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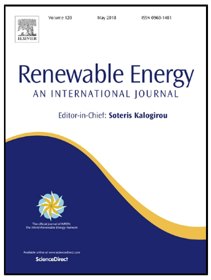

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Highlights

- A new scenario of research in wind energy
- A new data from Scopus collection
- We could identify key contributing countries, institutions, authors with Mexican institutions and researchers as well as trends in research topics.
- Offers valuable future research questions on wind in Mexico

Abstract

The demand on energy has reached very high levels, the main reason of it, is the rapid increase of urbanization, the neighbourhoods, built environment, public transportation and services. In order to achieve energy sustainability, renewable energies must be taken into account. Among the renewable energies, wind energy is one of the most sustainable, research in this field is a crucial role for the development of a country as Mexico. This paper analyzed the contribution of Mexican institutions in literature specialized on wind during the period 1969-2016, considering complete years; 31,890 documents have been considered. It has been used Elsevier's Scopus database and bibliographic analysis techniques, considering in the analysis all the material reported by Scopus as source type,

keyword, subject area, source title, affiliation, document type, country, journal articles or conference proceedings. Data reported in Scopus have been used in this study. An analysis has been done on many different publications such as document type, language, evolution on wind research, publication distribution, Gross Domestic Product (GDP) versus document published by State, h-index and the frequency of keyword appearance. A national map showing the distribution by state and a worldwide map presenting the collaboration with international researchers.

Keywords: Wind, Mexico, Research, Scopus, h-index

Nomenclature	
Btu	British thermal units
RES	Renewable Energy Systems
GW	Gigawatt
PV	Photovoltaic
CFE	Comisión Federal de Electricidad
INEEL	National Institute of Electricity and Clean Energies
UNAM	National Autonomous University of Mexico
CICESE	Center of Scientific Research and Higher Education of Ensenada
IPN	National Polytechnic Institute
CONACyT	National Board of Science and Technology
CEMIE- Eolico	Mexican Center in Innovation in Wind Energy
JCR	Journal Citation Reports
SCI	Science Citation Index
SSCI	Social Science Citation Index
SNI	National System of Researchers
GPD	Gross Domestic Product
CIBN	Biological Research Center from Norwest
INECOL	Institute of Ecology
IMP	Mexican Petroleum Institute
INAOE	National Institute of Astrophysics, Optics and Electronics
SJR	SCImago Journal Rank
IER	Institute of Renewable Energies

1. Introduction

The increase of the demand and consumption of energy resulting from technological progress and from advancement in human development are seen as the most important factors in the acceleration of climate and environmental changes observed and described by the scientific community [1]. Energy is fundamental because is one of the most important component of economic infrastructure, its secure and supply is vital to human development [2]. Total world consumption of marketed energy expands from 549 quadrillion British thermal units (Btu) in 2012 to 629 quadrillion Btu in 2020 and to 815 quadrillion Btu in 2040—a 48% increase from 2012 to 2040 [3]. Using Renewable Energy Systems (RES) has been prioritize for governments due to increasing environmental issues, imports, security of supply of fossil fuels, as a result of this RES has growing faster and its development on renewable energy installed capacity [4]. Wind is one of the most sustainable renewable energies worldwide [5]; 2.6% of the electricity is generated by wind. This type of energy produces the best ratio of investment cost to productivity [6]. Wind power capacity represents the highest share, growing from 48 GW in 2004 to 370 GW in renewable energy capacity [7].

In Mexico most of its power is from fossil fuels as oil and coal, the contribution to power output generation from RES is scarceness, only 20 % is from RES, Geothermal, Wind, Hydro and Solar PV with 6.4%, 5.1%, 88.4% and 0.04% respectively [8]. Wind energy increased its production from 13.27 PJ in 2012 to 31.48 PJ in 2015, that represents an increased around 230% but only represents the 0.04% of the energy mix [9]. Until 2008, the energy administration was in charge of *Comisión Federal de Electricidad* (CFE) Federal Commission of Electricity, owned by the government, who is responsible for the generation, control, distribution and transmission of electricity. In the same year, the government reformed the energy law and opened the participation of nationals and foreign investors in the tasks that CFE does. In 2015 the Ministry of Energy established the goal of a minimum share of clean energy in power generation which will be increasing from 25% by 2018, 30% by 2021 to 35% by 2024 [10]. The beginnings of wind research in Mexico were in the decade of 1980, the government created the Instituto de Investigaciones Eléctricas (IIE) Electrical Research Institute, now called Instituto Nacional de Electricidad y Energías Limpias (INEEL) National Institute of Electricity and Clean Energies focused on electricity and non-conventional energies, its research included wind, solar, hydro and geothermal [11]. At the present time there are 3 institution leaders in wind research: the Universidad Nacional Autónoma de México (UNAM) National Autonomous University of

Mexico [12], Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) Center of Scientific Research and Higher Education of Ensenada [13] and the Instituto Politecnico Nacional (IPN) National Polytechnic Institute [14]. In 2013 the Ministry of Energy through the Consejo Nacional de Ciencia y Tecnología (CONACyT) National Board of Science and Technology [15], created the Centro Mexicano en Innovación en Energía Eólica (CEMIE-Eolico) Mexican Center in Innovation in Wind Energy, that grouped Research Centers, Universities and Companies its aim should be formed by the integration of a consortium that will generate broad synergy in favor of the use of wind energy in the country, including scientific and technological planning in the medium and long term for knowledge and positive use of wind energy [16].

