https://dx.doi.org/10.22161/ijaers.6.6.50 *ISSN: 2349-6495(P) | 2456-1908(O)*

Repowering of Small Hydropower Plants: A bibliometric study in the Scopus Database

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***Abstract*—** *This study aimed to carry out a survey on the repowering of Small Hidropower Plants - SHP, which is related to energy innovation and sustainable development. To obtain the data was used to bibliometric study technique using the database Scopus Elsevier, through the CAPES portal, considering data from the last two decades. It was possible to verify the increase in quantity of articles related to the subject over the years and analyze the main authors, journals with higher frequency of publication on the subject, the main institutions, countries and areas of knowledge related to the work, and a survey the most relevant articles in each of the selected themes. For best performance, data were presented graphically.*
***Keywords*— Small Hydropower Plants (SHP); repowering; Energy Innovation; Sustainable development; Bibliometric study.**

I. INTRODUCTION

On the horizon of the Ten-Year Expansion Plan (PDE) 2026 (EPE, 2017), to meet add electricity demand is necessary to maintain a distributed energy sources, focusing on renewable sources (Hydropower, wind, solar and biomass), taking into account the social and environmental assumptions. The projection is that the renewable sources are responsible for 90% of the electricity generation in 2026.

Together, the hydropower plants, small hydropower - PCHs generating plants and hydropower stations are responsible for 64% of all electricity generated, and corresponding to 3.62% PCHs and CGHs (ANEEL, 2019).

According to the National Energy Plan - PNE - 2030 (EPE, 2007), most of the hydraulic potential to be tapped is in the North, bringing a number of challenges of economic, social and environmental character. It also calls for planning and participation of various sectors: government, academia, ONGs, local communities, etc.

The Hydro Power still has lower costs compared to other renewable energy sources, in addition to providing energy security, complementarity with other renewable,

https://dx.doi.org/10.22161/ijaers.6.6.50 *ISSN: 2349-6495(P) | 2456-1908(O)*

operating flexibility and maintaining a low carbon energy matrix (EPE, 2017).

According to ABRAGEL (2017), the power plants can meet the current difficulties of UHEs, reducing: transmission and distribution losses and delays in licensing / construction.

In an attempt to reduce environmental impacts from new hydropower projects and still meet the growing demand for electricity, there are some alternatives through technological innovations, among them we can highlight the repowering process.

According to Oliveira (2012), repowering is the application of a hydro development interventions and may be civil structures in hydraulic circuits or devices that comprise the generation process (turbine, generator, etc.) to improve efficiency and power.

Repowering is a procedure that is to somehow increase the power generation of an existing hydro plant.

According to Oliveira (2012), all hydro dams, be UHE, PCH or CGH, to a greater or lesser extent, can pass through repowering process, either undersized or lag.

Based on the large energy gain that can be provided through the repowering of Small Hydropower, through the application of new innovative or correcting design deficiencies technologies, this study aims to examine how this method has been used around the world.

II. METHODOLOGY

For this work, a bibliometrical study will be applied. According to Fonseca (1986), bibliometry is a quantitative analysis technique and statistical measurement of the rates of production and dissemination of specific knowledge.

It will apply the model proposed by Costa (2010), in which data about the main authors will be raised, countries, years, institutions, journals and areas of knowledge of publications related to the topic of repowering Small Hydropower Plants.

The original sample corresponds to articles indexed in the database Scopus Elsevier, with access through the Journals Portal of *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES*, in June 2019.

The survey was conducted by applying temporal filter, between the years 2000 and 2019, and document type, in this case, articles. Table 1 shows the selected keywords for search and the amount of found articles.

Table 1 – Keywords

Theme	Key Words	Articles Found
Small Hydropower Plant	" *Small Hidropower Plant"*	199
Repowering	*"Repowering"*	215
Energy innovation	*"Energy Innovation"*	9692
Sustainable development	*"Sustainable Development"*	77705

Source: Prepared by the author.

III. RESULTS AND DISCUSSION

By Elsevier Scopus database, the articles related to each of the keywords were analyzed.

The sample presented contains data related to the number of publications per year, authors, journals, institutions, countries and areas of knowledge more often published in addition to the most relevant articles within the range of the last two decades (2000-2019).

3.1 Small Hidropower Plant - SHP

For this session, the terms used for the research were "*Small Hidropower Plant*". Applying the filter to articles, the search returned 199 results.

3.1.1 Publications per year

In Figure 1 you can graphically view the data relating to publications per year, from 2000 to 2019 range.

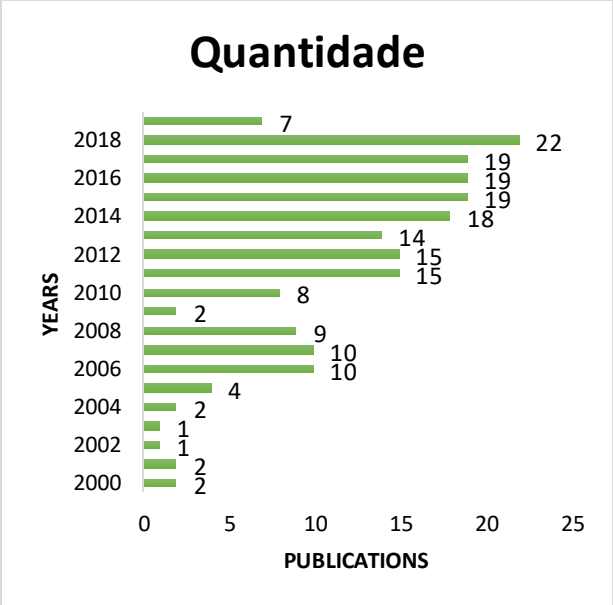

Fig.1: Frequency Plot publications per year in the period 2000-2019.

