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A Bibliographic Analysis: The Expansion and Evolution of Wind Energy Research from 1980 to 2021 *

Bir Bibliyografik Analiz: 1980'den 2021'e Rüzgar Enerjisi Araştırmalarının Gelişimi ve Evrimi

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Abstract

This paper examined the wind energy literature from 1980 to 2021 using bibliometric technique on the Web of Science database Social Science Citation Index (SSCI). Of 2531 publications, 85.89 % are journal articles, and about 99.17 % are published in English. In addition that, the "Environmental Sciences & Ecology" is the most productive research area. The USA is the most productive country based on the total publications, H-index and total citation. Indeed, when to analyze the academic collaborative relationships among countries, the USA and UK are the center of international collaboration and mostly work with China, Spain and Denmark respectively. Furthermore, "Energy Policy" is the most productive journal and "Renewable and Sustainable Energy Reviews" journal has the highest impact factor. Institution performance analysis is to reveal that the Holland, America, England and China universities are more active in the wind energy researches. Moreover, Devine-Wright P. is the most academically influential author in the wind energy. The article with the highest total citations is titled "Beyond NIMBY'ism: towards an integrated framework for understanding public perceptions of wind energy." According to keyword cooperation analysis, "power", "wind energy" and "renewable energy" have the highest link strength among other keywords.

Keywords: Wind Energy, Energy, Renewable Energy, Bibliographic Analysis, Collaborative Relationship.

Öz

Bu makale, Web of Science veri tabanı Social Science Citation Index (SSCI) üzerinde yer alan 1980'den 2021'ae kadar olan rüzgar enerjisi literatürünü bibliyometrik teknik kullanarak incelemiştir. 2531 yayının %85.89'u dergi makaleleridir ve yaklaşık %99.17'si İngilizce olarak yayınlanmıştır. Buna ek olarak, "Çevre Bilimleri ve Ekoloji" en verimli araştırma alanıdır. Toplam yayın, H indeksi ve toplam atıf bazında Amerika Birleşik Devletleri en verimli ülkedir. Dahası, ülkeler arasındaki akademik işbirliği ilişkileri analiz edildiğinde, ABD ve İngiltere uluslararası işbirliğinin merkezidir ve çoğunlukla sırasıyla Çin, İspanya ve Danimarka ile çalışmaktadır. Ayrıca "Energy Policy" en verimli dergidir ve "Renewable and Sustainable Energy Reviews" dergisi en yüksek etki faktörüne sahiptir. Kurum performans analizi, Hollanda, Amerika, İngiltere ve Çin üniversitelerinin rüzgar enerjisi çalışmalarında daha aktif olduğunu ortaya koymaktır. Ayrıca, Devine-Wright P. rüzgar enerjisi alanında akademik olarak en etkili yazardır. En yüksek toplam alıntıya sahip makalenin başlığı "Beyond NIMBY'ism: towards an integrated framework for understanding public perceptions of wind energy"dir. Anahtar kelime işbirliği analizine göre,"güç", "rüzgar enerjisi" ve "yenilenebilir enerji" kelimeleri diğer anahtar kelimeler arasında en yüksek bağlantı gücüne sahiptir.

Anahtar Kelimeler: Rüzgar Enerjisi, Enerji, Yenilenebilir Enerji, Bibliyografik Analiz, İşbirliği İlişkisi

1. INTRODUCTION

With the industrial revolutions, the production process has become more agility than before and consumers can easily reach and receive the products more quickly (Kagermann et al., 2013; Rüßmann et al., 2015). As a consequence of that, the demand for energy has been expanding continuously by the end of the century (Knox-Hayes et al., 2013: 611). Fossil fuel consumption is still the dominant energy sources for the companies (Rapier, 2020). Intense usage of the fossil fuels bring the some environmental problems such as emission of carbon dioxide, air pollution, acid rain so on (Pazheri et al., 2014: 838; Nakicenovic and Grubler, 2020). Moreover, production systems have been mostly depending on depleted fossil fuels that is very risk for the companies to survive the market and continue to production. Finally, clean energy sources have gathered the

* In this article, the principles of scientific research and publication ethics were followed. / Bu makalede bilimsel araştırma ve yayın etiği ilkelerine uyulmuştur.

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attention of researchers and practitioners in latest years and wind energy is one the environment friendly clean energy resource.

Bibliometric analysis is a quantitative analysis' tool to evaluate the performance of authors, institutions, journals and helps to scientists to detect hotspot topics for further research through organizing data to create meaningful result (Tsay, 2008). Thus, the aim of this paper is to identify dominant language of the studies, the most attractive subject, the most frequently cited articles, most frequently used keywords and hot topics and evaluate the performance of countries, journal, institution and author with using the Bibliometrix R-Package program.

2. METHODOLOGY

Bibliometric techniques is a systematic approach that used statistical methods of bibliography to analyse scientific publications (Tsay, 2008) to evaluate developmets in literature of a specific topic and appraise the quality and influence of publications (Bouyssou and Marchant, 2011: 1764). In bibliometric analysis, some mathematical and statistical techniques are used to create meaningful data which helps both to organize knowledge in a specific field to better understanding of recent and following research hotspots and to evaluate performance of the nation, institute, journal and author (Wallin, 2005). For example, the Bibliometrix R-Package program is mostly used by the researchers to analyse the collobaration and cooperation network (Aria and Cuccurullo, 2017; Moral Muñoz et al., 2020; Cagle, 2020). Moreover, Web of Science (WoS) database which published by Thomson Reuters, is vastly preferred and accepted database by researchers for bibliometric analysis (Chiu and Ho, 2005; Zhang et al., 2016; Zhang et al., 2019; Cagle, 2021).

This study aims to shed light on the current wind energy research in the following points: 1) showing how total publications are changed during the 1980-2021 time period and learning most productive research areas, 2) summarizing and evaluating the research trends in the wind energy fields, 3) assessing the performance of countries, journal, institution and authors, 4) a better understanding of global hot topics with keyword and co-operative keywords relationship analysis, which may contribute to the future development of wind energy literature and affect future research directions. Thus, the publications analyzed in this article were collected on 12.07.2021 from the Web of Science core collection database. The "wind energy" was selected as a keyword to search topic in the mentioned database of the Social Sciences Citation Index (SSCI). The study examines research dating from 1980 to 2021. As a result, 2531 publications were obtained. Among them, articles (2174) were the main contributions, approximately 84.17 of the total published literature. Additionally, other contributions included review articles (10.39%), proceedings papers (1.42%), editorial materials (1.14%), book reviews (0.87%), meeting abstracts (0.11%), corrections (0.08%), book chapter (0.04%) and retracted publications (0.04%) which were not included in the analysis. Consequently, 2174 SSCI articles were picked for further analysis in this study.