Nowadays different universities and research centers have created research groups focused in wind as topic, Scopus was used as tool to identify some of them [17, 18]. This database catalogues more than 49 million records that are based on 20,500 titles and publications from more than 5000 publishers following the methodology done by [19-24]. Some authors have done studies about database, [25] could show the relationship between the Journal Citation Reports (JCR) and H-index, [26] make the comparison between JCR of Science Citation Index (SCI) and Social Science Citation Index (SSCI) and Scopus database for the year 2012. [27] analyzed the relationship and correlation between h-index and Journal Related Indices. In this regard, H-index have been used by Tahira et al. [28] for the assessment as predictive correlation with national criteria for Engineering in Malaysians universities; or [29] studied the correlation strength between impact factor, h-index and Eigenfactor of chemical engineering (CE) journals and its subsequent relevance in indicating the influence and prestige of the journals, he found out that both variables, h-index and Eigenfactor had very high correlation and the combination of both index is the best indicator that the use of one of them individually. Bibliometrics is a powerful and widely use tool for research evaluation despite it has been criticized from technical, methodological and conceptual views [30-32]. Some papers have done a bibliometric research on wind, as did [33] who analyzed based review on wind power price; or [34] who used the Scopus database to show the increasing number of research publications on wind turbine optimization problems; [35] assess the global scientific research on low-carbon electricity both quantitatively and qualitatively. This paper is a review of the research on wind in Mexico, the main objective is to show where the research goes, as well as the main journals, institutions, international collaborations between Mexican and foreign researchers.

2. Material and Methods

Web of Science and Scopus are the largest databases of scientific literature: books, conference papers, patents and scientific journals. Delivering a comprehensive overview of global, interdisciplinary fields (arts, humanities, medicine, science, social science and technology) (http://www.elsevier.com/solutions/scopus), the database has been used to find out the wind topic in which Mexican have participated. This source has been divided by subareas, affiliation and country. Data treatment has made by openrefine.org which is a powerful tool for managing data. Scopus is the largest citations and abstracts database of peer-review literature (http://www.scopus.com/) and has been proved to be an excellent tool to search information about a topic, researcher, affiliation and country of publication, as did by [36-41]. Unfortunately, Scopus is subscription-based database which is not available for some developing countries [42]. Web of science is a scientific citation index service distributed by subscription and maintained by Thomson Reuters. This database is provided with a citation search platform (http://wokinfo.com).

The assessing of 460 Mexican institutions during the period 1969-2016 who have published on wind as renewable energy were done considering these features: language, document type, publication distribution by institutions and regions, characteristics of scientific output, distribution subject categories and journals, an analysis of index keywords and author were carried out [43-46]. An *h* index analysis has been done, this index is considered a good tool to characterize the scientific output of researchers, indicating the number of citations that have received their scientific articles [47-51].

3. Results and discussion

The Consejo Nacional de Ciencia y Tecnología (CONACyT) National Council of Science and Technology, is a decentralized public agency of Mexico's Federal Government which promotes technological and scientific activities, sets government policies, and provides scholarships for postgraduate studies. CONACyT assorts the Sistema Nacional de Investigadores, National System of Researchers (SNI), a governmental agency established in Mexico in 1984. This agency is in charge of promoting both the quality and quantity of research in the country, especially in the science fields. Members and potential members are evaluated according with their academic credentials and production. Other aspects are taken into account such as the creation of projects and programs. To become a member and maintain this condition, researchers must have a systematic research career in their fields and are linked with universities or research institutions. The results obtained from Scopus data set were 31,890 documents of wind as topic, 24,019 75.5% are articles, Conference Papers 3181-9.97%, Review 1829-5.74%, Book 1472-4.62%, Book chapter 1070-3.36%, Articles in press 60-0.19%, this distribution is shown in Fig. 1.

