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Article

Energy research in a pluralistic system: Bibliometric analysis of SA publications

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Abstract: This article presents the results of a bibliometric analysis of South African energy publications during the period 2011 to 2021. Bibliometric analyses have the potential to reveal policy issues that cannot be identified easily through other approaches (e.g., peer review). Several findings are important for policy. It is identified that a substantial number of the energy publications produced by South Africans are proceedings papers. Identification of the main funders leads to the assumption that the National Research Foundation funding for conferences has led to the overproduction of proceedings. The most prolific producers of energy research produce approximately the same number of publications. Energy research is distributed to a large number of universities in the country. It is suggested that this may create diseconomies of scale. Comparisons of the organizational outputs of the South African organizations with international entities identify that the country's organizations are subcritical. Analysis of the international collaborative patterns of energy identifies that collaboration is very light in comparison to collaborative patterns of all disciplines. It is noted that researchers moved towards renewable technologies even though there is no relevant support from the government. The investigation identifies that bibliometrics is a powerful approach for monitoring and evaluating disciplines within systems of innovation.

Keywords: energy and fuels; bibliometrics; South Africa; web of science (WoS)

1. Introduction

South Africa's science, technology, and innovation policy has been recently the subject of several government reports [1,2] which aim to restructure and redirect the national system of innovation. Probably the most important change recommended in the above reports is the restructuring of the system of innovation from a pluralistic one to a coordinated one.

Energy is identified as an important priority in the Decadal Plan [2]. After all, the country has suffered from load-shedding for some years, and it is expected that this challenge will remain with the country for some time. Furthermore, in 2015 the United Nations approved the Sustainable Development Goals (SDG). The 17 goals are strategic for achieving a sustainable future for humanity and the planet [3]. Among them, energy has an important role that has been addressed in SDG 7 (ensuring access to affordable, reliable, sustainable and modern energy for all). It is interesting to note that the most recent Integrated Resource Plan of the Department of Mineral Resources and Energy [4] focuses only on the issue of electricity.

It should be mentioned that the discipline of energy functions in a science and technology system can be characterized as pluralistic.

In a pluralist system, government departments, and their associated institutions, receive an appropriation and decide how to spend the resources on research and its

various elements. No supervision or coordination is present, and science policy is the total of the activities of the various departments [5]. This is the main reason for the choice of South Africa for the current investigation.

In a coordinated system, the various authorities initiate and manage their research activities, but they also set up mechanisms to be aware of each other's activities and be able to integrate them.

The challenges in a pluralistic system include fragmented research efforts; stop-go approaches in the funding of research; lack of understanding of how a disciplinary area will be affected by the introduction/closing of an incentive program, etc.

For the analysis of this article, we utilize bibliometrics. Bibliometric analysis, the quantitative study of the research system, is based mainly on publication indicators. An indicator is defined [6] as "statistics of direct normative interest which facilitate concise, comprehensive and balanced judgments about the condition of major aspects of society. It is in all cases a direct measure of welfare and is subject to the interpretation that, if it changes in the 'right' direction, while other things remain equal, things have gotten better, or people are better off." In bibliometrics, the number of publications in a field is considered an indicator of research activity, and the citations are indicators of impact. An increasing number of publications is indicative of a thriving scientific field. Similarly, comparisons of publications in a particular field *vis-à-vis* those of other countries may be indicative of relevant performance.

Despite the importance of the discipline of energy, the field is not monitored regularly in South Africa and academic researchers investigate it only rarely [7–9].

The current investigation is utilizing bibliometrics for monitoring and evaluation of the field of 'energy and fuels' within South Africa's pluralistic national system of innovation. The questions that are expected to be answered include the following: Is energy research increasing during the under-examination period? How do changes in funding incentives in the National Research Foundation (NRF) (main energy funder) affect the field of energy? How is the energy field affected in terms of scientific collaboration from the influence of traditional collaborators and new ones and others?

2. Literature review

Bibliometrics has been used to investigate a variety of issues in the context of South Africa. These include issues of industry 4.0 [10]; the state of the bioeconomy [11]; collaboration [12]; and others.

In the field of energy, investigations identify the research interest in particular sub-domains of the field [13,14]; undertake impact assessment [15]; foresight National Advisory Council on Innovation [9]; assessment of the field in the international context [16], and others.