The 2174 publications were downloaded from the web of science core collection and the Bibliometrix R-Package software program was used to plot the map and graph which show the global distribution of wind energy articles, the timeline of the top five subject categories, the academic collaborative relationships of countries and the cooperation network of the keywords. In addition that, this study was analyze languages and characteristics of the publications, performance of countries, journal, institution and author and display key trends of the wind energy research literature.

3. RESULTS and DISCUSSION

3.1. Languages and Characteristics of Publications

Language information of 2174 articles during 1980-2021 is shown in the Table 1. English (99.17%) is the most constantly used language, followed by Germany (0.45%), Spanish (0.18%), Portuguese (0.09%). Also, Czech and Russian rank in fifth place with a percentage of 0.04.

Table 1: Language information of articles during 1980-2021

Rank	Language	TP[a]	(%)[b]
1	English	2156	99.17
2	German	10	0.45
3	Spanish	4	0.18
4	Portuguese	2	0.09
5	Czech	1	0.04
5	Russian	1	0.04

TP[a]: the number of total publications during 1980-2021.
(%)[b]: the percentage of the publications

Table 2 shows several characteristics of the wind energy articles between 1980-2021. In addition that, the total amount of publications during 1980-2021 is clearly shown Figure 1. Results show that between 1980-2004, there were a few studies about wind energy except 2002. After 2004, the number of publications on wind energy increases substantially between 2005-2021, except 2014 where a slight decreased. Besides that, the average number of authors per article and average of references in a article fluctuated with high figures between 1980-2006, but steadily increased after 2006 and reached the peak in 2020.

For example, there was an average of 1.64 authors per wind energy article in 2006, while the number increased to 3.75 in 2020.

Table 2: Characteristics of "wind energy" publications between 1980-2021

Year	TP[a]	AU[b]	AU/TP[c]	NR[d]	NR/TP[e]	PG[f]	PG/TP[g]
1980	2	2	1.00	7	3.50	27	13.50
1981	5	6	1.20	41	8.20	47	9.40
1982	2	2	1.00	19	9.50	14	7.00
1983	1	2	2.00	76	76.00	25	25.00
1986	1	3	3.00	17	17.00	14	14.00
1987	2	6	3.00	36	18.00	31	15.50
1988	2	2	1.00	101	50.50	70	35.00
1990	1	3	3.00	25	25.00	9	9.00
1991	3	4	1.33	114	38.00	40	13.33
1994	2	5	2.50	18	9.00	21	10.50
1995	1	2	2.00	44	44.00	10	10.00
1996	3	5	1.67	105	35.00	34	11.33
1997	3	7	2.33	100	33.33	35	11.67
1998	1	4	4.00	48	48.00	23	23.00
1999	4	12	3.00	81	20.25	44	11.00
2000	6	8	1.33	194	32.33	82	13.67
2001	3	6	2.00	57	19.00	55	18.33
2002	11	19	1.73	224	20.36	110	10.00
2003	3	5	1.67	100	33.33	32	10.67
2004	7	19	2.71	274	39.14	105	15.00
2005	11	26	2.36	474	43.09	157	14.27
2006	14	23	1.64	491	35.07	187	13.36
2007	29	64	2.21	1036	35.72	380	13.10
2008	35	84	2.40	1268	36.23	500	14.29
2009	44	103	2.34	1807	41.07	560	12.73
2010	64	154	2.41	2439	38.11	747	11.67
2011	76	191	2.51	3615	47.57	1079	14.20
2012	90	267	2.97	4264	47.38	1167	12.97
2013	110	328	2.98	5070	46.09	1435	13.05
2014	93	253	2.72	4359	46.87	1281	13.77
2015	140	398	2.84	7719	55.14	2115	15.11
2016	141	461	3.27	7890	55.96	2038	14.45
2017	159	487	3.06	9900	62.26	2348	14.77
2018	213	682	3.20	13186	61.91	3215	15.09
2019	277	971	3.51	17291	62.42	4175	15.07
2020	337	1264	3.75	22917	68.00	5498	16.31
2021	220	801	3.64	15597	70.90	3713	16.87

[a]TP: the number of total publications during 1980-2021
[b]AU: the number of authors
[c]AU/TP: the average of authors in an article
[d]NR: the number of cited reference
[e]NR/TP: the average of cited references in an article
[f]PG: the number of total publications pages
[g]PG/TP: the average of pages in an article

Moreover, the average of cited for each publication fluctuated with high figures in 1983,1988,1991,1995 and 1998 but increased after 2006. For example, the average citations per article grew from 35.07 in 2006 to 70.90 in 2021.

That is indicating that wind energy research fields received expanding attentions of authors in the last 15 years, and more communication and cooperation among authors have been increased and more active.