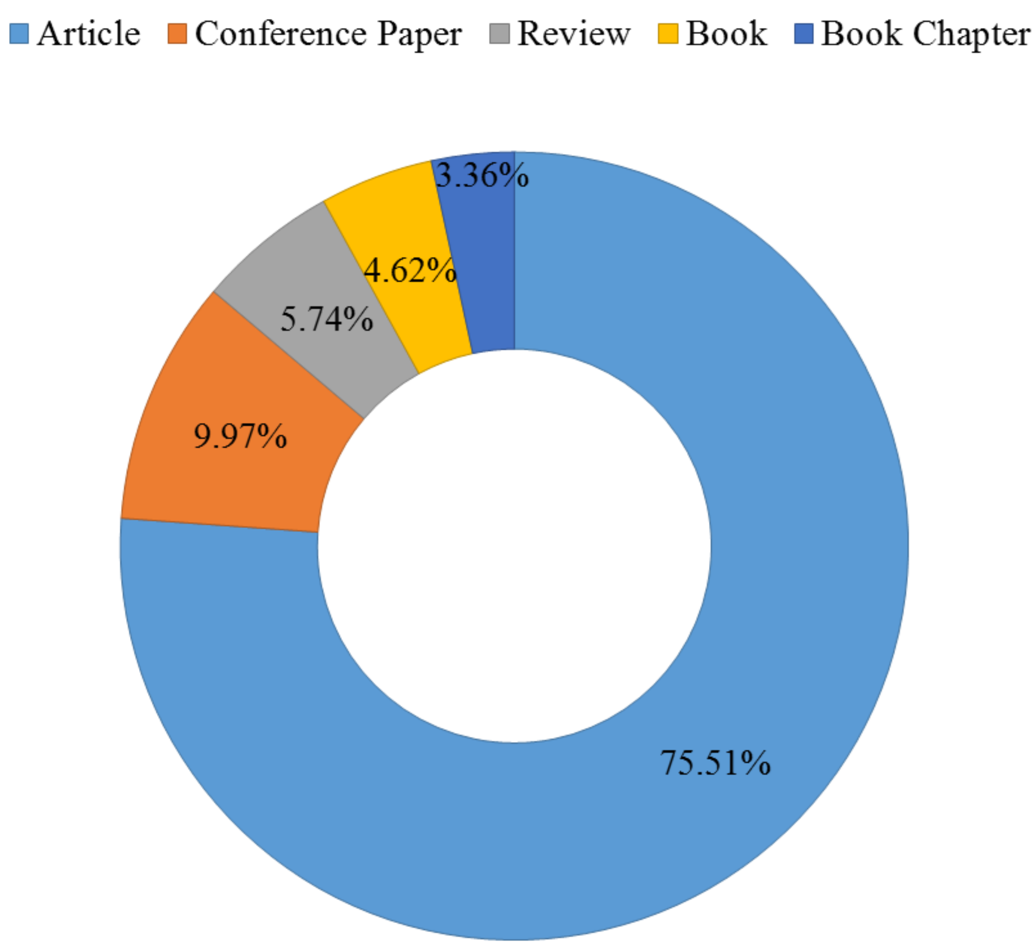


Fig. 1. Document Type in Mexico on wind research

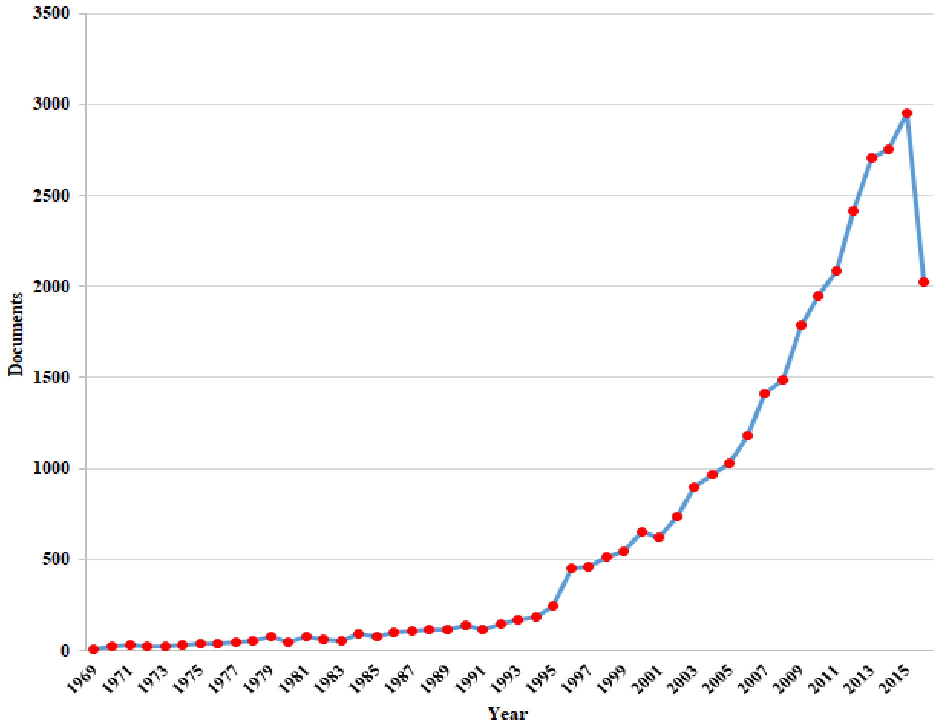
The most used language is English and this correlation is because most of the document type are articles; 31,081 documents are written in English, in Spanish 572, Chinese 199, among others. The reason that the articles are written mostly in English is because the most important journals are offered in that language, however, there are few journals in Latin America where is it allowed to write both in English and Spanish, is notable to see that Chinese is the third place even though this language is not commonly spoken in Mexico, this means that this is an accelerated process of change in the geography of science, both globally and at a Latin American level. New regional and local powers have modified the map of scientific production, which in just two decades has become very different from the traditional model of the last century; it is possible to group Portuguese, German and French because they represent the 0.5% and the sum of their documents could be compare with the written in Chinese, table 1 shows the language distribution.

Table 1. Language used on research in wind as renewable energy

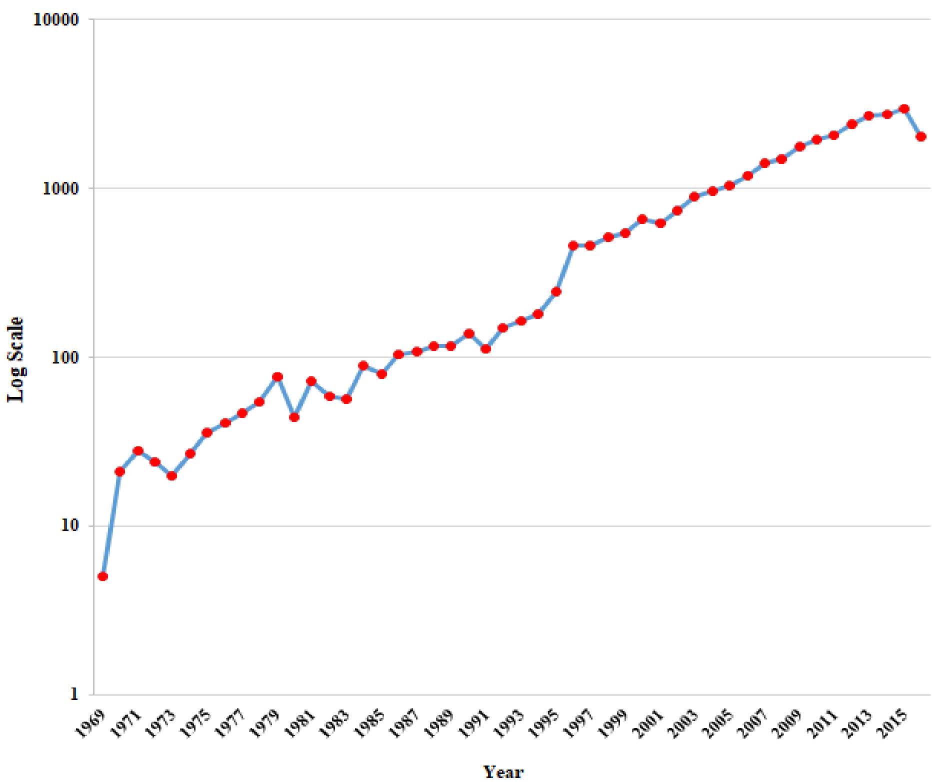
Language	Documents	(%)
English	31,081	96.922
Spanish	572	1.784
Chinese	199	0.621
Portuguese	62	0.193
German	56	0.175
French	47	0.147
Japanese	9	0.028
Italian	8	0.025
Polish	8	0.025
Russian	7	0.022
Turkish	4	0.012
Korean	3	0.009
Croatian	2	0.006
Persian	2	0.006
Arabic	1	0.003
Bosnian	1	0.003
Dutch	1	0.003
Estonian	1	0.003