Bibliometric assessments have several advantages. They are repeatable and verifiable exercises—a characteristic not available in approaches following peer reviews.

Probably their most important advantage is that they allow comparisons among different scientific disciplines and different countries. Both types of comparisons are not possible through peer review approaches as it is almost impossible to find peers with expertise in different scientific fields and knowledge of the research systems in

different countries (if a peer review approach was contemplated). Hence, bibliometrics provides a unique way to identify 'revealed' research priorities in a country or region as well. Similarly, bibliometric indicators can identify research centers and organizations contributing to the knowledge base of a particular sub-discipline and the relevant size of their contribution. Again, such information is valuable for benchmarking purposes. Bibliometric analysis can also reveal the funders as they are declared by the authors of the research. This baseline can be used in future efforts to identify changes in focus and increase/decrease in research activities.

The philosophy underlying the use of bibliometric indicators as performance measures has been summarized in De Solla Price's [17] statement that "for those who are working at the research front, publication is not just an indicator but, in a very strong sense, the end product of their creative effort." Scientists performing managerial or administrative functions may teach available knowledge or they may apply existing knowledge to making new products and in providing services. They have the common characteristic that they are far away from the research front.

Currently, disciplinary assessments based on quantitative indicators are used internationally in support of policy development [18,19]. There is a growing awareness of the advantages of basing opinions and subsequent choices on criteria that lend themselves more to quantitative evaluation [20]. Science policy reviews would seem inconceivable today without recourse to existing indicators [21].

Bibliometrics are not without their shortcomings. For example, the coverage of databases like Scopus and Web of Science (WoS) can be limited, affecting the accuracy of bibliometric analyses. Similarly, there may be language biases and researchers should be aware of the different characteristics of various disciplines and use appropriate approaches.

Approach

Bibliometric analyses require the availability of appropriate databases.

The WoS databases are the most often used for these types of investigations. The combined databases comprehensively cover the most prestigious journals in the world in all fields of research endeavors and constitute a unique information platform for the objectives of this effort. The most important advantage of the WoS journals is that they constitute the most important (in terms of impact) journals in the world.

An additional important characteristic is the fact that the databases provide the addresses of all authors, hence making detailed analyses possible.

In South Africa, the Department of Higher Education and Training (DHET) has accepted the ISI-indexed journals for subsidy purposes (universities receive approximately R 100 000 ($ 5 550) for each article they produce) and universities give incentives to their researchers to publish in ISI-indexed journals. Consequently, it is expected that the databases will cover not only the most important South African energy-related research but the majority of it as well.

The core set of the WoS is used for this analysis. It should be mentioned that despite the uniqueness of this database, there are challenges. For example, not all articles published are indexed, as not all journals are indexed; the WoS emphasizes the coverage of English language journals.

The fields ‘energy fuels’ and ‘electrochemistry’ are analyzed as they represent the research domain of ‘energy’. Five thousand, eight hundred and fifty-five (5855) documents belong to one or both energy categories. It is emphasized that additional articles related to energy may be published in other journals (e.g., in multidisciplinary journals) but it is expected that the majority and most important related articles will be published in the core energy journals.

The time covered includes data from 2011 to 2021. The most recent year for which complete data were available when we started investigating the issue was 2021.

The identified documents were analyzed in order to identify trends over time; types of documents (e.g., conference proceedings, research articles, etc.); subject areas contributing to the field of energy and electrochemistry; producers of energy research in the country; research emphasis in the main organizations producing energy research; countries and organizations collaborating on energy research with South Africa. Most of the energy indicators (e.g., degree of collaboration, collaborating countries, etc.) are compared with the same indicators related to the average number of all SA articles. Differences are explained on the basis of the context in which energy operates in the country (e.g., main funders and their programs).

3. Energy research in South Africa

Table 1 shows the number of energy publications with at least one author with a South African address.

Table 1. SA energy & fuels and electrochemistry-related publications 2011–2021.

