstract - **Research on solar energy and waste-to-energy technologies has expanded due to the growing emphasis on sustainable energy sources, and scientometric studies have provided valuable insights for future directions in these areas. The study examines the scientometric trends and impact of research in solar energy and waste-to-energy from 2008 to 2022, focusing on key indicators such as citation rates, growth rates, publication efficiency, and collaboration patterns. The study analyzed 17,469 research papers on solar energy and 8,149 on waste-to-energy published from 2008 to 2022 using scientometric methods. Key indicators, such as average citations per paper, annual growth rate, exponential growth rate, activity index, publication efficiency index, relative growth rate, doubling time, and degree of collaboration, were calculated. The highest average citation per paper was 64.30 for solar energy and 86.09 for waste-to-energy. The peak annual growth rate (AGR) was 50.00 in 2006 for solar energy and 38.64 in 2020 for waste-to-energy. Exponential growth rates reached 1.50 in 2013 for solar energy (585 publications) and 1.39 in 2020 for waste-to-energy (1,062 publications). The activity index was highest in 2022, with 144.05 for solar energy and 143.72 for waste-to-energy. The average publication efficiency index for both fields was 1.49, and the study highlighted significant contributions by multiple authors across both topics. Other indicators, including relative growth rate (RGR), doubling time (Dt) for publications and citations, and degree of collaboration, underscored substantial research momentum and collaboration in these fields. The data show a strong growth trend and significant impact on research in waste-to-energy and solar energy, along with a noticeable increase in collaborative research initiatives. These patterns indicate an ongoing interest in and solid understanding of renewable energy technologies, which are essential for achieving future sustainability and energy objectives.**
Keywords: **Solar Energy, Waste-To-Energy, Scientometric Trends, Collaboration Patterns, Renewable Energy Technologies**

I. INTRODUCTION

Solar energy is a clean, renewable power source that harnesses the sun's rays. The sun emits immense energy, which, if effectively harnessed, could meet global energy needs multiple times. This energy is captured and converted into usable forms of power using various technologies, primarily photovoltaic (PV) cells and solar thermal systems.

Photovoltaic Cells: Photovoltaic (PV) cells, commonly known as solar panels, convert sunlight directly into electricity through the photovoltaic effect. This electricity can be used immediately, stored in batteries, or fed into the power grid.

Solar Thermal Systems: These systems capture the sun's heat and use it for heating purposes or to generate electricity. Solar thermal technologies include solar water heaters, which provide hot water for domestic and industrial use, and concentrated solar power (CSP) systems, which use mirrors or lenses to focus sunlight onto a small area to produce high temperatures. These high temperatures can generate steam, which drives a turbine to produce electricity.

Waste-to-energy (WTE) is a sustainable method of waste management that converts municipal solid waste (MSW) and other waste materials into usable forms of energy, such as electricity, heat, or fuel. This process helps reduce the volume of waste in landfills and provides a renewable energy source, contributing to a more circular economy. The present investigation also analyzes research on solar energy and waste-to-energy using scientometric methods, providing direction for future research and enhancing the identity of this research domain. Therefore, this study aims to identify growth trends, key institutions, core journals, authorship patterns, and productive authors in this field.

II. REVIEW OF LITERATURE

Garg and Sharma (1991) analyzed the literature on solar power research from 1970 to 1984, showing strong growth after the energy crisis from 1973 to 1982. The focus is on solar collectors and solar cells, with the USA being the major producer. Research activity became global after the crisis, but developed countries' performance in some solar power fields remained low. Conference papers and journal references are closely related.

Francisco G. *et al.,* (2014) examined the contributions made by Spanish institutions to the specialized literature in the energy field from 1957 to 2012, using the Scopus Elsevier database and bibliometric analysis techniques. The results showed that the Spanish contribution was significant, with keywords such as power, energy, system, wind, and solar being the most frequently used terms. The study analyzed various aspects of publications, including publication type, field, language, subcategory, journal type, and keyword frequency. Spain's research is geographically and institutionally divided, with Madrid and Catalonia being the main research regions. Spain collaborates with France, the USA, Germany, and the United Kingdom at an international level. The most active categories in the energy field are engineering, materials science, and chemistry.

Daniel, Jian, and Ehsan (2021) examined solar photovoltaic (PV) systems, which are effective in reducing greenhouse gas emissions, but their large-scale exploitation leads to waste accumulation and environmental impact. This study reviewed emerging trends in solar PV waste management research from 1974 to 2019 using scientometric review techniques. The results showed that polymer solar cells have been the focus of recent research due to their lightweight, flexible, environmentally friendly materials, and lower cost compared to silicon-based solar cells. However, silicon-based modules are the most installed and will soon reach their end of life. The study also found that little attention was given to recycling, recovery, policies, and regulations on solar PV module waste management. Future research should focus on assessing recycling potential and emissions from current modules, as well as evaluating the ease of remanufacture, recovery, and reuse of future solar PV modules.

Selorm (2021) presented a scientometric analysis of solar cell research (SCR) in Africa and India, focusing on the outstanding contributions made by successful collaborations. Data were retrieved from the Web of Science from 2009 to 2018 and analyzed using MS Excel and VOSviewer. Global scholarly publications numbered 117,605, with Africa and India contributing 2,932 and 7,848, respectively. Joint research, represented by 92 academic journals, received 1,348 citations, with the highest citation count of 394 (29.23%) in 2018. H.C. Swart from the University of the Free State in South Africa contributed 14 publications, accounting for 2.147% of the total count. V. Kumar from the Indian Institute of Technology New Delhi, UCA, and UFS contributed 12 publications, accounting for 1.84% of the total count.

Mondal (2021) analyzed journals published between 2010 and 2020 and used bibliometric methods to conduct a research assessment of the *Issues in Science and Technology Librarianship* (ISTL) journal. A total of 224 research papers were published. The study focused on bibliometric indicators such as doubling time (DT), relative growth rate (RGR), and degree of collaboration (DC) concerning the published and cited papers. The analysis determined that the DC of ISTL publications was 0.5. During the research period, the RGR of the journal fluctuated unpredictably, while the DT of published articles continued to grow. The RGR of citations was relatively high between 2010 and 2012, with the mean RGR of citations at 0.45, but the DT of citations varied from 2013 to 2020.