Hungarian	1	0.003
Slovak	1	0.003
Swedish	1	0.003
Ukrainian	1	0.003

In Fig. 2a is presented the relationship between the number of publications where Mexican institutions have participated since 1969-2015, as can be seen the trajectory of the chart was exponential until 2015, in 2015 the number of publications decreased 31.3% compared with 2014, this can be inferred because during the course of 2014-2015, in Mexico the Law for the Use of Renewable Energies was being changed, then several Universities and research centers waited to have it to be able to investigate based on the new law.. Fig. 2b shows the information in logarithmic scale, which is a nonlinear scale, used when there is a large range of quantities, with this chart, it can represent a linear regression to determine its behavior, R-square obtained was 0.97 that represents that there is a positive trend on wind research in Mexico.



a) Historical evolution on wind research in Mexico



b) Logaritm chart on wind research in Mexico

Fig. 2. Evolution on wind research in Mexico

3.1 Publication by States and institutions

The scientific output production on wind energy by Mexican institutions is presented in this section; however, an analysis of Gross Domestic Product (GPD) by regions could help to correlate the development and determine if GPD has relation with scientific production in Mexico, as did by [52-54]. Fig. 3 represents both GPD and the number of documents published by states, Mexico City, Mexico, Nuevo Leon and Jalisco have the highest GDP and this can be observed because these regions are the most developed in Mexico. There are states in Mexico that do not have any institution where were published documents on wind as renewable energy, only 22 of 32 states have publications; it is important to consider that Mexico City has the highest number of documents published (Mexico City has several institutions) and has the highest GDP, meanwhile Campeche has the lowest production but its ranks sixth in GDP.Sinaloa and Chihuahua have the highest number of inhabitants per publication with 13.7 and 17 (per 10,000), respectively. Mexico City has the highest GDP and has the lowest number of inhabitants per publication in the country, even its population is the second higher (0.29); as well as the states of Baja California and Baja California Sur, that have 0.6 and 0.4 inhabitants per document published, both Baja California and Baja California Sur are zone developed in Mexico There are 10 states without research in wind as renewable energy, among these states is the last one, Tlaxcala, that has the lowest GDP, and it is important to see that 9 of the 10 states without research on wind are lower than the average of Mexican GDP that is 418,790 million of Mexican pesos, only Tabasco is above the average.

In Mexico, there are institutions leaders in research in wind energy, in Fig. 4 are presented the top 15 institutions. UNAM is the leader with 2354 documents published, even though UNAM has several research centers and campus, but Scopus register all these as UNAM which represents the 55.8% of the total published, follow by CICESE with the 8.1%, the last two institutions within this top 15 are INEEL and Centro de Investigaciones Biológicas del Noroeste (CIBN) Biological Research Center from Norwest with 78 documents each which represents the 1.8%.