	Category of fields	
Year	**Energy & Fuels**	**Electrochemistry**
2021	761	116
2020	570	150
2019	597	120
2018	548	90
2017	568	92
2016	477	86
2015	376	114
2014	376	161
2013	305	112
2012	212	108
2011	149	76

The category energy & fuels produced almost six times more publications than electrochemistry by the end of the period. Energy & fuels publications increased from 149 publications in 2011 to 761 publications in 2021. This was a 5.1 times increase over the period. During the period the total number of SA publications increased from 12,878 to 30,214—an increase of 2.3 times. Energy and fuels publications increased faster than the average SA publications on all scientific disciplines.

We identified the changes in the number of ‘articles’ only. The database identifies

articles, proceedings, reviews, etc. The increase of the energy articles was from 116 (2011) to 439 (2021) a multiple of 3.78. The issue of proceedings *vis-à-vis* research articles is of importance [22] (papers in conference proceedings receive far fewer citations than journal articles) and we discussed it further when we identified the funders of energy research in South Africa.

Energy & fuels publications show a drop during 2020 which can be argued is the result of the COVID-19 virus. The series appears to have recovered during 2021.

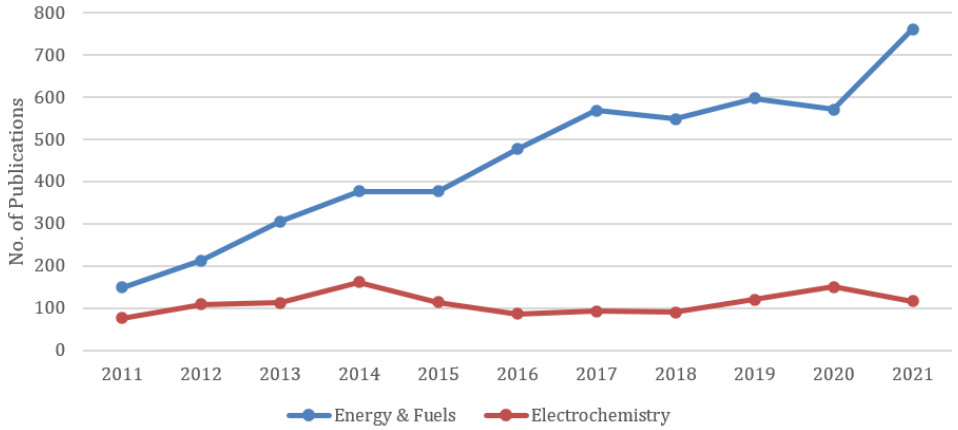

Figure 1. SA energy & fuels and electrochemistry 2011–2021.

Figure 1 provides a diagrammatic exposition of the number of publications from South Africa on energy & fuels and electrochemistry. It is apparent that while the publications related to energy & fuels increased from 2011 to 2017 the number of publications related to electrochemistry remained at the same level. During the most recent period 2017–2021, the number of electrochemistry publications remained at the same levels.

Table 2. Document types—Energy & fuels and electrochemistry.

Document types	Energy & Fuels	Electrochemistry
Articles	2651	1127
Proceeding Papers	2072	101
Review Articles	267	58
Book Chapters	130	7
Editorial Material	39	10
Early Access	16	0
Corrections	13	3
Letters	4	0
Retracted Publications	4	3
News Items	1	0
Retractions	1	0
Biographical-Items	0	2

Table 2 shows the document types produced by energy & fuels and electrochemistry. Out of 4939 energy documents 2651 were research articles.

Proceedings were 78% of the articles and 41.9% of the total publications. In the total SA publications, the average proceedings is 12%. Proceedings appear to be substantially more in the field of energy and fuels than in the average of SA publications. This is surprising as in general research articles are often considered more prestigious and influential. In South Africa the government provides half the subsidy for proceeding articles than in research articles.

The table also shows that electrochemistry attracts fewer non-articles (proceedings, reviews, etc.) in comparison to energy & fuels as a percentage of the relevant number of articles.

Table 3 shows the distribution of the energy & fuels publications to subject areas for the period 2011–2021. 2315 publications belong to both energy & fuels and engineering, electrical and electronic.

Table 3. Energy & fuel publications according to subject area.