Source: *Adapted from Scopus (2019).*

You can check that the year 2009 showed a very low number of publications in this area, only two, then the volume is growing again. In 2019 found 7 articles to date this research.

3.1.2 Authors

The authors further reported on small hydro power stations, in the range 2000 - 2019 are shown in Figure 2.

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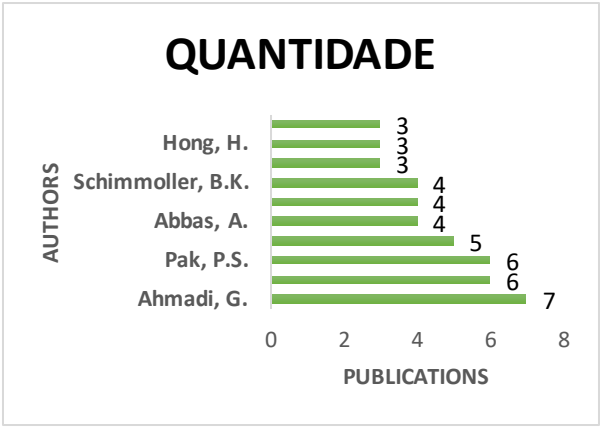

Fig.2: Graph authors with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.1.3 Journals

The data about which journals had higher publications on the subject are shown graphically in Figure 3.

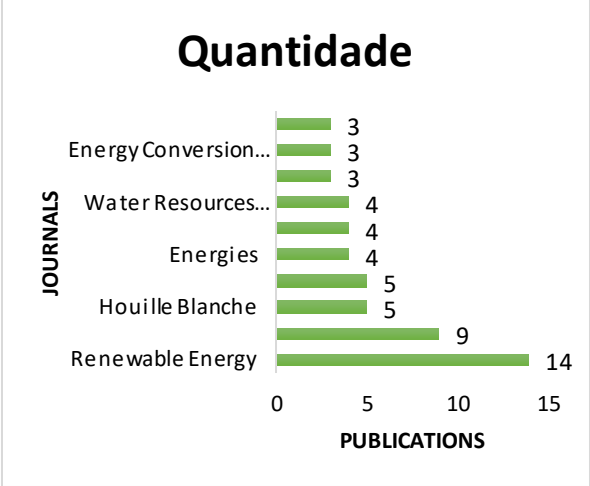

Fig.3: graph with periodic higher frequency of publication.

Source: Adapted from Scopus (2019).

3.1.4 Membership

The affiliates who contributed to the publications are illustrated graphically in Figure 4.

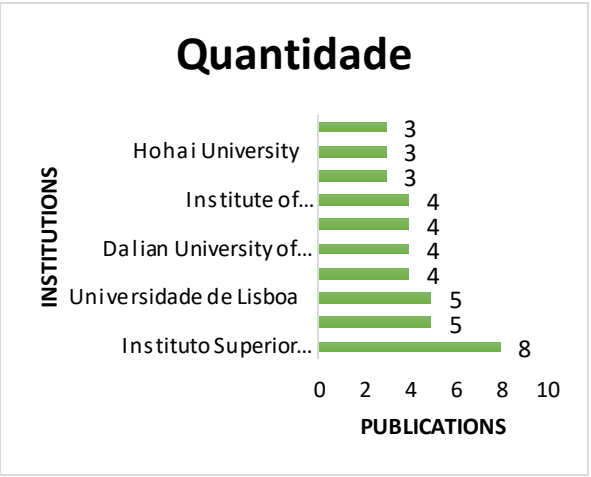

Fig.4: Graph institutions with higher frequency of publication.

Source: Adapted from Scopus (2019).

As noted, Brazil has highlighted this issue due to the work of the Federal University of Rio de Janeiro - UFRJ.

3.1.5 Countries

In Figure 5, below, are graphically represented the countries that contributed to publications in this period.

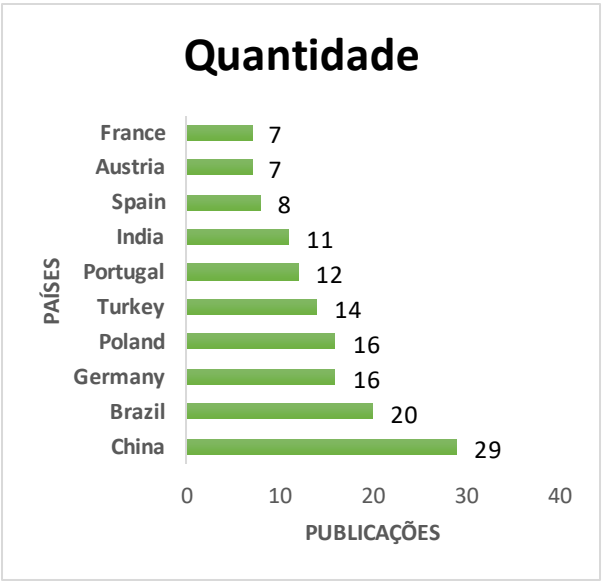

Fig.5: Graph of the countries with higher frequency of publication.

Source: Adapted from Scopus (2019).

Twenty publications, Brazil ranks second in the ranking, demonstrating that, in addition to having a predominant energy sources of hydropower, contributes to the development of the sector.

3.1.6 Knowledge Area

The data in Figure 6, illustrated below, graphically demonstrate knowledge areas with the highest frequency of publication on the subject.