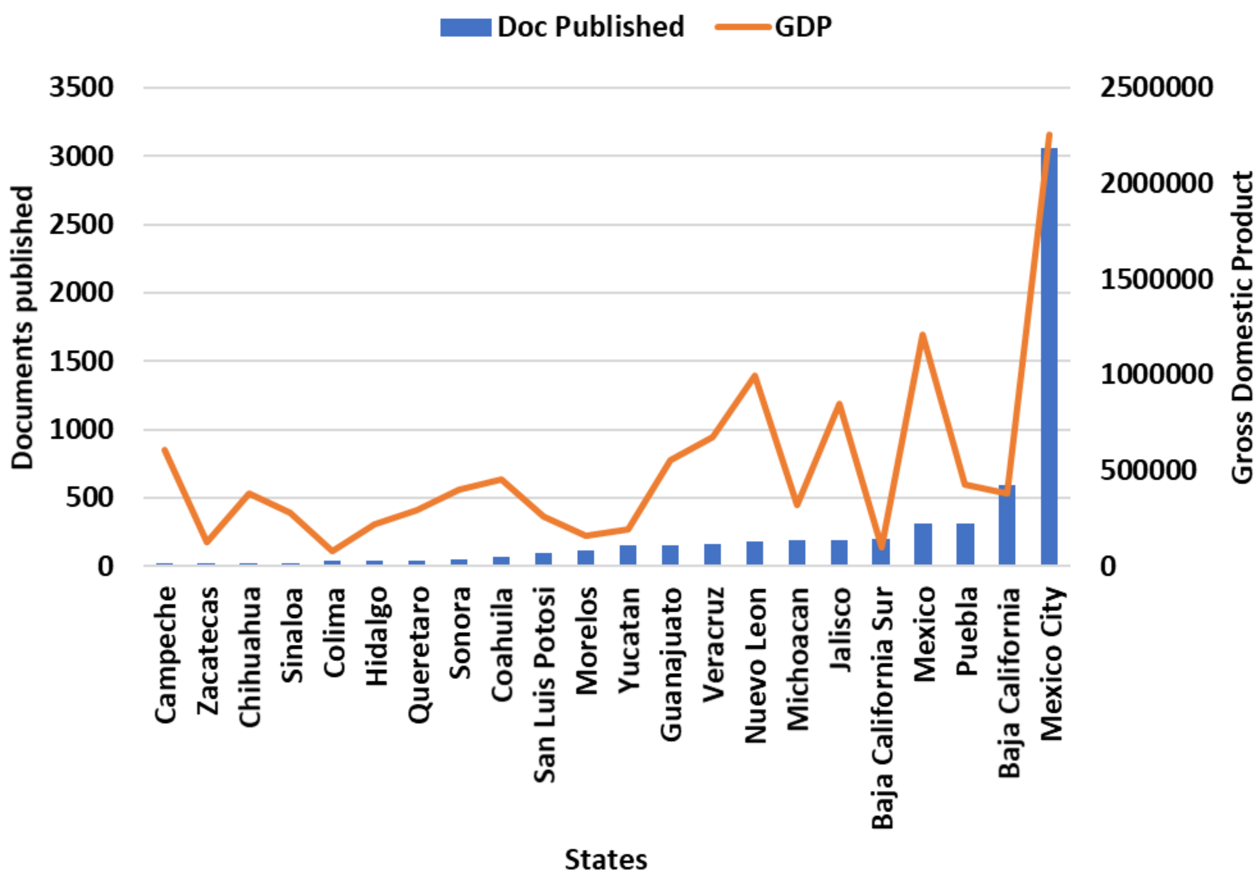


Fig. 3. Gross Domestic Product (GDP) per capita versus Documents published by regions in Mexico in 2016

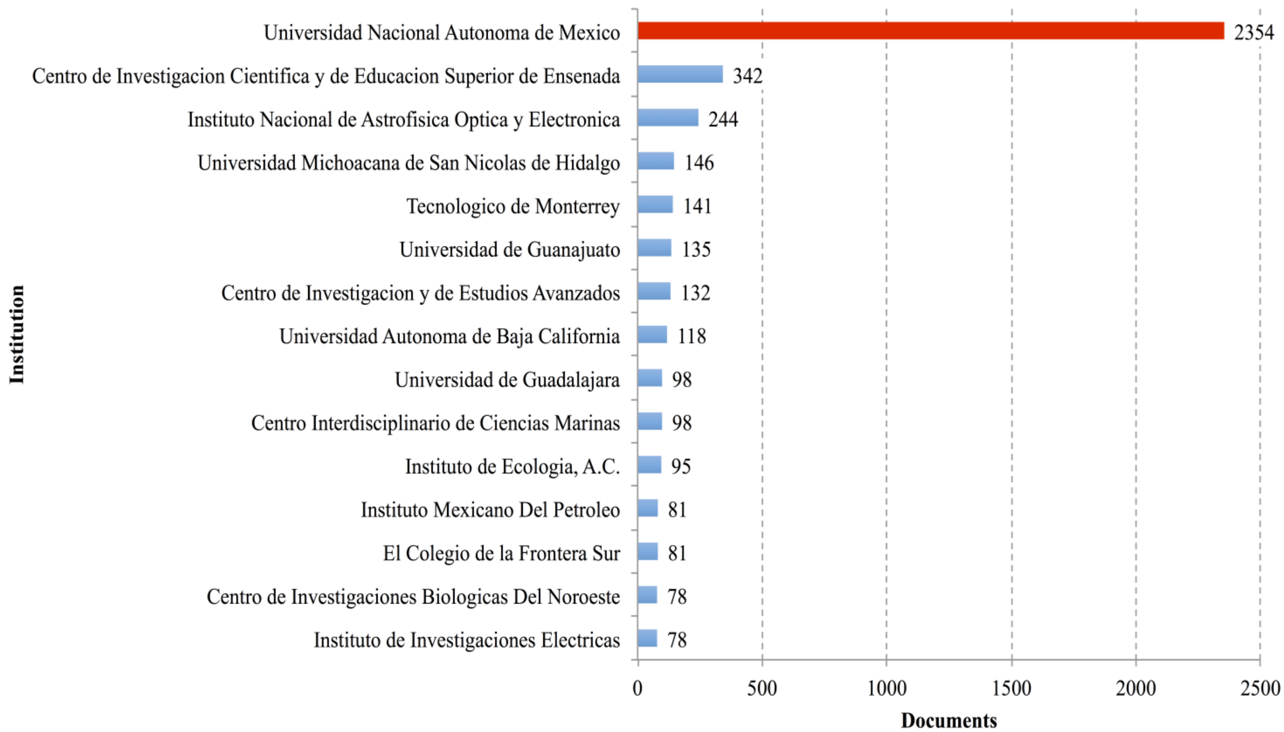


Fig. 4. Top 15 institutions on wind research in Mexico

To explain the relationship between the quality that the documents published by the top 15 institutions in Mexico an h-index analysis has done, as did by [55-59]. The h-index was obtained from Scopus database, Fig 5 shows this distribution, UNAM has the highest h-index, 16, however, is lower compared with a study did by [60] that ranked the best 50 institutions in the world, where the first one is Harvard University with an h-index of 86 and the last one are Washington University in St Louis with an h-index of 50, so between the best in the world and the best Mexican institution exist a range of 70 points. Following done by [36], the impact factor by institution is calculated dividing the number of total citations between the numbers of published papers.

Table 2 shows the most productive institution during 2002-2016, UNAM is the most productive, 1798 documents published, however, in 2016 have been published 153 documents meanwhile in 2015 were published 219 which represents a variation of -43.1%, but in general 10 institutions decreased their publishes, as it can see in table 3, e. g. the

Instituto de Ecología (INECOL) Institute of Ecology, decreased because in 2015 published 39 documents in 2016, 4 documents have been published; the University of Guadalajara and INEEL decreased as well. The institution that increased its number of documents was the Instituto Mexicano del Petróleo (IMP) Mexican Petroleum Institute (42.9%) followed by the Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE) National Institute of Astrophysics, Optics and Electronics, which increased in 30.8%, but in general the research on wind as topic of renewable energy in Mexico has decreased in the last years.

Fig. 6 shows all the collaborations between Mexican institutions and foreign. United States is the country with 15,636 documents published which represents 36.7% in collaborations, followed by the most representative countries: United Kingdom, China, Germany and Canada with 6.17%, 4.86%, 4.32% and 4.12 % respectively. In total people from 160 countries have been written with Mexican researchers, this international collaboration is equivalent to 87.04% which indicates that only the 12.96% of documents have been published by Mexican.