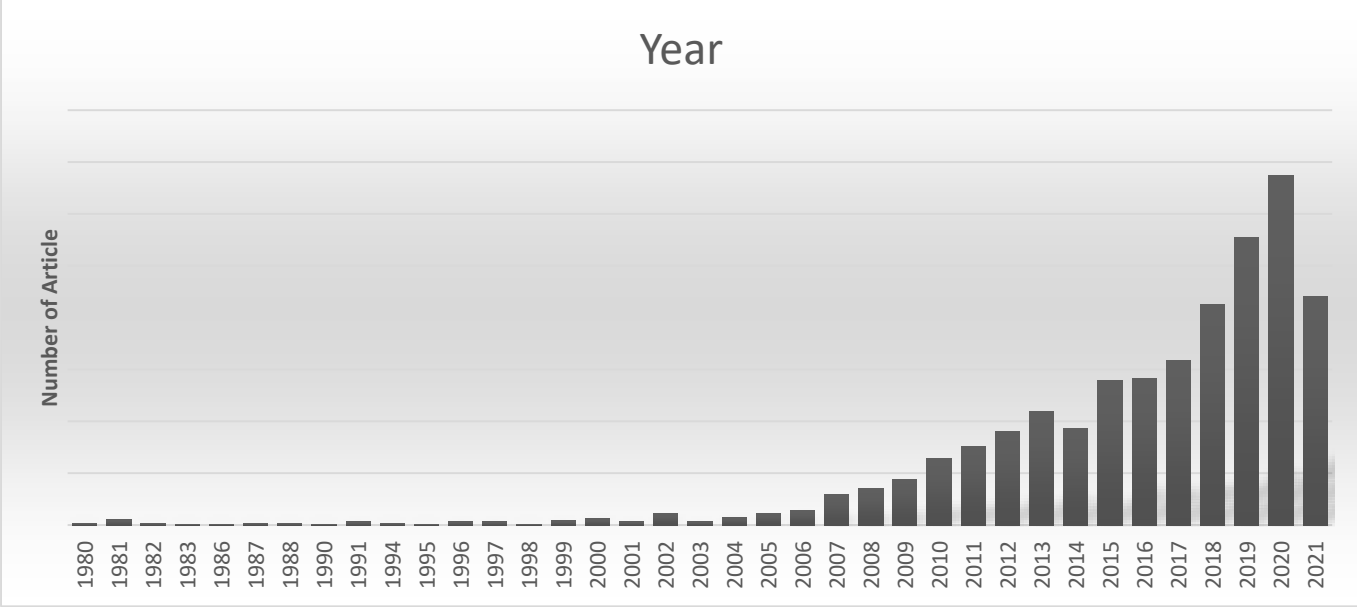

Figure 1: The annual number of wind energy articles during 1980-2021

3.2. Research Area

The contributions of the top 10 topics wind energy research from 1980 to 2021 are shown in Table 3. Environmental Sciences & Ecology is the most attractive subject with 1172 records, accounting for 26.70% of the total records, followed by Energy & Fuels and Business & Economics with 21.52% and 15.19% of the total number, respectively.

Table 3: The Top 10 most productive research areas about "wind energy" during 1980-2021

Rank	Research Area	TP[a]	Percentage (%)
1	Environmental Sciences & Ecology	1172	26.70
2	Energy & Fuels	945	21.52
3	Business & Economics	667	15.19
4	Science & Technology - Other Topics	433	9.86
5	Engineering	249	5.67
6	Public Administration	129	2.93
7	Thermodynamics	100	2.28
8	Geography	97	2.21
9	Government & Law	68	1.55
10	Development Studies	42	0.96

TP[a]: the total publications of the research areas during 1980-2021

The top five topics would be further analyzed and Figure 2 shows the amounts of publications on the top five subject categories from 1980 to 2021. It can be seen that the number of periodical publications of the top five categories remained steady from 1980 to 2001. The number of publications has been significantly increased since 2001, especially Environmental Sciences & Ecology, Energy & Fuels and Business & Economics subject categories has been grown rapidly between 2006-2014. Indeed, Environmental Sciences & Ecology subject had been leading position in last five years.

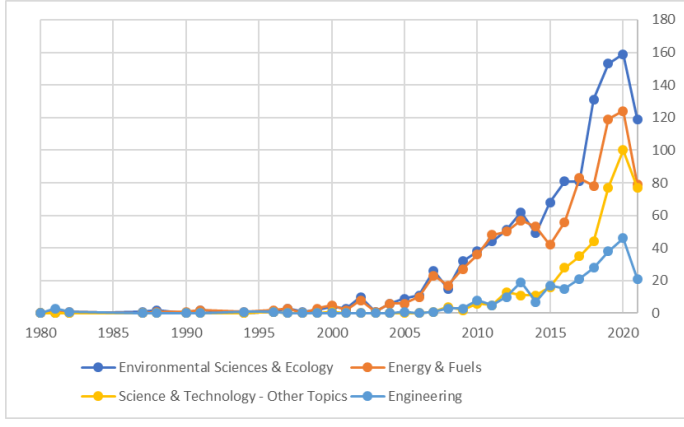

Figure 2: Timeline of the Top Five Subject Categories

3.3. Countries' Characteristics

3.3.1. Performance of Countries

Table 4 shows the total publications, citations and H-index of the top 10 productive countries regarding wind energy study. The map (Figure 3) that displays the geographical distribution of the total publications of the wind energy articles was calculated via R-package tool based on authors' addresses. Blue color represents the total publication of the

country. When the color is darken, total publication is higher. Grey means zero publication.

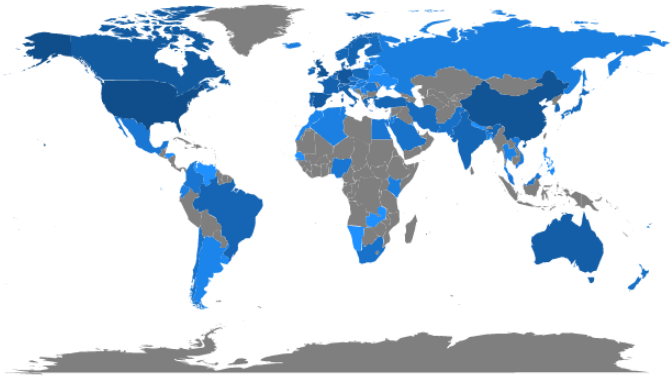

Figure 3: The Global Distribution of Wind Energy Articles

Table 4: Top 10 Most Productive Countries

Rank	Country	TP[a]	(%)[b]	TC[c]	CPP[d]	h-index
1	USA	546	25.11	10406	19.05	62
2	UK	272	12.51	8491	31.21	47
3	CHINA	255	11.73	3158	12.38	39
4	GERMANY	243	11.18	1901	7.82	40
5	NETHERLANDS	171	7.86	3967	23.20	40
6	SPAIN	166	7.63	1633	9.84	33
7	DENMARK	139	6.39	1268	9.12	27
8	CANADA	138	6.39	1830	13.26	27
9	AUSTRIA	111	5.10	1759	15.85	35
10	ITALY	88	4.05	1357	15.42	23

TP[a]: the total publications of the country during 1980-2021
(%)[b] : the percentage of the total publications from 1980-2021
TC[c]: the number of total citations
CPP[d]: citations per publication

These top 10 countries published 2129 articles, accounting for 97.93% of the total wind energy articles. The USA, accounting for 25.11% of all the publications, is the most productive country based on the total publications. Following USA, UK, accounting for 12.51% of the total searched publications, ranks the second in the total number of articles. Moreover, the USA is the most academically influential country with the H-index up to 62. Taking the total number of publications and the H-index (47) into consideration, UK is ranked second. Moreover, the USA has the highest total citation (10406) among the countries, followed by UK (8491), Netherlands (3967) and China (3158). Therefore, the USA is the most productive country with the largest number in total publication, citation and H-index except in citations per publication category. UK has similar profile with the USA and ranked second. Also, China is ranked as third based on the total publications, ranked as fourth in total citation and ranked as fifth in h-index. Therefore, in each category, the performance of China is in the top five, which indicates that China is academically productive and effective country.