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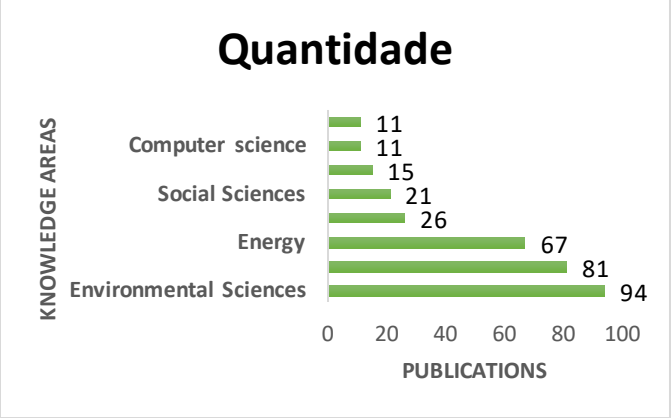

Fig.6: Chart of the areas of knowledge with higher frequency of publication

Source: Adapted from Scopus (2019).

3.1.7 Analysis of Articles

Table 2 presents the articles more relevantly, i.e. those with the largest number of citations, according to the database.

Table 2: Most relevant articles - Small Hydropower Plants.

TITLE	AUTHORS	YEAR	CITATIONS
Investment timing and optimal capacity choice for small hydropower projects.	BØCKMAN, T. et al.	2008	93
Energy Production in Water Distribution Networks: A PAT Design Strategy.	CARRAVETTA, A. et al.	2012	92
Ecological consequences of hydropower development in Central America: Impacts of small dams and water diversion on neotropical stream fish assemblages.	ANDERSON, E.P. et al.	2006	80
The role of hydro power and contribution of small hydropower plants for sustainable development in Turkey.	DURSUN, B., GOKCOL, C.	2011	66
Optimal sizing of a run-of-river small hydropower plant.	ANAGNOSTOPOULOS, J.S., PAPANTONIS, D.E.	2007	56

Source: Adapted from Scopus (2019).

3.2. Repowering

For this section, the term used for the research was "*Repowering*". Applying the filter to articles, the search returned 215 results.

3.2.1 Publications per year

In Figure 7, you can graphically display the number of publications per year about repowering, in the 2000 to 2019 range.

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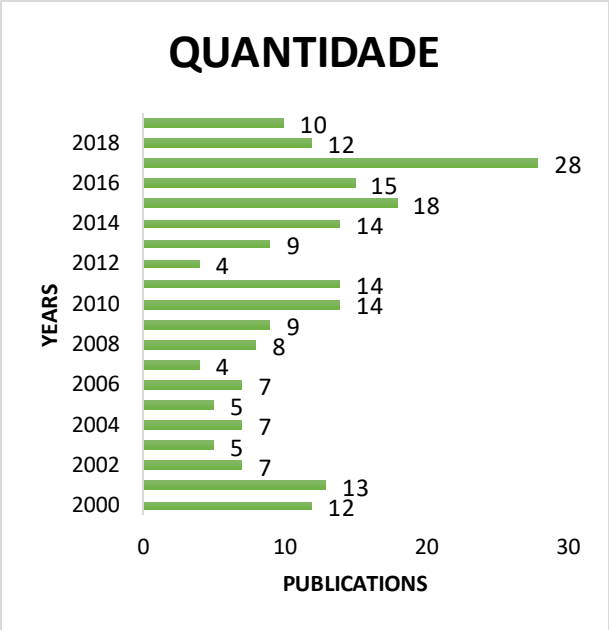

***Fig.7**: Frequency Plot of publications per year in the period 2000-2019.*

Source: Adapted from Scopus (2019).

Note that there was a peak of publications in the year 2017 (28 posts) and a fall in 2018 (12 publications). In 2019 the trend is for this number to further increase, considering that to date the research have been published 10 articles.

3.2.2 Authors

The authors most frequently published on Small Hydro Power in the range 2000 - 2019 are shown in Figure 8.

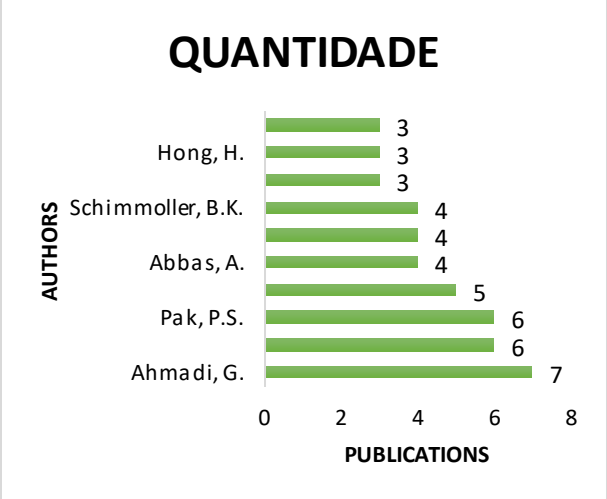

Fig.8: authors graph with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.2.3 Journals

The data about which newspapers had the highest frequency of publication on the subject are illustrated graphically in Figure 9.

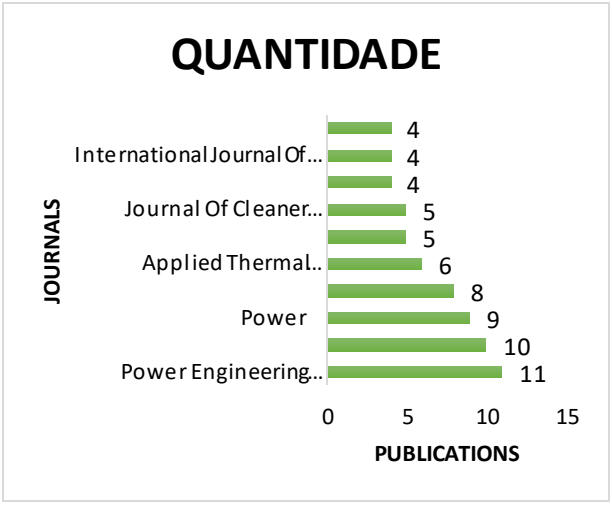

Fig.9: Graph periodic higher frequency of publication.