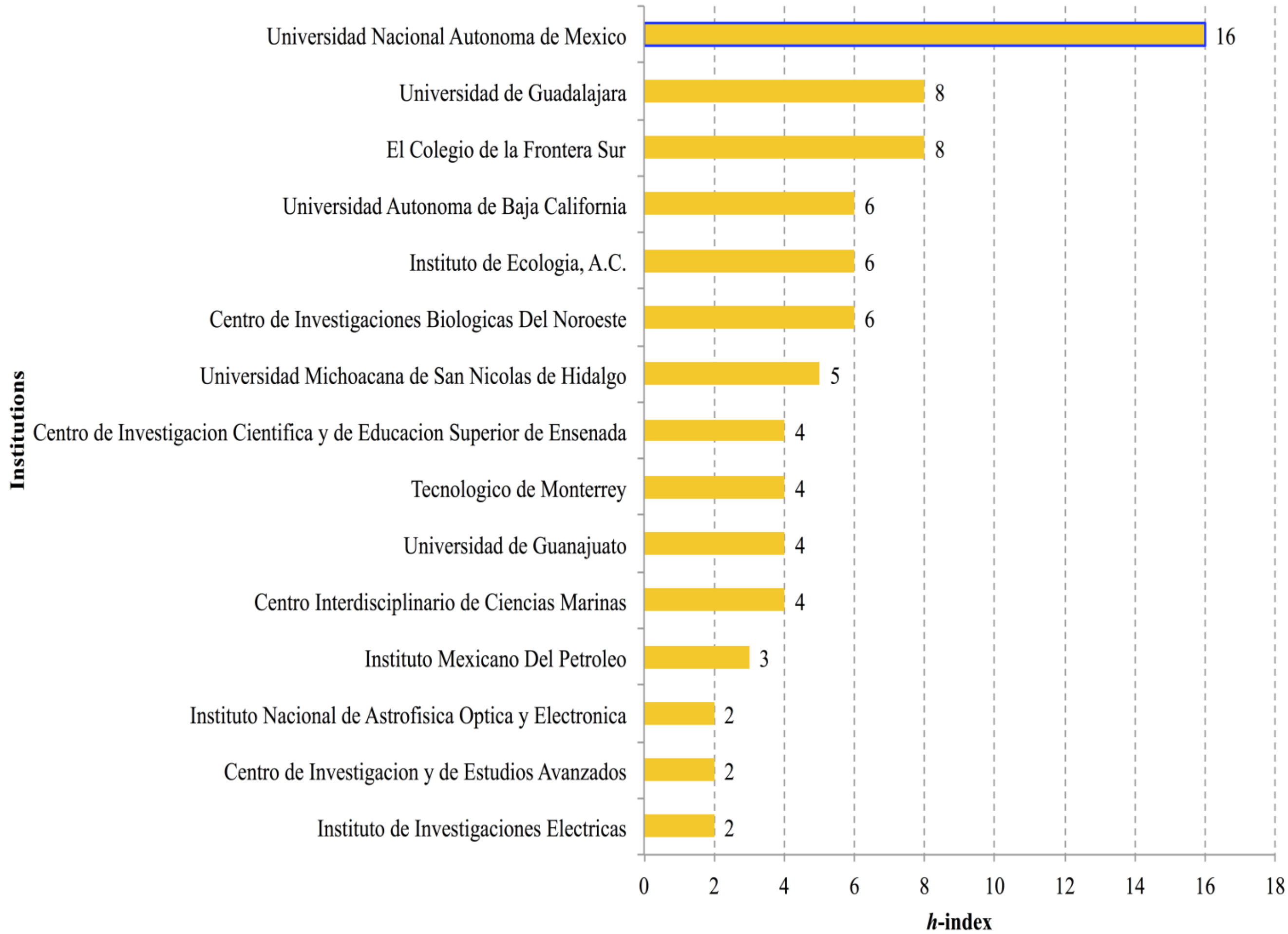


Fig. 5. *h*-Index for Mexican Institutions

Table 2. Evolution of the 15 most productive Institutions in Mexico since 2002.

Institution	Year															Total
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
UNAM	18	61	18	42	81	199	114	124	142	121	128	178	200	219	153	1798
INECOL	13	14	16	22	21	31	32	31	34	42	50	56	58	39	1	460
U A BCalifornia	3	2	7	9	14	19	21	22	28	16	24	39	32	39	32	307
CICESE	6	12	10	6	7	7	13	12	11	12	20	18	17	22	11	184
INAOE	0	6	0	6	10	8	12	17	11	13	8	13	12	9	13	138

U Guanajuato	4	4	4	0	5	6	4	14	8	8	17	12	18	17	10	131
Tecno Monterrey	0	0	2	5	6	3	1	11	7	8	21	14	16	21	15	130
U Guadalajara	5	4	1	2	7	2	10	5	7	17	16	13	19	13	1	122
U Michoa SNH	1	1	0	2	3	1	3	7	10	9	10	13	26	16	16	118
CINVESTAV	0	0	0	1	1	4	3	7	2	5	7	12	10	11	12	75
Centro Inter CM	3	0	1	1	3	6	2	3	7	3	5	12	9	9	5	69
Cole Frontera Sur	2	3	3	5	5	2	3	2	3	6	8	7	5	8	7	69
INEEL	0	2	7	1	1	0	5	9	2	7	9	4	4	9	4	64
IMP	2	3	3	4	2	4	3	4	2	7	1	3	10	4	7	59
Cen Inv Bio NoR	3	0	0	4	6	8	1	4	7	1	4	6	6	4	4	58

Table 3. Variation of the 15 most productive Institutions in Mexico since 2003.