In addition, in this area, articles of the UK (31.21%), Netherlands (23.20%) and USA (19.05%) had been received more citations per publication than other countries. Compared to the USA, UK ranked 2nd with respect to h-index (47) and ranked 1st with respect to citations per publication. This shows that the UK is an academically productive and influential country.

These results show that USA, China, European Countries such as UK and Netherlands are the core countries to make major contributions to the wind energy research. These outcomes can be explained by at least three reasons; technological innovations, oil crises and climate change.

New innovations and technological development have been enhanced the effectiveness of the energy production and decreased costs (Berry, 2009; Dominick, 2008; Smit et al., 2007). Moreover, the world had been faced the oil crisis for six years in 1973 (Fraenkel and Kenna, 1984; Lapin, 1977) and climate crisis has caused to find alternative way to produce energy to decrease carbon emission. To sum up, all of that reasons, countries put the new policies on their agenda to accelerate the wind power energy production. For example, in 2005, USA enacted the Energy Policy Act (U.S. Environmental Protection Agency, 2022) China introduced the Renewable Energy Sources Act policies in 2006 (Green Policy Platform, 2009) and the European Commission had proposed the “Europe 2020” project in 2010 to use renewable energy sources for energy consumption (European Commission, 2010).

3.3.2. Academic Cooperation

Figure 4 illustrates the research collaboration among top 20 countries during 1980-2021. This map is plotted using Bibliometric R-Package "Biblioshiny" software program. The lines between two countries displays they have cooperation relationship. When the collaboration is strong between countries, the line become thicker. In addition, the node size shows the centrality of a country, so that, the bigger node means bigger the centrality. Figure 4 shows the state of collaboration between the most productive countries.

As can be seen from the figure 4, there are three core clusters as follows: countries surrounding the USA (the red cluster), countries surrounding the UK (the blue cluster) and European countries (the green cluster). The USA and UK are in the central position for their cluster but there is not any dominant country for green cluster. The USA is highly connected to China, Australia and Canada. Moreover, the USA has cooperation with Turkey and India. It also is

apparent from the blue cluster UK collaborates with various countries, mainly centered on the Spain, Denmark, Italy and France. Besides, when to look the green cluster, Germany, Netherlands, Switzerland, Ireland, Sweden and Norway countries cooperate each other and work together. A possible explanation for this might be that, geographical and culture proximity of these European countries may be play active roles to increase collaboration.

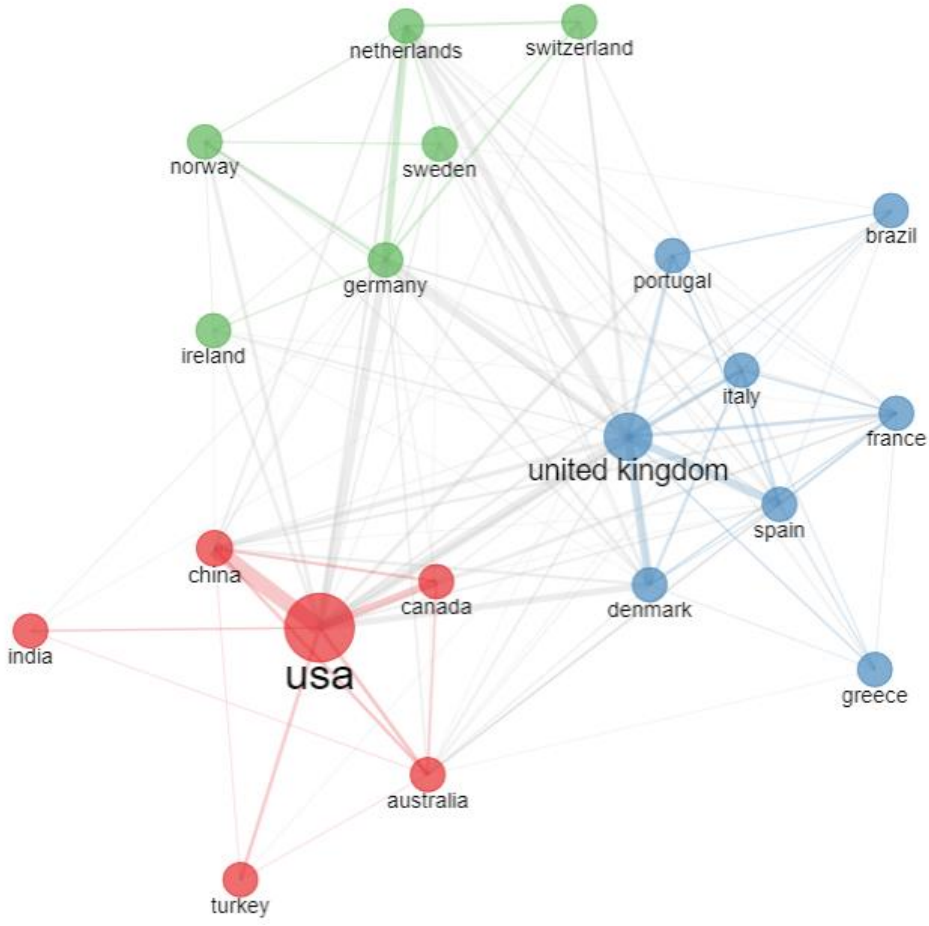

Figure 4: The Academic Collaborative Relationships among Top 20 Countries

Table 5: The Top 10 most productive journals during 1980-2021

Rank	Journal	TP[a]	(%)[b]	IF 2020[c]	TC[d]	CPP[e]
1	ENERG POLICY	429	19.73	6.142	17125	39.92
2	SUSTAINABILITY	172	7.91	3.251	1264	7.35
3	RENEWABLE ENERGY	100	4.60	8.001	3361	33.62
4	ENERGY RESEARCH & SOCIAL SCIENCE	99	4.55	6.834	1490	15.05
5	ENERGY	76	3.50	7.147	2156	28.36
6	APPLIED ENERGY	70	3.22	9.746	2693	38.47
7	ENERGIES	59	2.71	3.004	498	8.44
8	ENERGY ECONOMICS	45	2.07	7.042	1289	28.64
9	JOURNAL OF CLEANER PRODUCTION	41	1.89	9.297	685	16.70
10	RENEWABLE AND SUSTAINABLE ENERGY REVIEWS	36	1.66	14.982	175	4.86