Source: Adapted from Scopus (2019).

3.2.4 Membership

The affiliates who contributed to the publications are illustrated graphically in Figure 10.

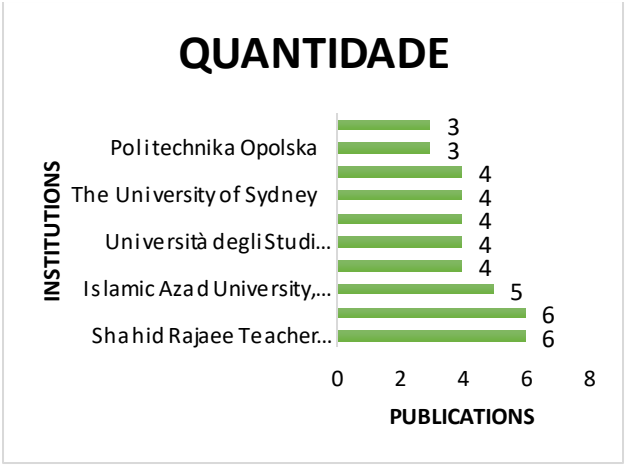

Fig.10: Graph institutions with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.2.5 Countries

In Figure 11, below, are graphically represented the countries that contributed to publications in this period.

https://dx.doi.org/10.22161/ijaers.6.6.50 ISSN: 2349-6495(P) | 2456-1908(O)

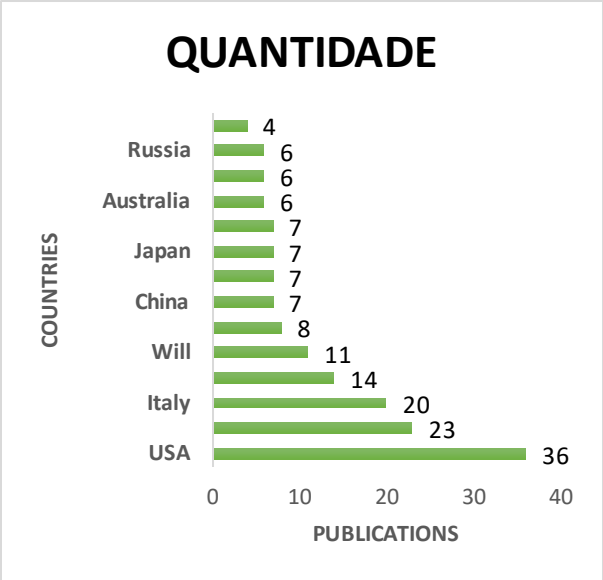

Fig.11: Graph of the countries with the highest frequency of publication.

Source: Adapted from Scopus (2019).

3.2.6 Knowledge Area

The data in Figure 12, shown below, graphically demonstrate knowledge areas with the highest frequency of publication on the subject.

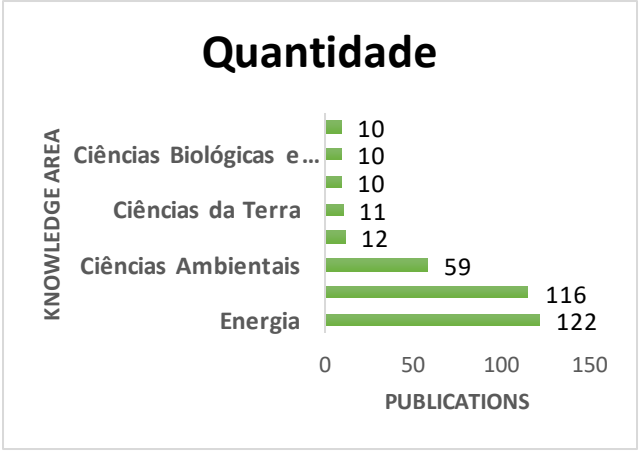

Fig.12: Graph of the areas of knowledge with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.2.7 Analysis Articles

Table 3 presents the articles more relevantly, i.e. those with the largest number of citations, according to the database.

Table 3: Most relevant articles – Repowering

Title	Authors	Year	Citations
Batteryless, wireless sensor powered by the microbial fuel cell sediment .	Donovan, C. et al.	2008	202
Collision fatality of raptors in wind farms does not depend on raptor abundance .	LUCAS, M. et al.	2008	118
An option for solar thermal repowering of fossil fuel fired power plants .	Popov, D.	2011	91
Study and design of a hybrid wind-diesel-compressed air energy storage system for remote areas .	Ibrahim, H. et al.	2010	84
Efficient use of energy by utilizing gas turbine combined systems.	NAJJAR, YSH	2001	81

Source: Adapted from Scopus (2019).

3.3 Energy Innovation

For this session, the terms used for the research were "*Energy Innovation*". Applying the filter to articles, the search returned 199 results.

3.3.1 Publications by year

In Figure 13, you can graphically display the number of publications per year about energy innovation subject, in the 2000 to 2019 range.