Gbey, Turkson, and Lee (2022) aimed to identify the social structure of the wireless charging module field by mapping research collaborations among authors and countries, measuring the influence of authors and sources, and identifying interactions between different researchers, influential authors, sources, documents, and organizations. A bibliometric search in the Scopus database returned 2,163 documents, which were manually filtered for further analysis. A scientometric analysis of the remaining 1,367 documents revealed that "object detection" and "shielding effectiveness" were the most current research topics. Authors from China, the USA, and the United Kingdom co-authored published works on the topic, indicating their significant contributions to the field's achievements. The number of international co-authored studies was low, with no research conducted in the less-developed world. The most cited and influential scholars were G.A. Covic, J.T. Boys, and C.C. Mi. The most influential sources were *IEEE Transactions on Power Electronics* and *IEEE Transactions on Induction Electronics*, while the most productive sources were *Energies* and *IEEE Access*. The most influential documents were those by Covic, G.A. (2013a) and Covic, G.A. (2013b).

Aguiar and Giovanetti El-Deir (2022) discussed the social, economic, and environmental implications of shopping malls, particularly emphasizing their solid waste regimes. By using bibliometric analysis of published research works, the paper explores the qualitative and quantitative patterns of solid waste management in shopping malls. Few studies have focused on waste management in shopping malls, but the trend has risen in the last five years, with many of them published from Europe and Asia and indexed in high-impact factor journals. Groupings of topics and categorization of subthemes were done based on the preferred words, such as waste food and environment. The study focuses on waste management to improve the quality of processes in shopping malls.

Ravichandran, Vivekanandhan, and Angeline (2022) analyzed 50,637 research publications on zero pollution, which received 342,076 citations from 2012 to 2021. The study reveals a decreasing trend in the relative growth rate (RGR) and an increasing trend in doubling time. India contributed the most publications, with 497 (40.28%) research papers. Computer science dominates with 18,054 (60.04%) publications. Future projections suggest continued growth, with 73,243 by 2025 and 107,333 by 2030. The most preferred communication channel was articles, and *SAE Technical Papers* is the most prolific journal.

Noor *et al.,* (2023) focused on the solar energy industry's growth from 2000 to 2019, including production, power capacity, government support, and cost reduction. It synthesizes 968 publications and 26,873 citations, identifying key contributors such as the USA, Germany, the UK, and China. Singh, Arya, and Jaiswal (2023) examined research trends, growth, and collaboration patterns in India's water resources field using data from the *Web of*

Science Core Collection database. It retrieved 797 publications from 2016 to 2021. The results revealed the top journals, including *Water Resources Management* (26 articles, 3.26%), *Arabian Journal of Geosciences* (22 articles, 2.76%), and *Environmental Earth Sciences* (21 articles, 2.63%). The peak year for publications was 2020, with 236 articles (29%). The most prolific author was Malik Anurag from Punjab Agricultural University. The USA is currently the top performer in collaborating with India, followed by China.

Berana, Saleem, and Mohmmed (2024) analyzed 1,855 papers published between 2010 and 2024 using VOSviewer software. China leads in publications and citations, while Egyptian research institutions are influential. An individual researcher has 3,419 citations for 54 solar desalination papers. The analysis highlights past and current advancements, identifies trends, and offers recommendations for overcoming challenges.

III. OBJECTIVES OF THE STUDY

1. To measure the year-wise distribution of publications and citations for solar and waste-to-energy research from 2008 to 2022.
2. To determine the relative growth rate and doubling time of the publications.
3. To analyze the degree of collaboration, the collaboration index, the collaboration coefficient, and the modified collaboration coefficient in solar and waste-to-energy research publications.
4. This study aims to analyze the exponential growth rate, annual growth rate, and compound annual growth rate in solar and waste-to-energy research publications.
5. To analyze the time-series data of solar and waste-to-energy research publications.
6. To examine the activity index and publication efficiency index in solar and waste-to-energy research publications.
7. To identify authorship patterns in the research areas, such as the average number of authors per paper and productivity per paper.

IV. METHODOLOGY

Researchers extracted data for this study from the Web of Science Core Collection database, covering the period from 2008 to 2022. The search string used to find all publications related to solar energy and waste-to-energy research across India and the world was as follows: 1) TS = ((solar energy*)) and 2) TS = ((waste-to-energy*)). The researchers used scientometric indicators such as the publication efficiency index (PEI), degree of collaboration (DC), activity index, exponential growth rate, annual growth rate, compound annual growth rate, collaboration index (CI), collaboration coefficient (CC), modified collaboration coefficient (MCC), and other relevant indicators for the analysis. The study also applied HistCite, BibExcel, and Microsoft Excel 2010 software.

V. ANALYSIS AND INTERPRETATION

A. Year-Wise Research Output of Solar Energy

Table I highlight the research productivity of the solar energy discipline in terms of annual growth across India and the world in the Web of Science (WoS) indexed databases.

TABLE I YEAR-WISE RESEARCH PUBLICATIONS OF SOLAR ENERGY RESEARCH: INDIA V/S WORLD

India						World					
Year	TP	%	TC	ACPP	H-Index	Year	TP	%	TC	ACPP	H-Index
2008	148	0.84	8595	58.07	45	2008	3429	1.89	195571	57.03	200
2009	216	1.22	13888	64.30	56	2009	4407	2.43	291575	66.16	224
2010	244	1.38	11619	47.62	56	2010	5115	2.83	302045	59.05	230
2011	304	1.72	15795	51.96	58	2011	6186	3.42	363474	58.76	248
2012	390	2.21	12857	32.97	61	2012	8031	4.44	383580	47.76	244
2013	585	3.31	22227	37.99	71	2013	9058	5.00	425295	46.95	249
2014	842	4.77	26954	32.01	73	2014	10896	6.02	491248	45.09	NA
2015	1015	5.75	28955	28.53	80	2015	11867	6.55	488529	41.17	NA
2016	1446	8.19	33597	23.23	88	2016	13399	7.40	528643	39.45	NA
2017	1546	8.76	37001	23.93	88	2017	15201	8.40	540306	35.54	NA
2018	1820	10.31	41494	22.80	93	2018	16328	9.02	566376	34.69	NA
2019	1614	9.14	34184	21.18	78	2019	17221	9.51	506129	29.39	NA
2020	1987	11.26	38884	19.57	77	2020	18258	10.08	453559	24.84	NA
2021	2523	14.3	36586	14.50	67	2021	20506	11.33	353998	17.26	NA
2022	2969	16.82	22380	7.54	45	2022	21142	11.68	191293	9.05	NA
Total	17649	100	385016				181044	100	6081621		

TP= Total Publications, %= Percentage, TC= Total Citations, ACPP= Average Citation per Paper, NA=Not Available

India's publication output in solar energy research from 2008 to 2022 comprised 17,649 papers, while the global publication output during this period was 181,044 papers. During the sample period, both India's and the world's research outputs increased. India's annual publication range was from 148 to 2,969, while the global range was from 3,429 to 21,142 publications. India recorded its highest number of citations, 41,494, in 2018, and the world recorded its highest at 566,376 citations in the same year. India's highest average citation per paper was 64.30, recorded in 2009, while the world's highest was 66.16, also in 2009. The highest h-index for India was recorded in 2018 at 93, while the lowest was 45, recorded in both 2008 and 2022. The world's highest h-index was recorded in 2013 at 249, with no available h-index data for the years 2014 to 2022.