TP[a]: the total publications of the journal during 1980-2021;
(%)[b]: The percentage of the publications of the journal
IF 2020[c]: the impact factor of journal in 2020;
TC[d]: the number of total citations;
CPP[e]: the citations per publication

To sum up, the USA and UK that are two countries have the biggest node size, so that they are the center of international collaboration and mostly work with the China, Australia, Canada and Spain and Denmark respectively. On

the other hand, the node size and lines displays that the India and Turkey have limited amount of collaboration and publications with other countries, thus they should be further collaborate with the various countries.

3.4. Journal Distribution

Wind energy articles had been published in 424 types of journals from 1980 to 2021. Table 5 displays the top 10 productive journals, the total publication, citation and 2020 impact factor of journals. More than 51% of the wind energy related articles are published in the top 10 journals. Energy Policy is the most productive journal with 429 articles, followed by Sustainability (172) and Renewable Energy (100). Renewable and Sustainable Energy Reviews ranks 10th in the number of publications, but has the highest impact factor (14.982) among the top 10 most productive journals, followed by Applied Energy (9.746) and Journal of Cleaner Production (9.297).

Moreover, Energy Policy has the highest total citation among the journals (17125), followed by Renewable Energy (3361) and Applied Energy (2693). Also, in this area, such as journals of Energy Policy (39.92), Applied Energy (38.47) and Renewable Energy (33.61) had been received more citations per publication than others. In general, therefore, it seems that Energy Policy, Renewable Energy, Applied Energy, Sustainability and Renewable and Sustainable Energy Reviews are the most influential journals in wind energy related fields, also other top journals support wind energy studies, but the total publication, citation and impact factor are relatively less.

Table 6: The most 10 productive institutions, 1980-2021

Rank	Institution	Country	Number of Articles
1	TECHNICAL UNIVERSITY DENMARK	DENMARK	84
2	NORTH CHINA ELECTRIC POWER UNIVERSITY	CHINA	51
3	UNIVERSITY OF UTRECHT	NETHERLANDS	48
4	TSINGHUA UNIVERSITY	CHINA	43
5	UNIVERSITY OF EDINBURGH	UK	42
6	UNIVERSITY OF GRONINGEN	NETHERLANDS	40
7	CARNEGIE MELLON UNIVERSITY	USA	38
7	DELFT UNIVERSITY OF TECHNOLOGY	NETHERLANDS	38
9	STANFORD UNIVERSITY	USA	36
9	UNIVERSITY OF STRATHCLYDE	UK	36

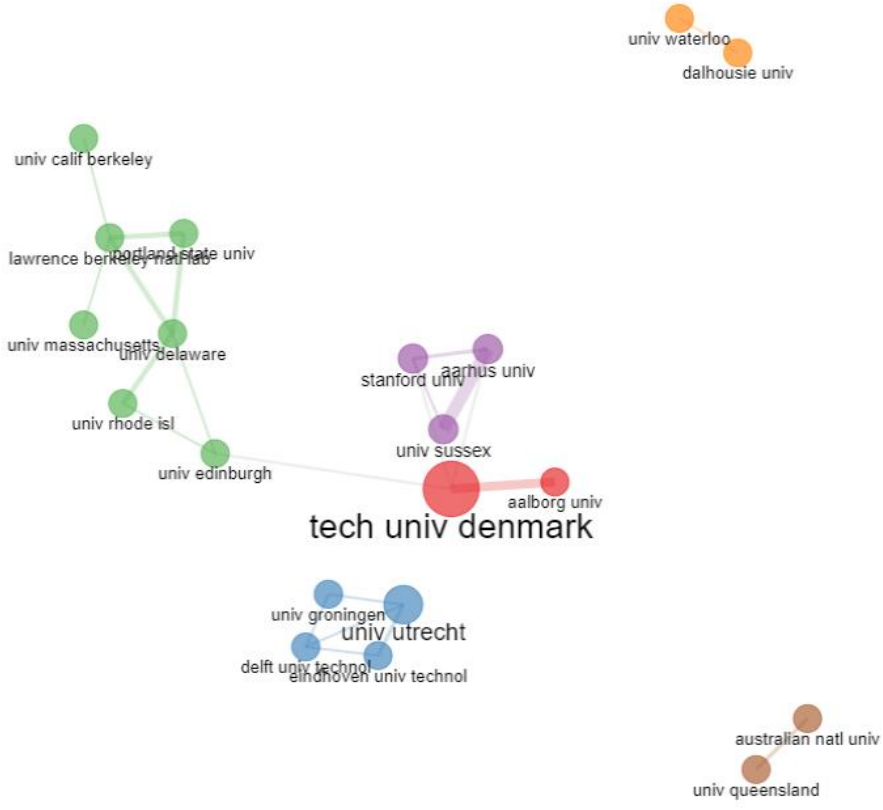

Figure 5: The Academic Collaborative Relationships between the Top 20 Most Productive Institutions

3.5. Institutions' Performance and Collaborative Relationships

Table 6 shows the performances of the top 10 productive institutions, of which three are come from in Netherlands, and two are in China, UK and USA. That reveals the Holland, American, England and China universities are more active in wind energy field research than other countries. Technical University Denmark ranked the 1st with respect total publications. Most of the 10 research institutions are from developed countries, with only North China Electric Power Unıversity and Tsinghua University coming from the developing country. Thus, developed countries are the most productive and developing countries should further support in the wind energy studies. Moreover, all productive institutions are universities that prove universities are core part for the developing and revealing new findings about wind energy field.