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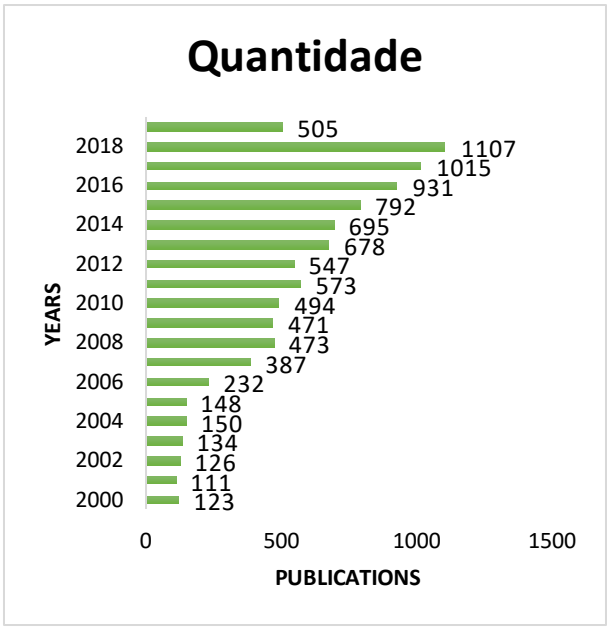

Fig.13: Frequency Plot of publications per year in the period 2000-2019.

Source: Adapted from Scopus (2019).

3.3.2 Authors

The authors most frequently published on Small Hydro Power in the range 2000 - 2019 are shown in Figure 14.

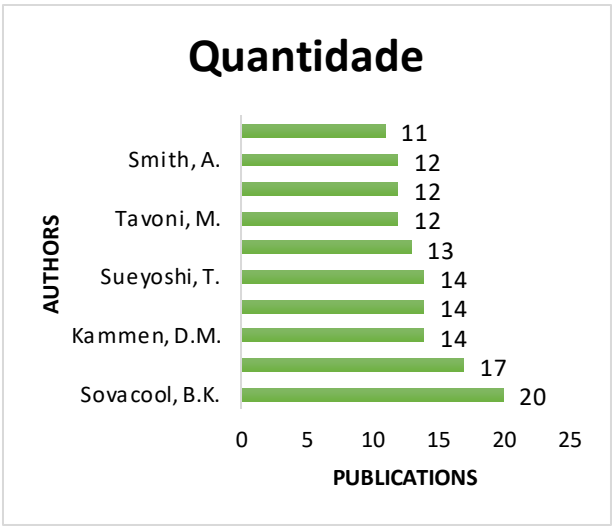

Fig.14: Graph of authors with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.3.3 Journals

The data about which newspapers had the highest frequency of publication on the subject are illustrated graphically in Figure 15.

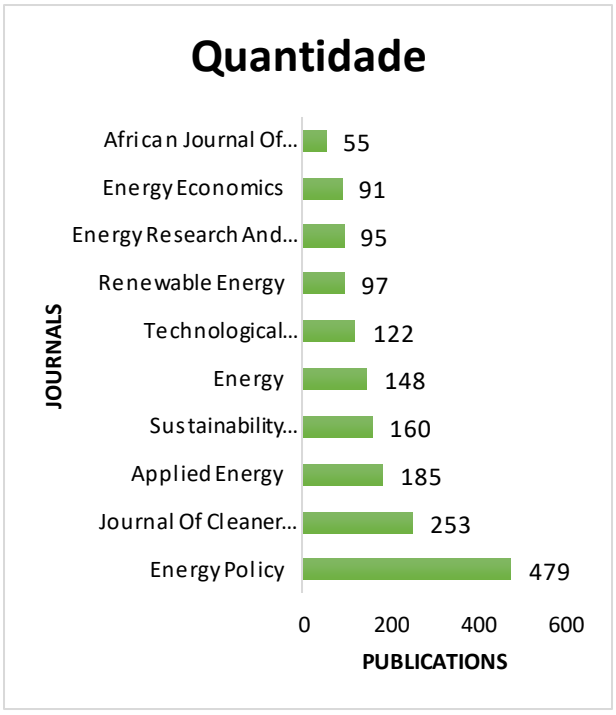

Fig.15: Graph periodic higher frequency of publication.

Source: Adapted from Scopus (2019).

3.3.4 Membership

The affiliates who contributed to the publications are illustrated graphically in Figure 16.

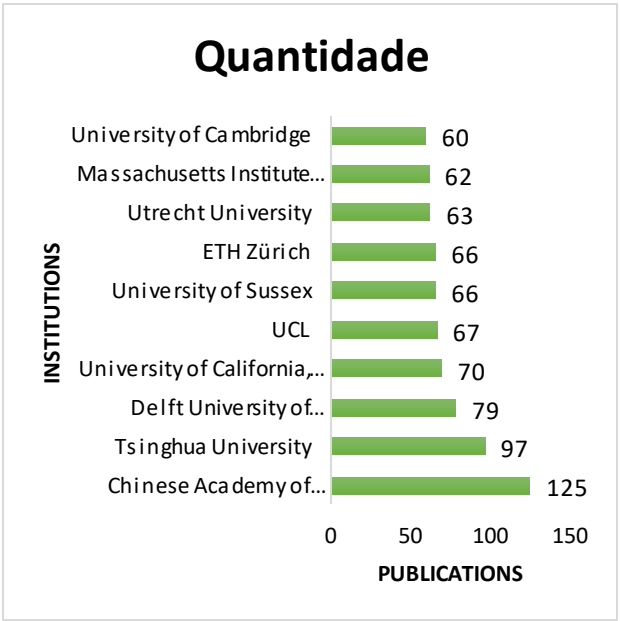

Fig.16: Graph institutions with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.3.5 Countries

In Figure 17, below, are graphically represented the countries that contributed to publications in this period.