B. Year-Wise Research Output of Waste-to-Energy

Table II highlight the research productivity growth of the waste-to-energy discipline across India and the world, indexed in the Web of Science (WoS) databases. India's publication output in the area of waste-to-energy research from 2008 to 2022 comprised 8,149 papers, while the global publication output during the same period was 91,190 papers.

During this period, both India's and the world's research outputs increased. India's annual publication range was from 85 to 1,702, and the global range was from 1,668 to 13,252 publications. Regarding annual citations, India recorded the highest number of citations, 31,254, in 2020, while the world recorded the highest number, 265,674, in 2018. India's highest average citation per paper was 86.09, recorded in 2008.

The highest average citation per paper globally was 67.18, also recorded in 2008. The highest h-index for India was recorded in 2020, at 80, while the lowest was 40, recorded in 2008. The highest h-index for the world was recorded in 2018, at 175, with no h-index data available for the years 2014 to 2022.

TABLE II YEAR-WISE RESEARCH PUBLICATIONS OF WASTE-TO-ENERGY RESEARCH: INDIA V/S WORLD

India						World					
Year	**TP**	**%**	**TC**	**ACPP**	**H-Index**	**Year**	**TP**	**%**	**TC**	**ACPP**	**H-Index**
2008	85	1.04	7318	86.09	40	2008	1668	1.83	112053	67.18	150
2009	115	1.41	9046	78.66	45	2009	2223	2.44	110501	49.71	156
2010	126	1.55	7985	63.37	46	2010	2408	2.64	126209	52.41	156
2011	170	2.09	9696	57.04	49	2011	2764	3.03	132333	47.88	163
2012	175	2.15	7971	45.55	49	2012	3268	3.58	146489	44.83	165
2013	235	2.88	11484	48.87	62	2013	3746	4.11	157852	42.14	162
2014	301	3.69	10719	35.61	58	2014	4166	4.57	163670	39.29	164
2015	368	4.52	14717	39.99	66	2015	4807	5.27	176956	36.81	162
2016	460	5.64	18032	39.2	68	2016	5811	6.37	207646	35.73	171
2017	530	6.5	17708	33.41	68	2017	7092	7.78	235970	33.27	167
2018	661	8.11	23132	35	75	2018	7868	8.63	265674	33.77	175
2019	766	9.4	25395	33.15	77	2019	9130	10.01	261576	28.65	158
2020	1062	13.03	31254	29.43	80	2020	10614	11.64	264558	24.93	NA
2021	1393	17.09	27408	19.68	65	2021	12373	13.57	212509	17.18	NA
2022	1702	20.89	17211	10.11	46	2022	13252	14.53	109854	8.29	NA
Total	8149	100	239076				91190	100	2683850		

TP = Total Publications, % = Percentage, TC = Total Citations, ACPP = Average Citation per Paper, NA = Not Available

C. Relative Growth Rate and Doubling Time of Publication in Solar Energy and Waste-to-Energy Research: India

Table III show India's relative growth rate and doubling time of publications in solar energy research from 2008 to 2022. The relative growth rate of research output decreased from 0.90 in 2009 to 0.17 in 2019. During the period from 2008 to 2022, the mean relative growth rate was found to be 0.32. The study period witnessed a mean relative growth rate at an appreciable level. The doubling time for publications increased from 0.77 in 2009 to 4.01 in 2019. However, there was an increasing trend in 2020, 2021, and 2022. The average doubling time for publications from 2008 to 2022 was 2.31, indicating a consistent increase in the number of publications in the field of solar energy research.

Table III show India's relative growth rate and doubling time of publications in waste-to-energy research from 2008 to 2022. The relative growth rate of research output decreased from 0.86 in 2009 to 0.21 in 2019. During the period from 2008 to 2022, the mean relative growth rate was found to be 0.30. The study period witnessed a mean relative growth rate at an appreciable level. The doubling time for publications increased from 0.81 in 2009 to 3.25 in 2019. However, there was an increasing trend in 2017 and 2018. The average doubling time for publications from 2008 to 2022 was 2.28, indicating a consistent increase in the number of publications in the field of waste-to-energy research.

TABLE III RELATIVE GROWTH RATE AND DOUBLING TIME OF PUBLICATION IN SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH: INDIA

India Solar Energy Research							India Waste-to-Energy Research					
Year	**TP**	**Cum**	**Log 1**	**Log 2**	**RGR**	**Dt**	**TP**	**Cum**	**Log 1**	**Log 2**	**RGR**	**Dt**
2008	148	148		5.00			85	85		4.44		
2009	216	364	5.00	5.90	0.90	0.77	115	200	4.44	5.3	0.86	0.81
2010	244	608	5.90	6.41	0.51	1.35	126	326	5.3	5.79	0.49	1.42
2011	304	912	6.41	6.82	0.41	1.71	170	496	5.79	6.21	0.42	1.65
2012	390	1302	6.82	7.17	0.36	1.95	175	671	6.21	6.51	0.30	2.29
2013	585	1887	7.17	7.54	0.37	1.87	235	906	6.51	6.81	0.30	2.31
2014	842	2729	7.54	7.91	0.37	1.88	301	1207	6.81	7.1	0.29	2.42
2015	1015	3744	7.91	8.23	0.32	2.19	368	1575	7.1	7.36	0.27	2.60
2016	1446	5190	8.23	8.55	0.33	2.12	460	2035	7.36	7.62	0.26	2.70
2017	1546	6736	8.55	8.82	0.26	2.66	530	2565	7.62	7.85	0.23	2.99
2018	1820	8556	8.82	9.05	0.24	2.9	661	3226	7.85	8.08	0.23	3.02
2019	1614	10170	9.05	9.23	0.17	4.01	766	3992	8.08	8.29	0.21	3.25
2020	1987	12157	9.23	9.41	0.18	3.88	1062	5054	8.29	8.53	0.24	2.94
2021	2523	14680	9.41	9.59	0.19	3.67	1393	6447	8.53	8.77	0.24	2.85
2022	2969	17649	9.59	9.78	0.18	3.76	1702	8149	8.77	9.01	0.23	2.96
Total	17649	Mean Value			0.32	2.31	8149	Mean Value			0.30	2.28