Subject Areas of energy & fuels	**Number of Documents**
Energy Fuels	4939
Engineering	2315
Science Technology & Other Topics	681
Chemistry	496
Electrochemistry	309
Thermodynamics	278
Materials Sciences	254
Environmental Sciences Ecology	233
Computer Science	165
Agriculture	140
Mechanics	125
Construction Building Technology	114
Physics	111
Business Economics	74
Robotics	66
Nuclear Science Technology	52
Geology	47
Mining Mineral Processing	36
Optics	20

Table 4 shows the electrochemistry publications according to subject areas. Chemistry is on top of the list with 612 records. It is followed by energy & fuels and materials science.

Table 4. Electrochemistry publications according to subject area.

Subject Areas	Number of Documents
Electrochemistry	1225
Chemistry	612
Energy Fuels	309
Materials Sciences	148
Instruments Instrumentation	71
Science Technology Other Topics	29
Physics	27
Biophysics	19
Biotechnology Applied Microbiology	18
Metallurgy Metallurgical Engineering	12
Engineering	7
Polymer Science	2
Biochemistry Molecular Biology	1
Life Sciences Biomedicine Other Topics	1

Table 5 shows the main organizations that produce energy research publications. The University of KwaZulu Natal (UKZN) is the most prolific university with 475 records during the period. The North-West University (NWU) follows with almost the same number of publications. Third in the list is the University of Pretoria (UP) with just 10 records less than the UKZN.

Table 5. Producers of energy research.

Organization	Number of Records
University of Kwazulu Natal (UKZN)	475
North-West University (NWU)	472
University of Pretoria (UP)	465
Stellenbosch University (SU)	455
University of Johannesburg (UJ)	434
University of Cape Town (UCT)	357
Tshwane University of Technology (TUT)	274
University of Witwatersrand (Wits)	209
Council For Scientific Industrial Research (CSIR)	176
Cape Peninsula University of Technology (CPUT)	174
University of the Western Cape (UWC)	155
Durban University of Technology (DUT)	133
University of South Africa (UNISA)	120

In comparison to 2001–2011, UP moved from the top position to the third one even though its number of publications increased from 105 to 465. Similarly, UCT moved to the 6th position from the second position in the previous ten years. NWU advanced by one rank to second position. It should be emphasized that the most prolific universities produce almost the same number of publications and small

changes can alter their relative ranking.

The closeness of the number of energy publications among the top universities means that the ranking is sensitive to the number of years used for the rankings.

Table 6. Research emphasis on top energy-research universities.

UJ	UKZN	SU	UP
Engineering Electrical Electronic 37%	Engineering Electrical Electronic 27%	Engineering Electrical Electronic 23%	Green Sustainable S T 19%
Green Sustainable S T 18%	Engineering Chemical 19%	Green Sustainable S T 20%	Engineering Chemical 13%
Chemistry Physical 5%	Green Sustainable S T 14%	Biotechnology Applied Microbiology 12%	Thermodynamics 12%

Table 6 shows the research emphasis of the top energy universities for a more recent period 2017–2021. Engineering, Electrical and Electronic, is the top discipline at UJ, UKZN, and SU. The UP emphasizes green sustainable science and technology. It is surprising that in a pluralistic environment like the one in South Africa the top 4 universities focus their research emphasis on the same disciplines.

It is interesting to compare SA's productivity in the field with some international organizations. For example, the USDOE produced 22 294 publications during the 10-year period; Harvard University 19 393, University of London 18 911, University of San Paulo 12 200, University of Queensland 6915, and University of New South Wales Sydney 6 621. Local SA organizations produce only a small fraction of the energy output of the international organizations. It is an issue for further research, but it can be argued that the pluralistic approach used in the support of energy research in the country creates small structures and diseconomies of scale.

Table 7. Collaborators of SA energy research.

Organization	Number of Records
IRGCP	81
League of European Research Universities	68
Covenant Universities	66
Islamic Azadi University	41
Indian Institute of Technology	33
Georgia Institute of Technology	30

Table 7 shows the foreign organizations with the highest number of collaborative documents with South Africa. It is interesting to note that collaboration with Islamic Azadi University, and the Indian Institute of Technology, does not appear high in the list of collaboration in other scientific disciplines in SA.

Table 8. SA energy collaboration with other countries.

Country	Number of Records
South Africa	4939
Nigeria	307
People's R China	263
USA	257
India	203
Canada	86
Italy	68
Norway	60
Denmark	52

Table 8 shows the main countries collaborating with South Africa in the field of energy. It is interesting to note that Nigeria is on top of the list followed by People's R China, USA and India.