https://dx.doi.org/10.22161/ijaers.6.6.50 *ISSN: 2349-6495(P) | 2456-1908(O)*

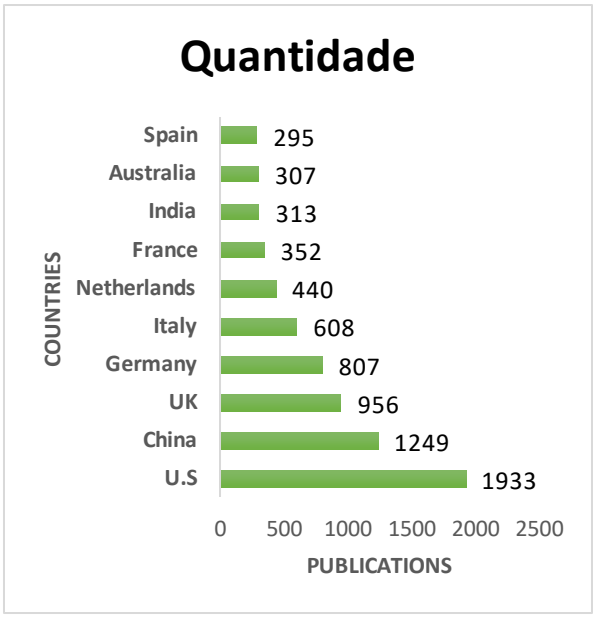

Fig.17: Graph of the countries with the highest frequency of publication.

Source: Adapted from Scopus (2019).

3.3.6 Knowledge Area

The data in Figure 18, shown below, graphically demonstrate knowledge areas with the highest frequency of publication on the subject.

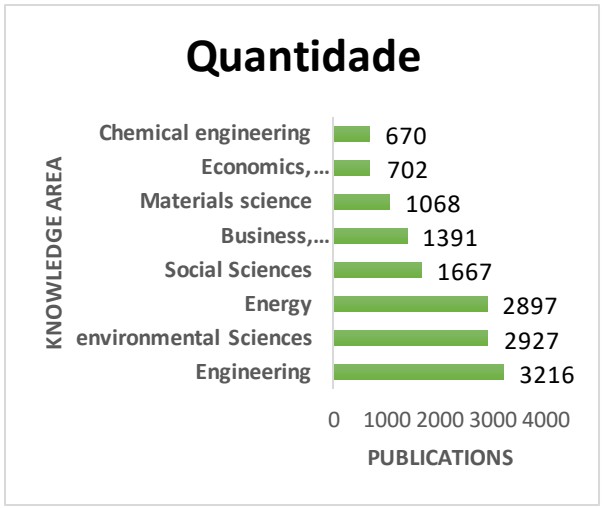

Fig.18: Graph of the areas of knowledge with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.3.7 Analysis of Articles

Table 4 presents the articles more relevantly, i.e. those with the largest number of citations, according to the database.

Table 4: Most relevant articles - Energy Innovation

Title	Authors	Year	Citations
The Swift Gamma-Ray Burst Mission	Gehrels, N. et al.	2004	2302
Microfibre-nanowire hybrid structure for energy scavenging	Qin, Y., Wang, X., Wang, ZL	2008	1111
Coordinated development of leading biomass pretreatment technologies	Wyman CE et al.	2005	929
Social acceptance of renewable energy innovation: An introduction to the concept	Wüstenhagen, R., Wolsink, M. Bürer, MJ	2007	882
Polymer-derived ceramics: 40 Years of research and innovation in advanced ceramics	COLOMBO, P. et al.	2010	816

Source: Adapted from Scopus (2019).

3.4. Sustainable development

For this session, the terms used for the research were "*Energy Innovation*". Applying the filter to articles, the search returned 199 results.

3.4.1 Publications by year

In Figure 19 it is possible to graphically display the number of publications per year about energy innovation subject, in the 2000 to 2019 range.

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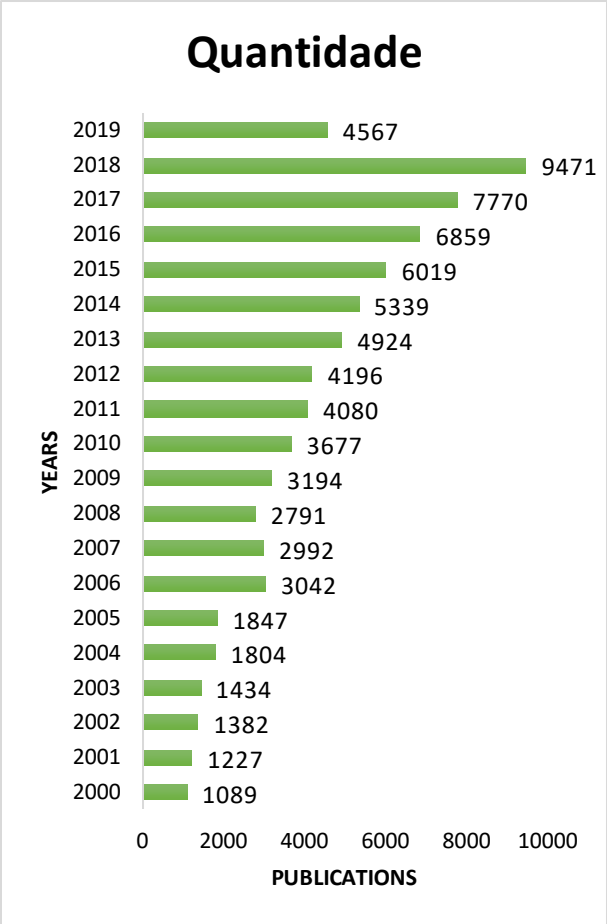

Fig.19: Frequency Plot of publications per year in the period 2000-2019.

Source: Adapted from Scopus (2019).

As shown in Figure 19, the number of publications on sustainable development has evolved over the past twenty years.

3.4.2 Authors

The authors most often published on Sustainable Development, in the range 2000 - 2019 are shown in Figure 20.