TP = Total Publication, Cum = Cumulative, RGR = Relative Growth Rate, Dt = Doubling Time

TABLE IV ANNUAL GROWTH RATE AND COMPOUND ANNUAL GROWTH RATE OF SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

India's Solar Energy					India's Waste-to-energy			
Year	**TP**	**CP**	**AGR**	**CAGR**	**TP**	**CP**	**AGR**	**CAGR**
2008	148	148			85	85		
2009	216	364	45.95	0.21	115	200	35.29	0.16
2010	244	608	12.96	0.06	126	326	9.57	0.05
2011	304	912	24.59	0.12	170	496	34.92	0.16
2012	390	1302	28.29	0.13	175	671	2.94	0.01
2013	585	1887	50.00	0.22	235	906	34.29	0.16
2014	842	2729	43.93	0.20	301	1207	28.09	0.13
2015	1015	3744	20.55	0.10	368	1575	22.26	0.11
2016	1446	5190	42.46	0.19	460	2035	25.00	0.12
2017	1546	6736	6.92	0.03	530	2565	15.22	0.07
2018	1820	8556	17.72	0.09	661	3226	24.72	0.12
2019	1614	10170	-11.32	-0.06	766	3992	15.89	0.08
2020	1987	12157	23.11	0.11	1062	5054	38.64	0.18
2021	2523	14680	26.98	0.13	1393	6447	31.17	0.15
2022	2969	17649	17.68	0.08	1702	8149	22.18	0.11
Total	17649				8149			

TP = Total Publication, CP = Cumulative Publications, AGR = Annual Growth Rate, CAGR = Compound Annual Growth Rate

D. Annual Growth Rate and Compound Annual Growth Rate of Solar Energy and Waste-to-Energy Research

The annual growth rate of solar energy research output is shown in Table IV. From 2008 to 2022, there were variations in the annual growth rate. The year 2013 had the highest AGR (50.00), followed by the second highest in 2009 (45.95). Further analysis revealed that the year 2019 had a negative annual growth rate. The years 2013 and 2022 had the highest and lowest compound annual growth rates, respectively, at 0.22 and 0.08. It was also found that the year 2019 had a negative compound annual growth rate.

The annual growth rate of waste-to-energy research output is shown in Table IV. From 2008 to 2022, there were variations in the annual growth rate. The year 2020 had the highest AGR (38.64), followed by the second highest in 2008 (35.29).

It was also found that all the years had a positive growth rate. The years 2020 and 2012 had the highest and lowest compound annual growth rates, respectively, at 0.18 and 0.01. It was also found that all the years had a positive growth rate.

E. Activity Index of Solar Energy and Waste-to-Energy Research

Table V shows the activity index of India's contribution to the world output in solar energy research from 2008 to 2022. The data reveal that the activity index for nine out of the fifteen years of study is less than 100, indicating lower activity in solar energy research output compared to the world average. The highest activity index, 144.05, was observed in 2022, followed by 126.21 in 2021 and 114.34 in 2018. The activity index was significantly lower in 2008, at 44.27, during the study period. Furthermore, the researcher observed fluctuations in the activity index throughout the study period.

Table V shows the activity index of India's contribution to the world output in waste-to-energy research from 2008 to 2022. The data reveal that the activity index for twelve out of the fifteen years of study is less than 100, indicating lower activity in waste-to-energy research output compared to the world average. The highest activity index, 143.72, was observed in 2022, followed by 125.99 in 2021 and 111.97 in 2020. The activity index was significantly lower in 2008, at 57.03, during the study period. Furthermore, the researcher observed fluctuations in the activity index throughout the study period.

TABLE V ACTIVITY INDEX OF SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

	Solar Energy Research			Waste-to-Energy Research		
Year	**World TP**	**India TP**	**AI**	**World TP**	**India TP**	**AI**
2008	3429	148	44.27	1668	85	57.03
2009	4407	216	50.28	2223	115	57.89
2010	5115	244	48.93	2408	126	58.55
2011	6186	304	50.41	2764	170	68.83
2012	8031	390	49.81	3268	175	59.92
2013	9058	585	66.25	3746	235	70.20
2014	10896	842	79.27	4166	301	80.85
2015	11867	1015	87.74	4807	368	85.67
2016	13399	1446	110.7	5811	460	88.58
2017	15201	1546	104.33	7092	530	83.63
2018	16328	1820	114.34	7868	661	94.01
2019	17221	1614	96.14	9130	766	93.89
2020	18258	1987	111.64	10614	1062	111.97
2021	20506	2523	126.21	12373	1393	125.99
2022	21142	2969	144.05	13252	1702	143.72
Total	181044	17649		91190	8149	

TP = Total Publication, AI = Activity Index

F. Exponential Growth Rate of Solar Energy and Waste-to-Energy Research

Table VI shows the exponential growth rate of publication output in solar energy research from 2008 to 2022. The study found the highest exponential growth rate of 1.50 in 2013, with 585 publications, and the lowest rate of 0.89 in 2019, with 1,614 publications. The table shows that the average exponential growth rate was 1.25. Overall, the study observed fluctuations in the exponential growth rate during the sample period.

Table VI shows the exponential growth rate of publication output in waste-to-energy research from 2008 to 2022. The study found the highest exponential growth rate of 1.39 in 2020, with 1,062 publications, and the lowest rate of 1.10 in 2010, with 126 publications. The table shows that the average exponential growth rate was 1.24. Overall, the study observed fluctuations in the exponential growth rate during the sample period.