Moreover, Figure 5 displays the academic collaborative relationships between the top 20 most productive institutions. The lines between two institutions shows cooperation relationship. When the collaboration is strong, the line become thicker and the node size shows the centrality of an institution, so that, the bigger node means bigger the centrality. As shown in Figure 5, Technıcal Unıversıty Denmark has the bigger node and mostly work with Allborh University and Unıversıty of Edınburgh. The institutions are located in the green cluster work closely to each other but there is not any dominant organization for that cluster. Moreover, when the purple cluster is analyzed, although Stanford University, Aarhus University and Sussex University are located different region, they have worked together. The result shows that the institutions collobarate with organizations within the international counterparts. This reveals that researchers have cooperated and work with international researchers about wind energy area.

3.6. Performance of Authors

Table 7 shows the performances of the top 20 productive authors based on the total publications, total citations, citation per publication and H-index regarding wind energy study. According to results, based on the total publication, the most productive author is Sovacool B.K. with 17 articles, followed by Kaldellis J.K. (15 articles), Devine-Wright P. (14 articles), Firestone J. (14 articles) and Liu Y. (14 articles). On the other hand, Devine-Wright P. has the highest total citation (2527) among the authors, followed by Wolsink M. (1015) and Pinson P. (836). In addition that, Devine-Wright P. receives the most citations per publication (181), followed by Wolsink M. (169) and Pınson P. (84). Considering the H-index, the most productive authors are Kaldellis J.K. (14), Devıne-Wrıght P. (12) and Sovacool B.K. (11) respectively.

Devine-Wright P. is the most academically influential author in the field because he has the highest total citation (2527) and most citations per publication (181) among the authors. Moreover, his performance ranked 2nd concerning h-index (12) and ranked as 3rd author in total publication. Thus, in each categories, the performance of author is in top three.

3.7. Research Hotspot

3.7.1. The most frequently cited articles

Table 8 indicates the top 20 highly cited articles in wild energy field with the total citations for 1980-2021. This table shows the critical articles that can be helpful for researchers in the wind energy field by reading field-related articles to understand the area better.

Among all the researches, the one authored by Devine-Wright (2005) is the most cited wind energy-related publication, followed by the article of Devine-Wright written in 2009 and Wolsink in 2000. Moreover, Devine-Wright's article whose name is "Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action" receives the highest total citations per publication (51.92), followed by article of Hansen and Coenen (2015) and Devine-Wright (2005). That reveals that Devine-Wright is the most effective and followed author in the wind energy field because his three articles are in the top 20 highly cited articles list and his two articles are ranked 1st in total citation and total citation per year categories.

Table 7: The top 20 productive authors, 1980-2021

Rank	Author	TP[a]	TC[b]	CPP[c]	H-index
1	KALDELLIS JK	15	818	55	14
2	DEVINE-WRIGHT P	14	2527	181	12
3	SOVACOOL BK	17	666	39	11
4	WISER R	12	542	45	10
5	FIRESTONE J	14	405	29	9
6	ZAFIRAKIS D	9	378	42	8
6	ZHOU Y	8	272	34	8
6	LIU Y	14	187	13	8
9	PINSON P	10	836	84	7
9	WANG C	7	267	38	7
9	BIDWELL D	10	258	26	7
9	ENEVOLDSEN P	10	141	14	7
13	WOLSINK M	6	1015	169	6
13	ZHANG X	7	282	40	6
13	ZHANG L	7	182	26	6
13	POHL J	6	120	20	6
13	DEL RIO P	9	169	19	6
13	RUDOLPH D	7	87	12	6
19	AZEVEDO IL	5	146	29	5
20	BAXTER J	7	179	26	5

TP[a]: the total publications of the author during 1980-2021
TC[b]: the number of total citations
CPP[e]: the citations per publication

The one with the highest total citations is titled "Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy." This article was published in Wind Energy journal in 2005 and received 694 total citations. The major contribution of this publication is to evaluate past researches based on the six different strands to understand public perceptions of wind energy and criticize and summarize whole works to create an integrated and multidimensional framework for the subsequent studies.

Table 8: Characteristics of the most frequently cited articles during 1980-2019

Rank	PY[a]	TC[b]	TCY[c]	Article Title	Journal Name	Author/s
1	2005	694	40.82	"Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy."	Wind Energy	Devine-Wiıght P.
2	2009	675	51.92	"Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action."	Journal of Communıty & Applied Social Psychology	Devine-Wright P.
3	2000	499	22.68	"Wind power and the NIMBY-myth: institutional capacity and the limited significance of public support."	Renewable Energy	Wolsink M.
4	2010	471	39.25	"Disruption to place attachment and the protection of restorative environments: A wind energy case study."	Journal of Envıronmental Psychology	Devine-Wright P. and Howes Y.
5	2007	464	30.93	"Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance"	Energy Polıcy	Gross C.
6	2005	438	25.76	"The 'Social Gap' in Wind Farm Siting Decisions: Explanations and Policy Responses"	Envıronmental Politics	Bell D., Grey T. and Haggett C.
7	2010	402	33.50	"Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul"	Energy	Kaya T. and Kahraman C.
8	2007	354	23.60	"Trading Wind Generation From Short-Term Probabilistic Forecasts of Wind Power"	IEEE Transactions on Power Systems	Pinson P., Chevallier C. and Kariniotakis G.N.
9	2007	350	23.33	"Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation."	Energy Policy	Wolsink M.
10	2002	312	15.60	"Renewable energy from the ocean."	Marina Policy	Pelc R. and Fujita R.M.
11	2010	302	25.17	"Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland"	Land Use Policy	Warren C.R. and McFadyen M.
12	2015	300	42.86	"The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field"	Envıronmental Innovation and Societal Transitions	Hansen T. and Coenen L.
13	2005	262	15.41	"Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations"	Ecological Economics	Beise M. and Rennings K.
14	2009	255	19.62	"The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply"	Ecological Economics	Gerbens-Leenes P.W., Hoekstra A.Y. and van der Meer T.
15	2007	253	16.87	Local acceptance of wind energy: Factors of success identified in French and German case studies	Energy Policy	Jobert A., Laborgne P. and Mimler S.
16	2012	248	24.80	"Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses"	Proceedings of the National Academy of Sciences	White C., Halpern B. S. and Kappel C.V.
17	2010	223	18.58	"Public attitudes of wind energy in Texas: Local communities in close proximity to wind farms and their effect on decision-making."	Energy Polıcy	Swofford J. and Slattery M.
18	2006	216	13.50	"The effectiveness of different policy regimes for promoting wind power: Experiences from the states"	Energy Polıcy	Menz F.C. and Vachon S.
19	2005	213	12.53	"The impact of R&D on innovation for wind energy in Denmark, Germany and the United Kingdom"	Ecological Economics	Klaassen G., Miketa A., Larsen K. and Sundqvist T.
20	2009	208	16.00	"Ecological and economic cost-benefit analysis of offshore wind energy"	Renewable Energy	Snyder B. And Kaiser M. J.