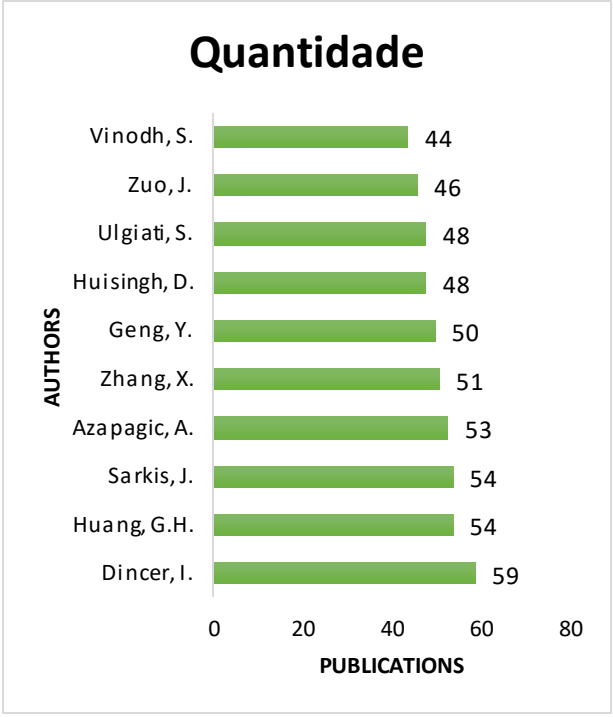

Fig.20: Graph of authors with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.4.3 Journals

The data about which newspapers had the highest frequency of publication on the subject are illustrated graphically in Figure 21.

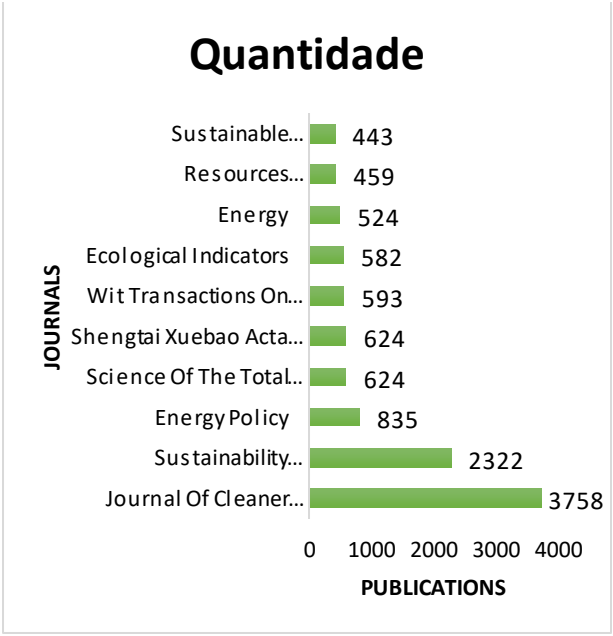

Fig.21: Graph periodic higher frequency of publication. Source: Adapted from Scopus (2019).

https://dx.doi.org/10.22161/ijaers.6.6.50 ISSN: 2349-6495(P) | 2456-1908(O)

3.4.4 Membership

The affiliates who contributed to the publications are illustrated graphically in Figure 22.

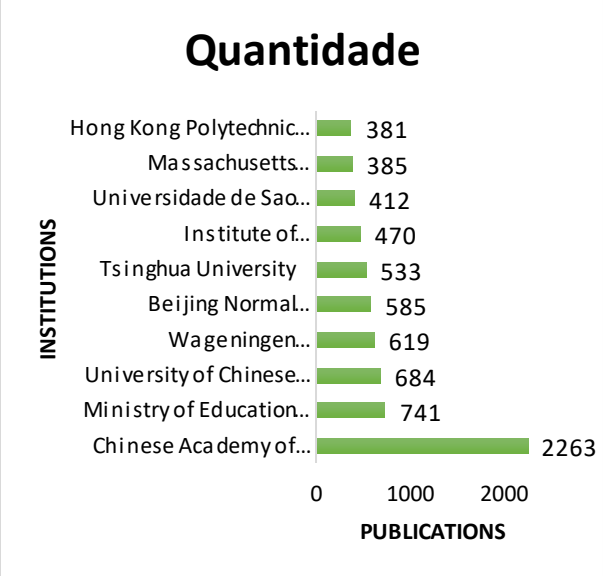

Fig.22: Graph institutions with higher frequency of publication.

Source: Adapted from Scopus (2019).

Dealing with sustainable development, the institutions that most frequently contribute to publications, are Chinese, especially the Chinese Academy of Sciences, with 2263 publications.

The University of São Paulo (USP) also obtained relevant figures, totaling 412 publications on the subject.

3.4.5 Countries

In Figure 23, below, are graphically represented the countries that contributed to publications in this period.

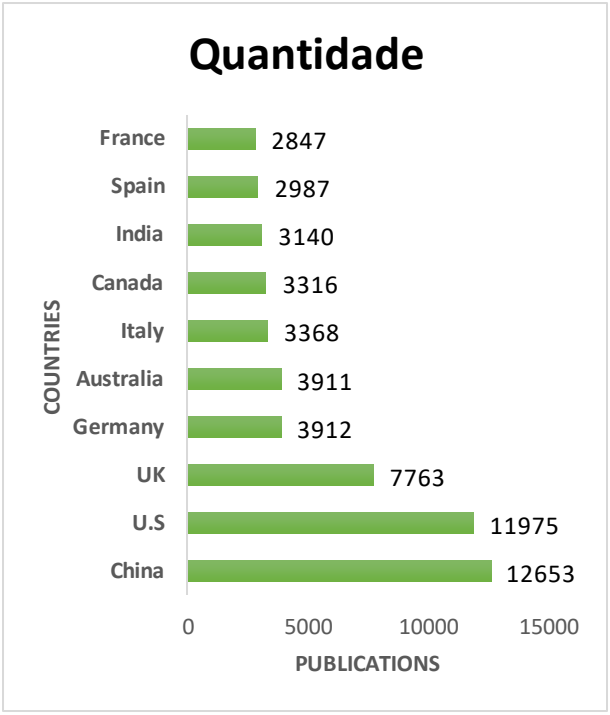

Fig.23: Graph of the countries with the highest frequency of publication.