TABLE VI EXPONENTIAL GROWTH RATE OF SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

Solar Energy Research			Waste-to-Energy Research	
Year	**TP**	**EGR**	**TP**	**EGR**
2008	148		85	
2009	216	1.46	115	1.35
2010	244	1.13	126	1.10
2011	304	1.25	170	1.35
2012	390	1.28	175	1.03
2013	585	1.50	235	1.34
2014	842	1.44	301	1.28
2015	1015	1.21	368	1.22
2016	1446	1.42	460	1.25
2017	1546	1.07	530	1.15
2018	1820	1.18	661	1.25
2019	1614	0.89	766	1.16
2020	1987	1.23	1062	1.39
2021	2523	1.27	1393	1.31
2022	2969	1.18	1702	1.22
Total	17649	1.25	8149	1.24

TP = Total Publication, EGR = Exponential Growth Rate

G. Publication Efficiency Index in Solar Energy and Waste-to-Energy Research

Table VII reveals the publication efficiency index of overall publications on solar energy research output during the study period. The average publication efficiency index was 1.49 during the sample period. The highest publication efficiency index was 2.95 in 2009, with 216 publications, followed by the 2008 publication efficiency index of 2.66, with 148 publications, and the 2011 publication efficiency index of 2.38, with 304 publications. The lowest publication efficiency index was recorded at 0.35 in 2022, with 2,969 publications.

Table VII reveals the publication efficiency index of overall publications on waste-to-energy research output during the study period. The average publication efficiency index was 1.49 during the sample period. The highest publication efficiency index was 2.93 in 2008, with 85 publications, followed by the 2009 publication efficiency index of 2.68, with 115 publications, and the 2010 publication efficiency index of 2.16, with 126 publications. The lowest publication efficiency index was recorded at 0.34 in 2022, with 1,702 publications.

TABLE VII PUBLICATION EFFICIENCY INDEX IN SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

Solar Energy Research				Waste-to-Energy Research		
Year	**TP**	**TC**	**PEI**	**TP**	**TC**	**PEI**
2008	148	8595	2.66	85	7318	2.93
2009	216	13888	2.95	115	9046	2.68
2010	244	11619	2.18	126	7985	2.16
2011	304	15795	2.38	170	9696	1.94
2012	390	12857	1.51	175	7971	1.55
2013	585	22227	1.74	235	11484	1.67
2014	842	26954	1.47	301	10719	1.21
2015	1015	28955	1.31	368	14717	1.36
2016	1446	33597	1.07	460	18032	1.34
2017	1546	37001	1.10	530	17708	1.14
2018	1820	41494	1.05	661	23132	1.19
2019	1614	34184	0.97	766	25395	1.13
2020	1987	38884	0.9	1062	31254	1.00
2021	2523	36586	0.66	1393	27408	0.67
2022	2969	22380	0.35	1702	17211	0.34
Total	17649	385016	1.49	8149	239076	1.49

TP = Total Publications, TC = Total Citations, PEI = Publication Efficiency Index

H. Future Growth Trend (Time Series) of Solar Energy and Waste-to-Energy Research

Table VIII shows the time series data for solar energy research output from 2008 to 2022. The formula used to calculate the straight-line equation model is provided below Straight Line Equation Yc = a + bX Since ΣX = 0

Y- Publications
X- Unit of time
a & b constants to be calculated

Since ∑X = 0
a = ΣY/N = 17649/25 = 1176.60
b = ΣXY/ΣX2 = 54360/280= 194.14

Estimated literature in 2027 = 1176.60+ (194.14*(2027-2010) = 4477.03
Estimated literature in 2032 = 1176.60+ (194.14*(2032-2010) = 5447.74
Estimated literature in 2040 =1176.60+ (194.14*(2040-2010) = 7000.89
Estimated literature in 2050 = 1176.60+ (194.14*(2050-2010) = 8942.31

Therefore, the predicted solar energy research output for the years 2027, 2032, 2040, and 2050 is 4477.03, 5447.74, 7000.89, and 8942.31, respectively.

I. Waste-to-Energy Research

Table VIII shows the time series data for solar energy research output from 2008 to 2022. The formula used to calculate the straight-line equation model is provided below

Straight Line Equation Yc = a + bX Since ΣX = 0
Y- Publications
X- Unit of time
a & b constants to be calculated

Since ∑X = 0
a = ΣY/N = 8149/15 = 543.27
b = ΣXY/ΣX2 = 28258/280 = 100.92
Estimated literature in 2027 = 543.27+ (100.92*(2027-2010) = 2258.93
Estimated literature in 2032 =543.27+ (100.92*(2032-2010) = 2763.54
Estimated literature in 2040 =543.27+ (100.92*(2040-2010) = 3570.91
Estimated literature in 2050 = 543.27+ (100.92*(2050-2010) = 4580.12

Therefore, the predicted waste-to-energy research output for the years 2027, 2032, 2040, and 2050 is 2258.93, 2763.54, 3570.91, and 4580.12, respectively.

TABLE VIII FUTURE GROWTH TREND (TIME SERIES) OF SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

	Solar Energy				**Waste-to-Energy**			
Year	**TP**	**X**	**X2**	**XY**	**TP**	**X**	**X2**	**XY**
2008	148	-7	49	-1036	85	-7	49	-595
2009	216	-6	36	-1296	115	-6	36	-690
2010	244	-5	25	-1220	126	-5	25	-630
2011	304	-4	16	-1216	170	-4	16	-680
2012	390	-3	9	-1170	175	-3	9	-525
2013	585	-2	4	-1170	235	-2	4	-470
2014	842	-1	1	-842	301	-1	1	-301
2015	1015	0	0	0	368	0	0	0
2016	1446	1	1	1446	460	1	1	460
2017	1546	2	4	3092	530	2	4	1060
2018	1820	3	9	5460	661	3	9	1983
2019	1614	4	16	6456	766	4	16	3064
2020	1987	5	25	9935	1062	5	25	5310
2021	2523	6	36	15138	1393	6	36	8358
2022	2969	7	49	20783	1702	7	49	11914
Total	17649		280	54360	8149		280	28258

TP = Total Publications

J. Average Author Per Paper and Productivity Per Author of Solar Energy Research

Table IX depicts the data on the average number of authors per paper in the field of solar energy research during the sample period from 2008 to 2022. The table reveals that the average number of authors per article is 4.31 for 17,649 articles published, with 80,224 authors contributing to the study period.

It is also evident from the table that the highest average number of authors per article was 6.14 in 2008, while the lowest average number was 3.56 in 2013. The average productivity per author for the period from 2008 to 2022 is 0.24. The highest authors' productivity was 0.28 in 2009, 2010, and 2013, while the lowest productivity per author was 0.16 in 2008.