PY[a]: publication year, TC[b]: total citations , TCY[c]: total citations per year

3.7. Research Hotspot

3.7.1. The most frequently cited articles

Table 8 indicates the top 20 highly cited articles in wild energy field with the total citations for 1980-2021. This table shows the critical articles that can be helpful for researchers in the wind energy field by reading field-related articles to understand the area better.

Among all the researches, the one authored by Devine-Wright (2005) is the most cited wind energy-related publication, followed by the article of Devine-Wright written in 2009 and Wolsink in 2000. Moreover, Devine-Wright's article whose name is "Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action" receives the highest total citations per publication (51.92), followed by article of Hansen and Coenen (2015) and Devine-Wright (2005). That reveals that Devine-Wright is the most effective and followed author in the wind energy field because his three articles are in the top 20 highly cited articles list and his two articles are ranked 1st in total citation and total citation per year categories.

The one with the highest total citations is titled "Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy." This article was published in Wind Energy journal in 2005 and received 694 total citations. The major contribution of this publication is to evaluate past researches based on the six different strands to understand public perceptions of wind energy and criticize and summarize whole works to create an integrated and multidimensional framework for the subsequent studies.

3.7.2. Main research fields

Author keywords analysis can be beneficial for researchers to reveal research priorities and interest of scientists and indicate research trends in the field (Zhang et al, 2016; Zhang et al, 2019). Figure 6 displays the author keywords and the top 50 keywords are shown in the cluster to ensure that the results are understandable and reviewable. Thus, Figure 6 represent the dominant topics and subtopics of wind energy related articles. When the keyword is used more frequently which has bigger font size. Keywords have larger font size mean they are used more often by researchers. Based on the keywords analysis, the top five keywords are power (441), wind energy (383), renewable energy (289), energy (217) and policy (183).

Moreover, the cooperative relationship among the top 50 keywords in the wind energy research area from 1980 to 2021 is also plotted using Bibliometric R-Package "Biblioshiny" software program and is shown in Figure 7. Each keyword is defined by its label and circle. The bigger node means the higher the frequency of used, and the mostly utilize keywords are situated in the central position in the cluster. In addition that, the lines between the keywords indicate the co-occurrence links. The stronger the link mean stronger co-occurrence. When the network is strong between the keywords, the line become thicker. Thus, the thick size of the keywords shows the number of articles, in which terms used together. As can be seen from the figure, there are three core clusters as follows: keywords surrounding the Power (the red cluster), keywords surrounding the Wind Energy (the blue cluster) and keywords surrounding the Energy, the electricity and the generation (the green cluster). The Renewable Energy and Wind Energy are in the central position for their cluster but there is not certain dominant keyword for green cluster.

For the red cluster, the Renewable Energy is highly connected to the Power, these are frequently used together in an article. In general, this cluster aggregates papers related to maximum wind power generation. For example, an article focus on how electricity system criteria effect the wind power penetration (Markevičius et al., 2007), the other one try to find the most optimum location for wind turbine to produce energy through optimal probability function (Malik et al., 2020) and another one search the how government policies support the large-scale investments in wind power energy (Ydersbond and Korsnes, 2016).

Figure 6: Wind Energy Keyword Cluster

Furthermore, for the blue cluster the Wind Energy and the Policy are strongly connected to each other. In this cluster, papers are examined to the wind energy policies, programs and their effects. For instance, Rajsekhar and coworkers (1999) study on specification of the Indian wind energy programme, besides, García-Álvarez and her friends (2017) made an empirical study to examined the feed-in tariff and renewable portfolio standard policies about wind energy. On the other hand, in the green cluster, The Energy, the

Electricity and the Generation are moderately connected to each other but there is not any dominant highly connected the keywords in that cluster.

As shown in Figure 6, the most frequently used keyword are "power", "wind energy" and "renewable energy" have the highest link strength among other keywords (Figure 7). Thus, these words have play key role in the cooperation network.