	Year													
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	Variation (%)													
UNAM	70.5	-238.9	57.1	48.1	59.3	-74.6	8.1	12.7	-17.4	5.5	28.1	11	8.7	-43.1
INECOL	7.1	12.5	27.3	-4.8	32.3	3.1	-3.2	8.8	19	16	10.7	3.4	-48.7	-3800
U A BCalifornia	-50	71.4	22.2	35.7	26.3	9.5	4.5	21.4	-75	33.3	38.5	-21.9	17.9	-21.9
CICESE	50	-20	-66.7	14.3	0.0	46.2	-8.3	-9.1	8.3	40	-11.1	-5.9	22.7	-100
INAOE	100	0.0	100	40	-25	33.3	29.4	-54.5	15.4	-62.5	38.5	-8.3	-33.3	30.8
U Guanajuato	0.0	0.0	0.0	100	16.7	-50	71.4	-75	0.0	52.9	-	33.3	-5.9	-70

											41.7			
Tecno Monterrey	0.0	100	60	16.7	-100	-200	90.9	-57.1	12.5	61.9	-50	12.5	23.8	-40
U Guadalajara	-25	-300	50	71.4	-250	80	-100	28.6	58.8	-6.3	-23.1	31.6	-46.2	-1200
U Michoa SNH	0.0	0.0	100	33.3	-200	66.7	57.1	30	-11.1	10	23.1	50	-62.5	0.0
CINVESTAV	0.0	0.0	100	0.0	75.0	-33.3	57.1	-250	60	28.6	41.7	-20	9.1	8.3
Centro Inter CM	0.0	100	0.0	66.7	50.0	-200	33.3	57.1	-133.3	40	58.3	-33.3	0.0	-80
Cole Frontera Sur	33.3	0.0	40.0	0.0	-150	33.3	-50	33.3	50	25	-14.3	-40	37.5	-14.3
INEEL	100	71.4	-600	0.0	0.0	100	44.4	-350	71.4	22.2	-125	0.0	55.6	-125
IMP	33.3	0.0	25.0	-100	50	-33.3	25	-100	71.4	-600	66.7	70	-150	42.9
Cen Inv Bio NoR	0.0	0.0	100.0	33.3	25	-700	75	42.9	-600	75	33.3	0.0	-50	0.0

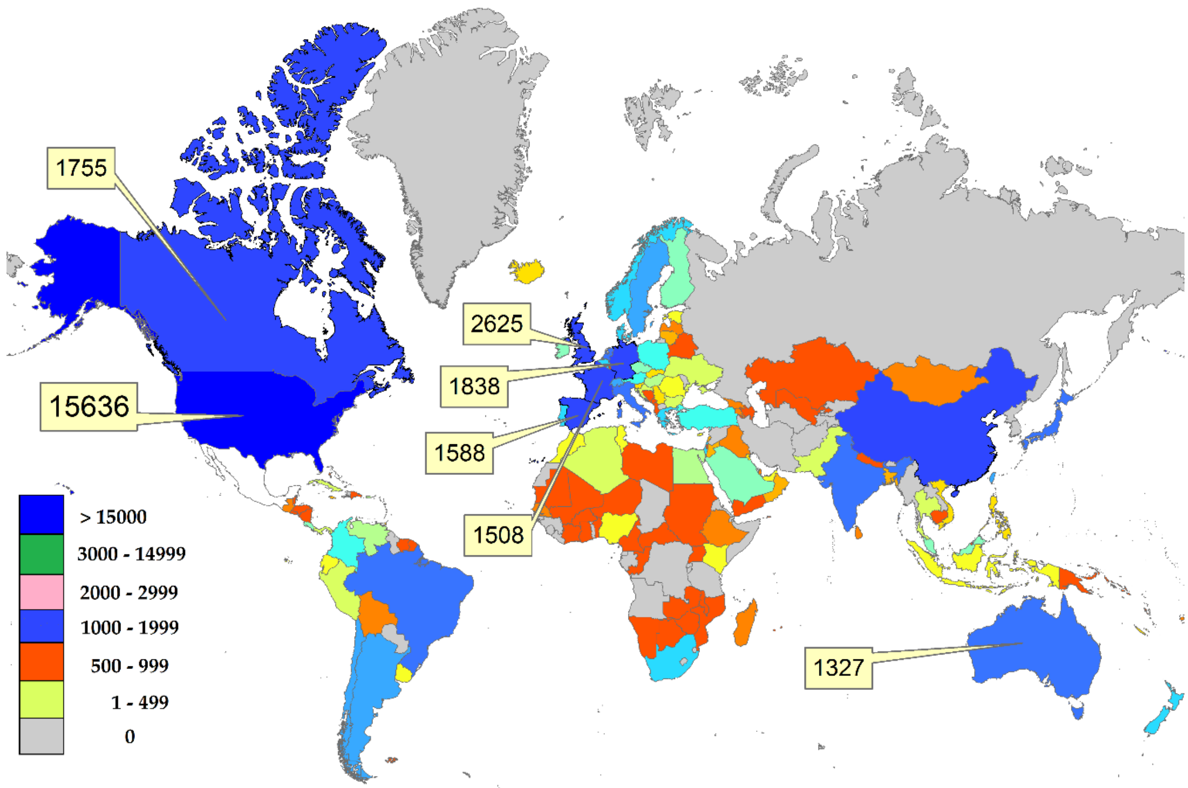


Fig. 6. Countries with collaboration with Mexican researcher on wind.

3.2 Universidad Nacional Autonoma de Mexico (UNAM) National Autonomous University of Mexico.

UNAM is the institution with the highest indicators, the National Autonomous University of Mexico was founded on September 21, 1551 with the name of the Royal and Pontifical University of Mexico. It is the largest and most important university in Mexico and Latin America. Its main purpose is to serve the country and humanity, train professionals useful to society, organize and conduct research, mainly about national conditions and problems, and extend as broadly as possible, the benefits of culture. It has several campuses in different parts of Mexico all of them researching on wind energy, in Mexico City, Temixco in the state of Morelos, Ensenada in the state of Baja California, Morelia in the state of Michoacan, Queretaro and Tlalnepantla in the state of Mexico.