Table IX depicts the average number of authors per paper in the waste-to-energy research sample period from 2008 to 2022. The table reveals that the average number of authors per article is 3.91 for 8,149 articles published, with 35,484 authors contributing to the study period.

It is also evident from the table that the highest average number of authors per article was 5.06 in 2022, while the lowest average number was 3.22 in 2009. The average productivity per author for the period from 2008 to 2022 is 0.26. The highest authors' productivity found in the study was 0.31 in 2009, while the lowest productivity per author was 0.20 in 2022.

TABLE IX AVERAGE AUTHOR PER PAPER AND PRODUCTIVITY PER AUTHOR OF SOLAR ENERGY RESEARCH

Solar Energy Research					Waste-to-Energy Research			
Year	**TP**	**Total Author**	**AAPP**	**PPA**	**TP**	**Total Author**	**AAPP**	**PPA**
2008	148	908	6.14	0.16	85	301	3.54	0.28
2009	216	785	3.63	0.28	115	370	3.22	0.31
2010	244	872	3.57	0.28	126	442	3.51	0.29
2011	304	1445	4.75	0.21	170	560	3.29	0.30
2012	390	1560	4.00	0.25	175	621	3.55	0.28
2013	585	2084	3.56	0.28	235	856	3.64	0.27
2014	842	3396	4.03	0.25	301	1079	3.58	0.28
2015	1015	4047	3.99	0.25	368	1380	3.75	0.27
2016	1446	5464	3.78	0.26	460	1727	3.75	0.27
2017	1546	7177	4.64	0.22	530	2244	4.23	0.24
2018	1820	7028	3.86	0.26	661	2640	3.99	0.25
2019	1614	7751	4.80	0.21	766	3282	4.28	0.23
2020	1987	8609	4.33	0.23	1062	4700	4.43	0.23
2021	2523	12399	4.91	0.20	1393	6673	4.79	0.21
2022	2969	13952	4.70	0.21	1702	8609	5.06	0.20
Total	17649	80224	4.31	0.24	8149	35484	3.91	0.26

TP = Total Publication, TA = Total Authors, AAPP = Average Author per Paper, PPA = Productivity per Author

K. Degree of Collaboration in Solar Energy and Waste-to-Energy Research

Table X reveals the authors' productivity in solar energy research from 2008 to 2022. The single-author contribution is 2.50% (441 publications), while multi-authors produced 97.50% (17,208 publications) of the articles. The degree of collaboration increased from 0.93 to 0.98 during the study period from 2008 to 2022. The average degree of collaboration is 0.98, indicating that collaborative efforts contributed to more articles.

TABLE X DEGREE OF COLLABORATION IN SOLAR ENERGY AND WASTE-TO-ENERGY RESEARCH

Solar Energy Research					Waste-to-Energy Research				
Year	**SA**	**N+NM**	**TP**	**DC**	**Year**	**SA**	**N+NM**	**TP**	**DC**
2008	9	139	148	0.94	2008	5	80	85	0.94
2009	13	203	216	0.94	2009	6	109	115	0.95
2010	18	226	244	0.93	2010	6	120	126	0.95
2011	15	289	304	0.95	2011	14	156	170	0.92
2012	16	374	390	0.96	2012	7	168	175	0.96
2013	24	561	585	0.96	2013	7	228	235	0.97
2014	23	819	842	0.97	2014	12	289	301	0.96
2015	35	980	1015	0.97	2015	13	355	368	0.96
2016	32	1414	1446	0.98	2016	19	441	460	0.96
2017	30	1516	1546	0.98	2017	9	521	530	0.98
2018	37	1783	1820	0.98	2018	13	648	661	0.98
2019	38	1576	1614	0.98	2019	13	753	766	0.98
2020	53	1934	1987	0.97	2020	20	1042	1062	0.98
2021	48	2475	2523	0.98	2021	24	1369	1393	0.98
2022	50	2919	2969	0.98	2022	28	1674	1702	0.98
Total	441	17208	17649	0.98	Total	197	7953	8149	0.98
%	2.50	97.50			%	2.42	97.59		

TP = Total Publication, % = Percentage, SA = Single Authors, MA = Multiple Authors, and DC = Degree of Collaboration

Table X reveals the authors' productivity in waste-to-energy research from 2008 to 2022. The single-author contribution is 2.42% (197 publications), while multi-authors produced 97.58% (7,953 publications) of the articles. The degree of collaboration increased from 0.92 to 0.98 during the study period from 1998 to 2022. The average degree of collaboration is 0.98, indicating that collaborative efforts contributed to more articles.

J. Collaboration Index, Collaboration Coefficient, Modified Collaboration Coefficient in Solar Energy Research

Table XI provides an explanation of various collaboration components in solar energy research during a fifteen-year period (2008-2022). The Collaborative Index (CI), Collaborative Coefficient (CC), and Modified Collaborative Coefficient (MCC) are all included in the study. The table shows that the Collaborative Index was highest in 2022 (4.48) and lowest in 2008 and 2010 (3.45). The mean CI during the study period is 3.77. In this study, both the CC and MCC had their highest rate of 0.71 in 2022 and their lowest rate of 0.62 in 2010. The mean CC and MCC are 0.66.

TABLE XI COLLABORATION INDEX, COLLABORATION COEFFICIENT, MODIFIED COLLABORATION COEFFICIENT IN SOLAR ENERGY RESEARCH

Year	SA	TA	TA	FA	FA	SA	SA	EA	NA	MTA	TP	CI	CC	MCC
2008	9	43	39	21	16	13	3	2	1	1	148	3.45	0.63	0.63
2009	13	65	58	36	14	10	6	4	4	6	216	3.52	0.63	0.63
2010	18	67	67	39	24	15	3	3	3	5	244	3.45	0.62	0.62
2011	15	76	70	45	41	17	19	8	6	7	304	3.90	0.66	0.66
2012	16	106	107	67	27	30	20	6	4	7	390	3.66	0.65	0.65
2013	24	172	164	105	52	28	16	11	3	10	585	3.48	0.64	0.64
2014	23	237	244	128	77	52	27	15	12	27	842	3.71	0.66	0.66
2015	35	299	243	188	119	55	29	14	9	24	1015	3.62	0.65	0.65
2016	32	393	432	240	143	98	43	27	15	23	1446	3.64	0.66	0.66
2017	30	462	386	282	162	89	54	37	20	24	1546	3.67	0.66	0.66
2018	37	459	486	353	198	139	56	42	18	32	1820	3.77	0.67	0.67
2019	38	406	387	320	193	113	59	41	17	40	1614	3.86	0.67	0.67
2020	53	431	481	358	237	185	92	57	33	60	1987	4.07	0.68	0.69
2021	48	534	550	466	332	241	127	91	49	85	2523	4.22	0.70	0.70
2022	50	571	632	519	361	265	192	141	106	132	2969	4.48	0.71	0.71
Total	441	4321	4346	3167	1996	1350	746	499	300	483	17649	3.77	0.66	0.66