In order to make a valid comparison we identified the main countries collaborating with SA in all scientific fields. During this period SA had 209,477 publications. Of these 36,341 were with the United States of America (USA); 23,992 with England; 13,950 with Germany and 13,615 with Germany. China appeared in the 8th position in the list with 8335 common publications and India in the 9th position with 8289 common publications. Nigeria occupied the 14th position in the list with 6017 common publications with South Africa.

Comparing the two groups—energy and SA all disciplines—it becomes evident that only USA is common among the top four countries collaborating with SA. Furthermore, collaboration in the field of energy is very light. The top three countries contribute 15% of the total number of publications in the field of energy while in the total disciplines, the top three countries contribute 35% of the total number of publications.

Table 9 shows the number of SA publications in each Web of Science category during the period 2011–2021. The energy & fuels category with 4939 publications is in the 13th position.

Table 9. Web of Science categories—SA 2011–2021.

Category	Number of records
Public Environmental Occupational Health	9430
Environmental Sciences	9244
Infectious Diseases	8688
Engineering Electrical Electronic	8616
Multidisciplinary Sciences	8238
Plant Sciences	7583
Education Educational Research	7184
Ecology	6479
Medicine General Internal	6372
Astronomy Astrophysics	6164

Table 9. (*Continued*).

Category	Number of records
Immunology	6144
Materials Science Multidisciplinary	5835
Energy Fuels	4939
Religion	4753
Chemistry Multidisciplinary	4615
Biochemistry Molecular Biology	4301
Pharmacology Pharmacy	4261
Chemistry Physical	4108
Zoology	4 006
Microbiology	3824
Economics	3817
Geosciences Multidisciplinary	3724
Physics Applied	3577
Area Studies	3550
Psychology Multidisciplinary	3493

Table 10 provides a ranking of countries in the field of energy & fuels. On top of the list are China and the USA. South Africa is ranked 31st.

During 2019 SA was ranked 28th in the world.

Table 10. Ranking of countries on energy & fuels (2019).

Ranking	Countries	Energy & Fuels
1	People's R China	25,502
2	USA	9525
3	India	3939
4	Germany	3375
5	England	3295
6	Australia	2629
7	Italy	2597
8	South Korea	2508
9	Iran	2441
10	Canada	2246
11	Spain	2215
12	Japan	2126
13	France	1847
14	Russia	1589
15	Brazil	1538
16	Poland	1099
17	Turkey	1095
18	Sweden	1080
19	Malaysia	1077

Table 10. (*Continued*).

Ranking	Countries	Energy & Fuels
20	Denmark	1029
21	Saudi Arabia	1008
22	Netherlands	904
23	Taiwan	888
24	Egypt	886
25	Switzerland	875
26	Singapore	795
27	Portugal	732
28	Norway	699
29	Romania	655
30	Pakistan	598
31	South Africa	590
32	Mexico	567

We have further for those 6311 publications constituting the energy domain (energy & fuels, electrochemistry, and nuclear science and technology) estimated those that may be considered as belonging to alternative forms of energy (solar, wind, geo*, hydro*, wood, bio*, nuclear, alternative). We identified that 3467 publications were related to the subject (55% of the total). When a stricter definition was used the relevant word was supposed to be in the title of the publication the population was reduced to 1677 (26.5%)

Similarly, we investigated the concept of 'efficiency'. Among the energy publications, 1574 (25%) belonged to the concept. When the word was required to be in the title the relevant number of publications was reduced to 227 (3.6%).

The most prolific producers on the topic of alternative forms of energy appear in **Table 11**. The universities of Stellenbosch, Johannesburg, and Pretoria are at the top of the list.

Table 11. Prolific SA organizations in the field of alternative forms of energy.

Organization	Number of records
University of Johannesburg (UJ)	609
University of Kwa-Zulu Natal (UKZN)	563
University of Pretoria (UP)	558
Stellenbosch University (SU)	555
Nort-West University (NWU)	520
University of Cape Town (UCT)	438
Tshwane University of Technology (TUT)	374
University of the Witwatersrand (Wits)	285
Cape Peninsula University of Technology (CPUT)	201
Council for Scientific and Industrial Research (CSIR)	197

Table 12 shows the most prolific organizations in the field of efficiency. North-

West University appears on top of the list followed by the University of Pretoria.