Source: Adapted from Scopus (2019).

3.4.6 Knowledge Area

The data in Figure 24, shown below, graphically demonstrate knowledge areas with the highest frequency of publication on the subject.

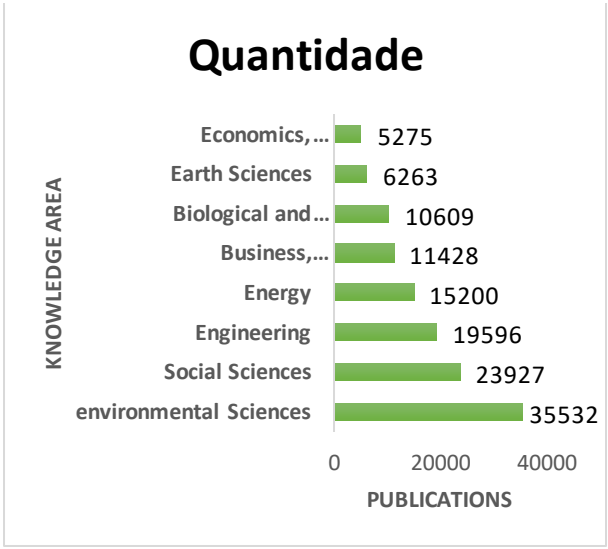

Fig.24: Graph of the areas of knowledge with higher frequency of publication.

Source: Adapted from Scopus (2019).

3.4.7 Analysis of Articles

https://dx.doi.org/10.22161/ijaers.6.6.50 ISSN: 2349-6495(P) | 2456-1908(O)

Table 5 shows the most relevant articles with, namely, those with the highest number of citations, according to the database.

Table 5: most relevant articles - Sustainable Development

Title	Authors	Year	Citations
Explicating dynamic capabilities: The nature and Microfoundations of (sustainable) enterprise performance .	Teece, DJ	2007	3234
Solutions for the cultivated planet .	FOLEY, JA et al.	2011	2368
Adaptation, adaptive capacity and vulnerability .	Smit, B., WANDEL J.	2006	2095
From a literature review to a conceptual framework for sustainable supply chain management.	SEURING, S. Muller, M.	2008	2027
Social and ecological resilience: Are they related?	Adger, WN	2000	1544

Source: Adapted from Scopus (2019).

IV. CONCLUSION

In this work it was possible to check and analyze aspects related to Small Hydropower Plants, interventions via Repowering, Energy Innovations and Sustainable Development, in view of the objective.

The study bibliometrical technique is effective, together with the choice of a suitable database, in this case, Elsevier Scopus. In this study, it was decided to collect data on the number of publications per year, authors, journals, institutions, countries and areas of knowledge, but this is not a rule, the methodology can be applied to other variables.

Countries with higher frequency of publications were the United States and China, the latter being what else had articles related to small hydropower plants. Brazil also presented excellent figures in this subject.

Importantly, the repowering of small Hydropower energy is inseparable from innovation and sustainable development, in view of the great benefits that the investment in this renewable energy source brings to the national energy matrix and, consequently, for the whole society.

Finally, it appears that an increasing number of papers related to the topics covered in this article, proving that has increased worldwide, the need to achieve "optimum use" of water resources, whether in developed countries, where much resources have been exploited, in Brazil, where there is still great potential to be tapped.

REFERENCES

[1] National Electric Energy Agency (2019). ANEEL. Bank of Generation Information: Brazil's generation capacity. Available at: <http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm>. Access: 3 June.

[2] ARAUJO, Carlos Alberto. (2006). Bibliometrics: historical development and current issues. In Question, Porto Alegre, v.12, n. 12, p.11-32, jan / jun.

[3] Brazilian Association of Clean Energy Generation - ABRAGEL. (2017). Challenges Seminar on Electricity Generation in Brazil (ANEEL). Brasilia, 2017. Available at: http://www.aneel.gov.br/documents/10184/15266087/painel +3+ap+4+ABRAGEL+-+2017-10-19+-+Semin%C3%A1rio Challenges of + + + Generates% C3% A7% C3% A3o of Energy + + + El +% C3% A9trica Brasil_ANEEL.pdf the + / a5822d40-a750-7434-6905-9a53c971b951. Access: 20 October 2018.

[4] COSTA, H. (2010). Model for webibliomining: Proposal and application case. Rev. FAE, Curitiba, Volume 13, n.1, pp. 115-126, Jan./June.

[5] Energy Research Company - EPE. National Energy Plan 2030 v. 12, Brasília, 2007.

[6] Energy Research Company - EPE. (2017). Ten Year Plan for Energy Expansion 2026 Brasilia: MME / EPE7. Available at: <http://www.mme.gov.br/documents/10584/0/PDE2026.pdf /474c63d5-a6ae-451c-8155- ce2938fbf896>. Access> 20 October 2018.

[7] FONSECA, EN. (1986). Bibliometry: theory and practice. São Paulo, Cultrix; Typeset USP, 141p.

[8] OLIVEIRA, MA. (2012). Repowering Small Hydropower: technical and economic evaluation. 2012. 195 p. Dissertation (Masters in Energy Engineering) - Federal University of Itajubá.