SA= Single Authors, TA= Two Authors, TA= Three Authors, FA= Four Authors, five authors, SA= Six Authors, seven authors, EA= Eight Authors, NA= Nine Authors, MTA= More Than Ten Authors, CI= Collaboration Index, CC= Collaboration Coefficient, MCC= Modified Collaboration Coefficient

TABLE XII COLLABORATION INDEX, COLLABORATION COEFFICIENT, MODIFIED COLLABORATION COEFFICIENT IN WASTE-TO-ENERGY RESEARCH

Years	SA	TA	TA	FA	FA	SA	SA	EA	NA	MTA	TP	CI	CC	MCC
2008	5	25	27	17	4	3	3	0	0	1	85	3.21	0.62	0.62
2009	6	29	38	23	15	3	1	0	0	0	115	3.22	0.63	0.64
2010	6	30	43	25	8	9	2	1	0	2	126	3.42	0.64	0.65
2011	14	44	56	25	18	8	1	1	1	2	170	3.25	0.61	0.61
2012	7	39	51	37	22	10	7	2	0	0	175	3.55	0.66	0.66
2013	7	65	58	58	25	12	5	1	1	3	235	3.50	0.65	0.66
2014	12	72	92	52	41	14	7	7	1	3	301	3.56	0.65	0.66
2015	13	100	88	67	52	25	10	6	3	4	368	3.64	0.66	0.66
2016	19	104	140	81	61	29	14	4	2	6	460	3.60	0.66	0.66
2017	9	137	140	88	74	43	14	11	6	8	530	3.78	0.67	0.67
2018	13	138	179	126	79	56	37	15	10	8	661	3.95	0.69	0.69
2019	13	187	180	151	105	49	37	24	8	12	766	3.91	0.68	0.68
2020	20	241	226	182	124	126	59	34	21	29	1062	4.19	0.69	0.69
2021	24	237	273	210	185	154	126	61	43	80	1393	4.71	0.72	0.72
2022	28	271	290	277	198	199	145	88	84	122	1702	4.95	0.73	0.73
Total	217	1806	1969	1470	1035	752	473	259	180	285	8149	3.76	0.66	0.67

SA= Single Authors, TA= Two Authors, TA= Three Authors, FA= Four Authors, five authors, SA= Six Authors, seven authors, EA= Eight Authors, NA= Nine Authors, MTA= More Than Ten Authors, CI= Collaboration Index, CC= Collaboration Coefficient, MCC= Modified Collaboration Coefficient

L. Collaboration Index, Collaboration Coefficient, Modified Collaboration Coefficient in Waste-to-Energy Research

Table XII provides an explanation of various collaboration components in waste-to-energy research during a fifteen-year period (2008-2022). The Collaborative Index (CI), Collaborative Coefficient (CC), and Modified Collaborative Coefficient (MCC) are all included in the study. The table shows that the Collaborative Index was highest in 2022 (4.95) and lowest in 2008 (3.21). The mean value of CI during the study period is 3.76. In this study, CC was highest in 2022 (0.73) and lowest in 2011 (0.61). The mean value of CC during the study period is 0.66. The MCC had the highest rate in 2022 (0.73) and the lowest rate in 2011 (0.61). The mean value of MCC during the study period is 0.67.

VI. FINDINGS OF THE STUDY

1. In the year-wise publication of solar energy research in India, 2969 research papers were published in 2022 out of 17649 in the sample period by the Indian researcher. In 2009, the highest average number of citations per paper was 64.30, and the highest h-index received was 93 in 2018.
2. In the year-wise publication of solar energy research worldwide, 21142 research papers were published in 2022 out of 181044 in the sample period by the world researcher. In 2009, the highest average number of citations per paper was 66.16, and the database needed to provide the H-index for 2014 to 2022.
3. In the year-wise publication of waste-to-energy research in India, 1702 research papers were published in 2022 out of 8149 in the sample period by the Indian researcher. In 2008, the highest average number of citations per paper was 86.09, and the highest h-index received was 80 in 2020.
4. In the year-wise publication of waste-to-energy research worldwide, 13252 research papers were published in 2022 out of 91190 in the sample period by the world researcher. In 2008, the highest average number of citations per paper was 67.18, and the database needed to provide the H-index for 2020 to 2022.
5. The relative growth rate and doubling time of publications for different years are fluctuating in both solar and waste-to-energy research.
6. In the solar energy research, annual growth rate and compound annual growth rate received positive and negative trends, but in the waste-to-energy research, annual growth rate and compound annual growth rate received positive trends.
7. In the study, the average exponential growth rate of solar energy was 1.25, and the average exponential growth rate of waste-to-energy was 1.24. On the whole, it was clearly known that there was a fluctuation in the exponential growth rate during the study period.
8. The result of the Publication Efficiency Index was 1.49 in both research areas, like solar and waste-to-energy, in the sample period.
9. The study found that the expected future growth rate of solar and waste-to-energy is in an increasing trend.
10. The average number of authors per article is 4.31, and the average productivity per author is 0.24 in solar energy. The average number of authors per article is 3.91, and the average productivity per author is 0.26 in waste-to-energy.
11. The average degree of collaboration is 0.98 recorded, the same in solar and waste-to-energy.
12. The study analysis of CI, CC, and MCC mean values is 3.77, 0.66, and 0.66, respectively, in solar energy. The CI, CC, and MCC mean values are 3.76, 0.66, and 0.67, respectively, in waste-to-energy.

VII. CONCLUSION

The study analyzed the comparative research performance regarding publication outputs and their impact on citations in solar and waste-to-energy research during 2008-2022. A total of 17,649 research publications were published and received 385,016 citations. In comparison, world publications in solar energy totaled 181,044 research papers, which received 6,081,621 citations during 2008-2022. In the study, waste-to-energy research published a total of 8,149 research papers and received 239,076 citations. In comparison, world publications in waste-to-energy research included 91,190 research papers, which received 2,683,850 citations during 2008-2022. The overall observation of the study shows an increasing trend in the research growth rate for both solar and waste-to-energy research, as indicated by various scientometric parameters.