Table 12. Prolific SA organizations in the field of 'efficiency'.

Organization	Number of records
North-West University	263
University of Pretoria	202
University of Johannesburg	190
University of Kwa-Zulu Natal	150
Stellenbosch University	144
Tshwane University of Technology	134
University of Cape Town	91
University of the Western Cape	84
University of the Witwatersrand	84
UNISA	68

Table 13 shows the main funders of the research as they appear in the list of acknowledgments of the research documents. On top of the list is the NRF with 641 records. The other funders on the list are all foreign organizations except ESKOM. The South African National Energy Development Institute (SANEDI) (does not appear in the list) had 20 records.

The NRF is a government organization supporting research across all disciplines in South Africa. NRF reports to the Department of Science and Innovation. Most programs at NRF support all scientific disciplines and they don't discriminate according to the subject matter of the research applications.

The importance of the NRF in the funding of energy may provide suggestions for a large number of proceeding papers. NRF supports traveling to conferences. This is probably one of the few ways that a researcher can benefit from NRF funding. Based on this assumption it can be argued that energy researchers are supported by NRF to participate in international conferences, and this affects their outputs in proceedings.

Table 13. Main funders of energy research.

Funder	Number of records
National Research Foundation South Africa*	394
National Research Foundation NRF	122
National Natural Science Foundation of China NSFC	108
Department of Science Technology India	98
National Research Foundation	90
Council of Scientific Industrial Research CSIR INDIA	69
NRF	62

Note: * The National Research Foundation (South Africa) is shown in multiple lines depending on the way it was referred to in the various publications.

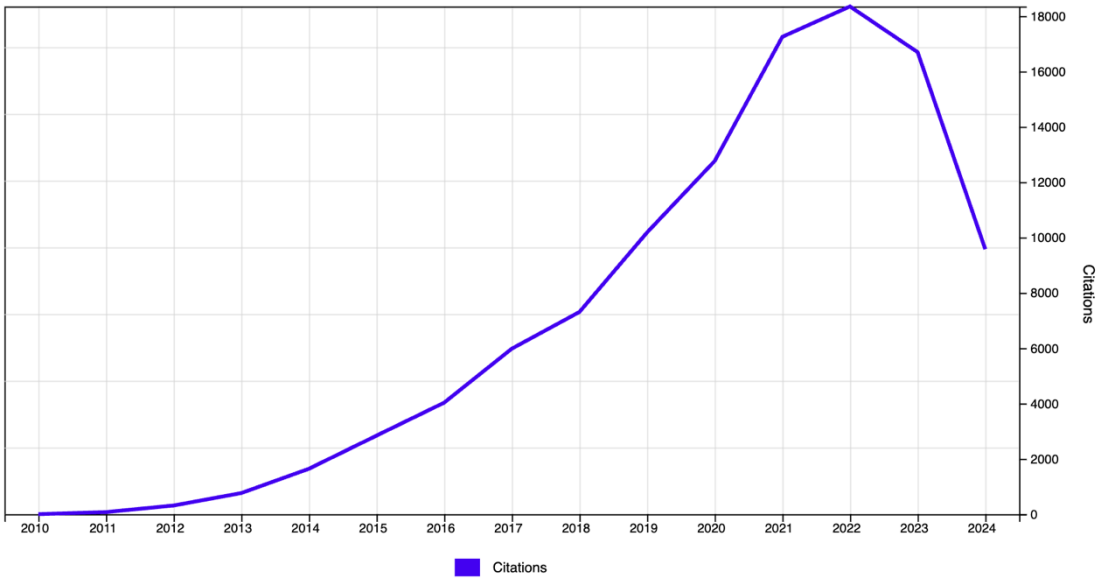

Figure 2. Citations received by the energy fuels and electrochemistry articles.

Figure 2 shows the number of citations received by the South Africa energy publications. The 4939 publications produced during the period received 107,777 citations. The average number of citations per article was 21.8 and the set has an H-index of 129.

The 1225 electrochemistry publications received 39,638 citations giving an average number of citations per article of 32.3. The H-index of the set is 80 (**Figure 3**).