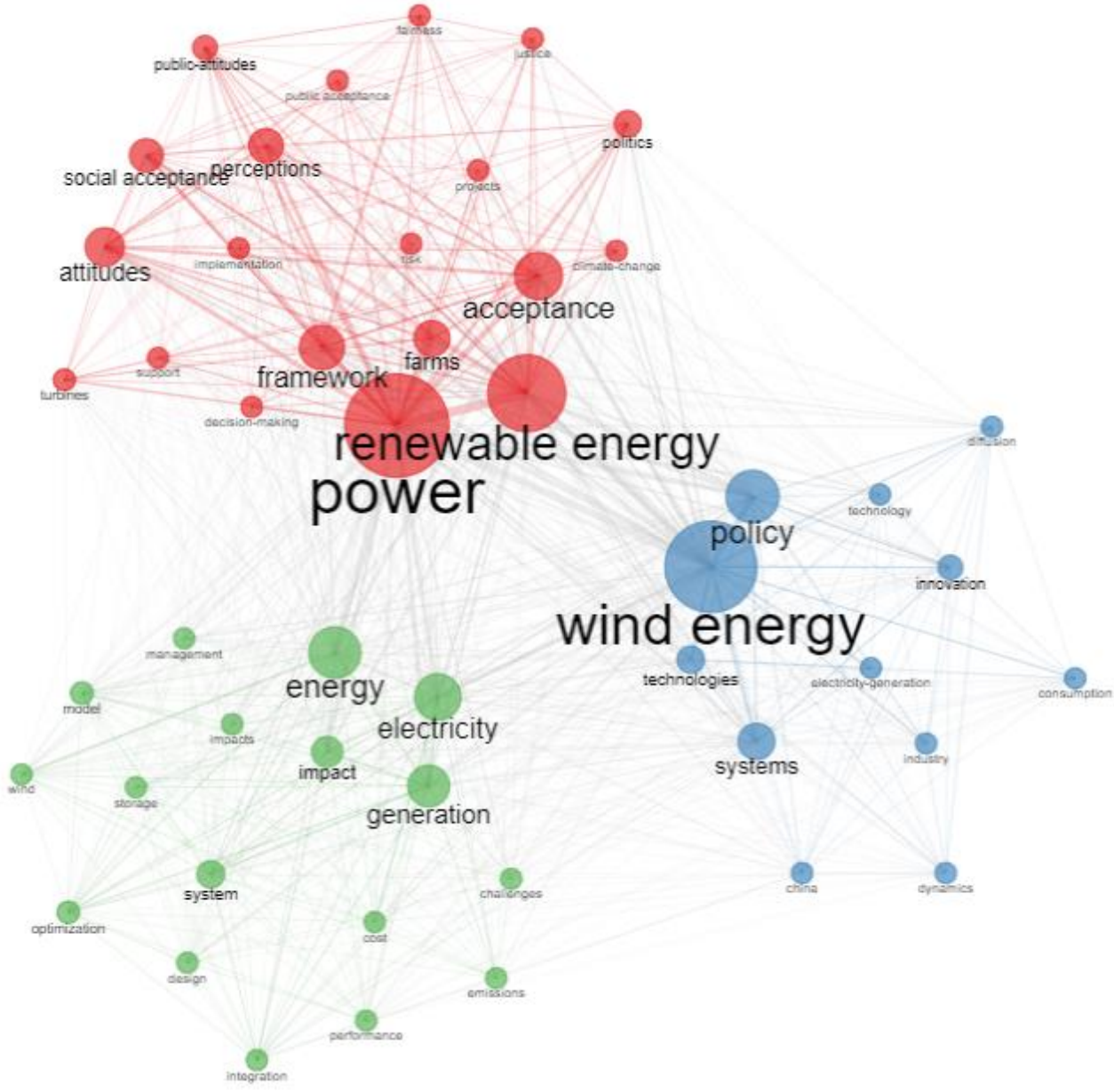

Figure 7: The Network of the Most Frequently Used 50 Keywords in Wind Energy Research

4. CONCLUSION

Using bibliometric methods, the characteristics of the wind energy literature from 1980 to 2021 based on the SSCI database have been examined. This paper reveals that the number of articles on wind energy increases substantially between 2005 to 2021. To sum up, the literature on wind energy has grown over the past 16 years.

In language analysis, the publications concerning wind energy are available in 6 languages, with English being dominant, accounting for 2156 articles (99.17%). "The Environmental Sciences & Ecology" is the most productive research area with 1172 records, accounting for 26.70% of the total records. The USA is a significant contributor to the wind energy literature with the most publications (546), highest h-index (62) and total citation (10406) among the countries. Following USA, UK ranks the second in the total number of articles (272), the H-index (47) and the highest total citation (8491).

In addition that, the USA and UK have played a key role in the collaboration network of the 20 productive countries, thus, they are the center of international collaboration and mostly work with China, Spain and Denmark respectively.

The research has also shown that "Energy Policy" is the most productive journal (429 articles), has the highest total citation (17125) and has been received more citations per publication (39.92) than others. On the other than, when to look highest impact factor score, "Renewable and Sustainable Energy Reviews" journal has the highest score. Technical University Denmark is the most effective institution (publishing 84 articles) and ranks the 1st with respect total publications. Devine-Wright P. is the most academically influential author in the field because he has the highest total citation (2527) and most citations per publication (181) among the authors, ranked as 2nd in h-index (12) and as 3rd author in total publication

Furthermore, the most highly cited article Entitled "Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy", authored by Devine-Wright (2005) and published in "Wind Energy" journal and had been cited 694 times. This study has identified five core keywords which are "power" (441), "wind energy" (383), "renewable energy" (289), "energy" (217) and "policy" (183). Furthermore, "power", "wind energy" and "renewable energy" keywords have the highest link strength among other keywords, so that, they have play key role in the cooperation network.

New technologies and innovations in wind turbine design (Walford, 2006; Smith et al., 2007; Berry, 2009), enhanced wind and utility industries information (Berry, 2009) and economies of scale (Smit et al., 2007) have accelerated generating wind energy power for the countries. Additionally, unpleasant impact of the climate change such as atmospheric carbon dioxide, prolonged drought and extreme hurricanes take attention to all worlds, so that countries have been taken some precautions to decrease carbon emission and try to find clean energy sources. Moreover, USA and China are two biggest carbon emitters and they have been facing great pressure of carbon emissions reduction. Additionally, the European countries have been powerful supporter of renewable energy sources and reducing carbon emissions.

Hereby, both of them are accelerating renewable energy production for the countries. For example, USA enacted the Energy Policy Act (U.S. Environmental Protection Agency, 2022) in 2005, thus, USA wind energy producing capacity increased from 2500 megawatts (MW) in 1993 to 45.000 MW in 2021 (American Wind Energy Association, 2009). The USA country have policies and programs concentrate on expanding the renewable energies infrastructure investment and generating renewable energies to reach cleaner future (American Clean Power Association, 2020). Moreover, market projections await that offshore wind which capacity is about 20.000 to 30.000 MW will be operational by 2030. Thus, U.S. economy will make investment between $28 – $57 billion to offshore wind energy. Furthermore, The European countries launched the "Europe 2020" program that is 10 years strategy. The aim of this program is producing energy from renewable sources to procure 20% of gross final energy consumption by 2020 and at least 32% by 2030. Additionally, the Renewable Energy Law of the People's Republic of China law that was enacted in 2006 by China that aims encouraging the development and utilization of renewable energy and giving priority for renewable energy development. Moreover, Turkey signed Paris Aggrement in 2016 and ratified in 2021. Turkey has started to apply new climate policy to reduce global temperature increase and reaching net zero emissions. Therefore, this policy has accelerated not only the investment and usage of the renewable energy but also academic papers and collaboration.

Therefore, all these reasons explain that the USA, European Countries and China are the most productive countries in the wind energy literature and that the most efficient institutes are located in these countries. Moreover, this papers reveals that, these laws are positively affect the wind energy research because when to analyze annual number of wind energy articles, there is an increase both the number of total articles and the average citations per article.

These results demonstrate the importance of bibliometric techniques as methods for exposing research trends globally. This paper is expected to benefit to scientists for the future research about wind energy. Moreover, the insights gained from this study may be of assistance to practitioners to able to know the most famous institution, author, universities and journal in such a field and get more proper consulting from them in decision making processes.

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