REFERENCES

[1] Ankudey, A. S. (2021). Scientometric analysis of solar cell research: A comparison between Africa and India. *Journal of Information & Knowledge Management, 20*(2), 2150018. https://doi.org/10.1142/S0219649221500180

[2] Berana, Y., Saleem, M. W., Ali, H., & Mohmmed, A. (2024). Visualizing the landscape and evolution of solar energy-integrated desalination systems via scientometric analysis. *Energies, 17*(12), 1-20. https://doi.org/10.3390/en17122857

[3] Dehnad, A., & Abdekhoda, M. (2023). Mapping the publications of e-learning during the COVID-19 pandemic: A bibliometric analysis. *Journal of Scientometric Research, 12*(1), 35-43. https://doi.org/10.5530/jscires.12.1.007

[4] Garg, K. C., & Sharma, P. (1991). Solar power research: A scientometric study of world literature. *Scientometrics, 21*(2), 147-157. https://doi.org/10.1007/BF02017565

[5] Ganasen, N., Bahrami, A., & Loganathan, K. (2023). A scientometric analysis review on agricultural wastes used as building materials. *Buildings, 13*(2), 1-28. https://doi.org/10.3390/buildings13020426

[6] Gbey, E., Turkson, R. F., & Lee, S. (2022). A bibliometric survey of research output on wireless charging for electric vehicles. *World Electric Vehicle Journal, 13*(2), 37-61. https://doi.org/10.3390/wevj13020037

[7] Giovanetti El-Deir, S., & Cardim de Aguiar, A. (2022). Bibliometrics of scientific articles on solid waste management in shopping malls (1999-2020). *Advances in Environmental and Engineering Research, 3*(3), 1-18. https://doi.org/10.21926/aeer.2203034

[8] Mondal, A. K. (2021). A bibliometric study on DC, RGT, and DT of publications and citations of ISTL Journal during 2010-2020. *Library Philosophy and Practice*, 2021(June), 1-12.

[9] Montoya, F. G., Montoya, M. G., Gómez, J., Manzano-Agugliaro, F., & Alameda-Hernández, E. (2014). The research on energy in Spain: A scientometric approach. *Renewable and Sustainable Energy Reviews, 29*, 173-183. https://doi.org/10.1016/j.rser.2013.08.094

[10] Nandeesha, B., & Begum, K. J. (2023). Scientometric analysis of communication disorders. *Asian Journal of Information Science and Technology, 13*(2), 39-45. https://doi.org/10.51983/ajist-2023.13.2.3779

[11] Narendra, A., & Kannappanavar, B. U. (2022). Relative growth rate and doubling time of publications of IASLIC Bulletin: A scientometrics study from 2004 to 2018. *Journal of Xi'an University of Architecture & Technology, XII*(II), 1321-1331.

[12] Neeraj, & Swain, P. N. K. (2022). Contribution of India to research on big data. *IJFANS International Journal of Food and Nutritional Sciences, 11*(13), 259-267. https://www.ijfans.org/issue-content/contribution-of-india-to-research-on-big-data-3952

[13] Noor, M. I. M., Awang, N., & Abdullah, M. F. (2023). A scientometric review of solar energy research in business economics. *Journal of Scientometric Research, 12*(1), 114-129. https://doi.org/10.5530/jscires.12.1.014

[14] Oteng, D., Zuo, J., & Sharifi, E. (2021). A scientometric review of trends in solar photovoltaic waste management research. *Solar Energy, 224*, 545-562. https://doi.org/10.1016/j.solener.2021.06.036

[15] Patel, M. K., & Verma, M. (2024). Authorship pattern and degree of collaboration in the field of diabetes research output in India: A scientometric analysis. *Journal of Ravishankar University, Part A, 30*(2), 55-63.

[16] Ramakrishnan, J., Ravi Sankar, G., & Thavamani, K. (2022). Literature of aesthetic plastic surgery: A bibliometric study. *Asian Journal of Information Science and Technology, 12*(1), 8-17. https://doi.org/10.51983/ajist-2022.12.1.3030

[17] Ravichandran, S., Siva, N., & Vivekanandhan, S. (2025). Research trend on robotics during 2012-2021: A scientometric analysis. *International Journal of Scientific Engineering and Applied Science (IJSEAS), 8*(5), 28-45.

[18] Ravichandran, S., Vivekanandhan, D. S., & Vinita Angeline, G. (2022). Citations and publications on zero pollution research during 2012-2021: A scientometric study. *International Journal of Research in Library Science, 8*(4), 63-79. https://doi.org/10.26761/ijrls.8.4.2022.1589

[19] Ravichandran, S., Vivekanandhan, S., & Siva, N. (2022). Publications and citations analysis of Twitter research output from SCOPUS database: A scientometric analysis. *International Journal of Research in Library Science, 8*(2), 9-26. https://doi.org/10.26761/ijrls.8.2.2022.1527

[20] Sameer, I., Simmou, W., & Ibrahim, M. (2023). Mapping the intellectual structure of corporate social responsibility in emerging markets: A scientometric analysis from 1984 to 2021. *Journal of Scientometric Research, 12*(1), 92-97. https://doi.org/10.5530/jscires.12.1.012

[21] Sankar, V., & Ramaswamy, S. (2022). Global scientific productivity of top four journals of virology over three decades: A scientometrics study. *Asian Journal of Information Science and Technology, 12*(2), 29-40. https://doi.org/10.51983/ajist-2022.12.2.3345

[22] Singh, H., Arya, R., & Jaiswal, B. (2023). Tracking the impact and trends in water resources research in India: A scientometric analysis. *Library Progress International, 43*(2), 172-186. https://doi.org/10.48165/bpas.2023.43.2.5

[23] Vasantha, B., & Sangeetha, M. (2023). Research productivity of Prof. Sunilkumar S. Manvi: A scientometric portrait. *Asian Journal of Information Science and Technology, 13*(2), 8-16. https://doi.org/10.51983/ajist-2023.13.2.3600

[24] Verma, M. K., & Shukla, R. (2019). Mapping the Indian contribution in pathogen research during 2008-2017: A scientometric analysis. *Library Philosophy and Practice, 2019*(9), 1-12.