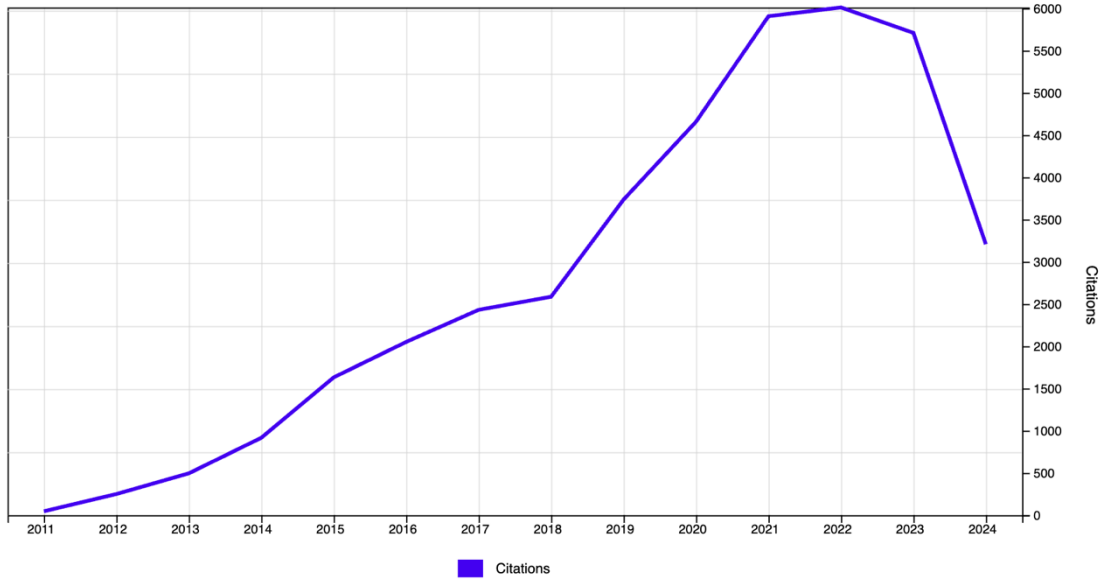

Figure 3. Citations received by the electrochemistry articles.

4. Conclusions and recommendations

This article presents the results of a bibliometric evaluation of the field of energy in South Africa. Although energy is of critical importance in South Africa the field is

not monitored regularly. The most recent assessment appears to be in a 2016 publication [8] by the author, with data of almost 10 years old. Such approaches have the potential to identify weakness in the research system under investigation and recommend remedies for improvement of efficiency and effectiveness in the system.

The current analysis identifies that the number of 'energy' publications has increased substantially during the period 2011–2021. However, comparisons with other countries show that the country is ranked 31st.

Further analysis of the identified publications reveals that the number of conference proceedings in the particular domain is substantially higher than the one expected by other disciplines in South Africa. It is argued that this may be a side effect of the fact that the incentives applied to energy research led the researchers to participate in conferences. This assumption was confirmed when an analysis of the data revealed that the main funder of energy research in the country is the NRF. NRF provides bursaries to all disciplines and one of its programs supports participation in conferences. As energy researchers do not have other sources of finance, they use NRF and comply with NRF's guidelines.

Comparative analysis with international organizations identifies that South African universities are 'sub-critical' in comparison with universities abroad. Energy research in South Africa follows the country's pluralistic approach, which allows the stakeholders to follow their priorities. As a result, universities create small units of energy research. While there may be diseconomies of scale present, the issue requires further investigation. Small research units do not create optimal utilization of research equipment; easy access to colleagues' research; limitations to research outputs; duplications within the country and others. All these make sure that the country cannot become a competitive global player.

The international collaborative patterns of the field of energy also appear to diverge from the national patterns. Energy appears to be less collaborative than the average discipline in the country and the main collaborators (Nigeria, China, and India) are different from the main collaborators in other disciplines. It should be mentioned that during 2011 SA joined the BRIC countries. This appears to have led to collaboration with the new partners. Furthermore, the identification of the main funders indicates that SA researchers were supported financially by Chinese and Indian organizations. There is no optimal size of collaboration and optimal identification of collaborators; hence, the two issues are the subject of further research.

The findings show that bibliometrics/scientometrics can make a valuable contribution to monitoring and evaluating particular scientific disciplines in different countries.

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References

1. Department of Science and Innovation. Draft Science, Technology, and Innovation Decadal Plan. Department of Science and Innovation, Pretoria; 2022.

2. Department of Science and Innovation. Higher education, science, technology, and innovation institutional landscape (HESTIIL)—Review Report. Department of Science and Innovation, Pretoria; 2021.
3. United Nations. Transforming our world: The 2030 agenda for sustainable development 2015. Available online: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed on 11 September 2015).
4. Department of Mineral Resources and Energy. Integrated Resource Plan 2023. Available online: https://www.dmre.gov.za/mining-minerals-energy-policy-development/integrated-resource-plan/irp-2023 (accessed on 11 September 2024).
5. Pouris A. Towards a metric of organizational structures for S&T policy: The concept of science policy space. South African Journal of Science. 1995; 91: 489-492.
6. Department of Health, Education and Welfare. Towards a Social Report. Department of Health, Education and Welfare University of Michigan Press, Ann Arbor; 1970.
7. Academy of Science of South Africa. The state of energy research in South Africa. Academy of Science of South Africa, Pretoria; 2014.
8. Pouris A. Structure of energy related literature: An application of citation analysis. South African Journal of Science. 1988; 83: 138–142.; doi/pdf/10.10520/AJA00382353_4679
9. Pouris A. bibliometric assessment of energy research in South Africa. South African Journal of Science. 2016; 112(11/12): 8. doi: 10.17159/sajs.2016/20160054
10. Dhamija P. South Africa in the era of Industry 4.0: An Insightful Investigation. Scientometrics. 2022; 127(9): 5083-5110. doi: 10.1007/s11192-022-04461-z
11. Bambo TL, Pouris A. Bibliometric analysis of bioeconomy research in South Africa. Scientometrics. 2020; 125(1): 29-51. doi: 10.1007/s11192-020-03626-y
12. Sooryamoorthy R. Scientific knowledge in South Africa: information trends, patterns and collaboration. Scientometrics. 2019; 119(3): 1365-1386. doi: 10.1007/s11192-019-03096-x
13. Chinnasamy B, Yuvakkumar R, Kumar PS, et al. Mapping and Scientometric Measures on Research Publications of Energy Storage and Conversion. Topics in Catalysis. 2022; 65(5-6): 753-764. doi: 10.1007/s11244-022-01597-3
14. Cristino TM, Faria Neto A, Costa AFB. Energy efficiency in buildings: analysis of scientific literature and identification of data analysis techniques from a bibliometric study. Scientometrics. 2017; 114(3): 1275-1326. doi: 10.1007/s11192-017-2615-4
15. Kostoff RN. Semi-quantitative methods for research impact assessment. Technological Forecasting and Social Change. 1993; 44: 231-244. doi: 10.1016/0040-1625(93)90070-N
16. National Advisory Council on Innovation. Big analytics for South Africa: National STI foresight. National Advisory Council on Innovation, Pretoria; 2019.
17. De Solla Price D. The productivity of research scientists. Yearbook of Science and the Future, Encyclopaedia Britannica Inc., University of Chicago, Chicago; 1975.
18. Pinto T, Teixeira AAC. The impact of research output on economic growth by fields of science: a dynamic panel data analysis, 1980–2016. Scientometrics. 2020; 123(2): 945-978. doi: 10.1007/s11192-020-03419-3
19. Thelwall M, Levitt JM. National scientific performance evolution patterns: Retrenchment, successful expansion, or overextension. Journal of the Association for Information Science and Technology. 2017; 69(5): 720-727. doi: 10.1002/asi.23969
20. World Bank. Monitoring and evaluation. International Bank for Reconstruction and Development World Bank, Washington, D.C; 2004.
21. Georgiou L. Assessing the framework programmes—A meta-evaluation. Evaluation.1995; 1(2): 171-188. doi: 10.1177/135638909500100
22. González-Albo B, Bordons M. Articles vs. proceedings papers: Do they differ in research relevance and impact? A case study in the Library and Information Science field. Journal of Informetrics. 2011; 5(3): 369-381. doi: 10.1016/j.joi.2011.01.011