3.2.1 Instituto de Energias Renovables (IER) Renewable Energies Institute

UNAM has an institute called Instituto de Energias Renovables (IER) Renewable Energies Institute which is the UNAM references in this type of energy. The institute has as main objective, to do basic and applied scientific research, especially in renewable energies, that support the development in sustainable technologies, to form specialized human resources and disseminate knowledge. It has 5 research lines, Renewable energy sources; Planning, prospective and sustainable development; Use of energy; Energy and society and Basic aspects that contribute to the development of new knowledge and sustainable energy technologies. Currently, the IER has a large number of research projects funded by CONACYT and extraordinary income. Most of its research have published in indexed journals, congresses and books, its h-index 52 is the highest in Mexico.

3.3 Categories and journals production.

Fig. 7 shows the Scopus distribution by subject, sometimes one paper is classified in different categories [61-67]. The subject with the most papers published is Earth and Planetary Sciences, this subject has 15,247 documents which represents 30.1%, followed by Environmental Science and Agricultural and Biological Sciences with 7672 and 7553 which represents 15.15% and 14.92% respectively, the subjects with less than 10% but more than 2% are Engineering (3764, 7.43%), Physics and Astronomy (3499, 6.91%), Social Sciences (2615, 5.16%), Energy (1946, 3.84%), Medicine (1428, 2.82%) and Arts and Humanities (1269, 2.51%). The expected results were that Engineering and Energy were the subjects with most documents published however Earth and Planetary Sciences has contributed with most documents.

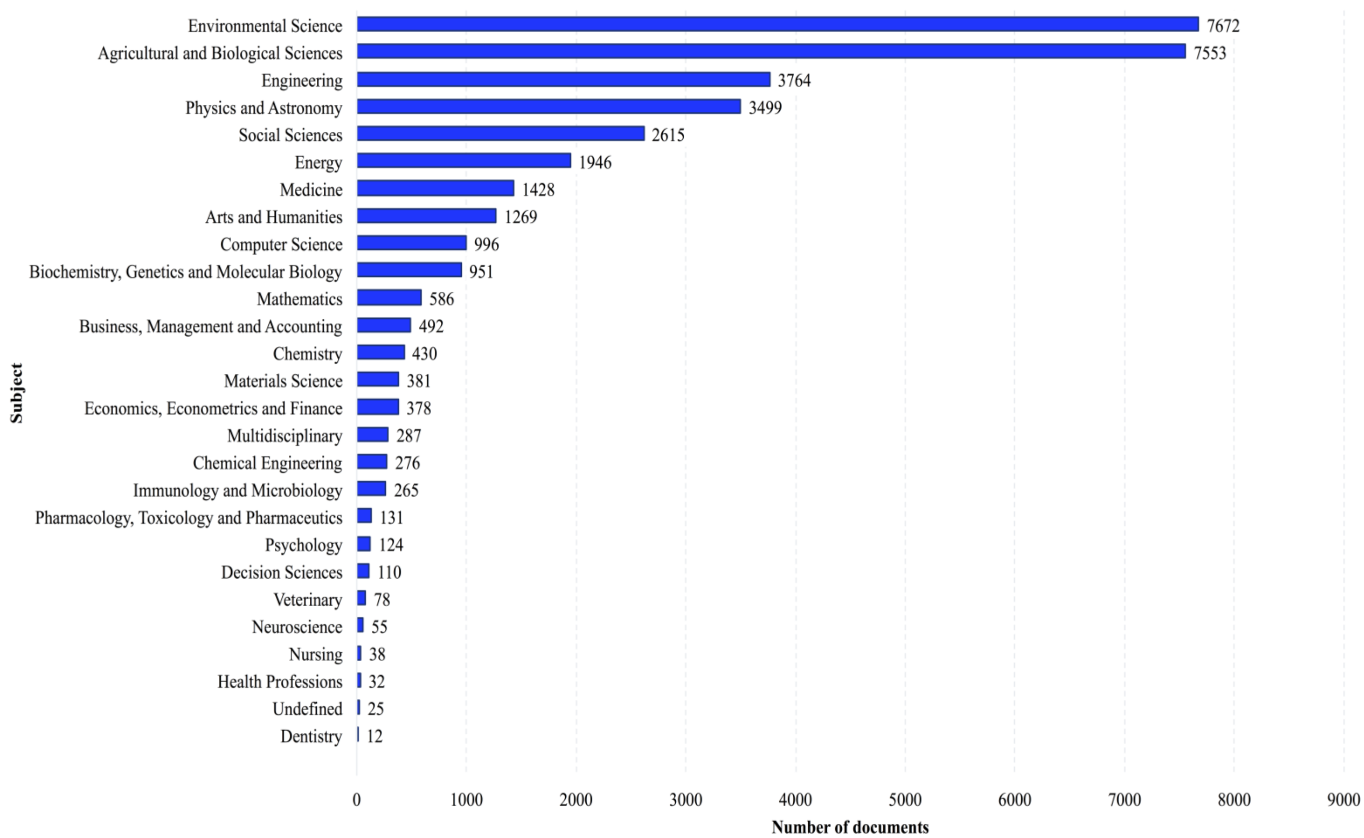


Fig. 7. Documents published by subject

In table 4 is shown the top 30 journals where Mexican researchers have written during the period 1969-2016 , this information contains the number of items of each journal; the impact factor of the JCR and the SCImago Journal Rank from Scopus, SJR, as well as, h-index and country. The journals Astrophysical Journal, Journal od Geophysical Research Atmospheres, Atmospheric Environment and Atmospheric Chemistry and Physics have the highest amount of references, their impact factor from JCR and SRJ has a correlation coefficient of 0.81 that indicates, that they have good relationship, as founded by [68-75], another important information obtained is that USA has most of the principal journals publishing about wind, followed by England, Netherland, France and Germany. h-index apparently presents some variation with respect to the impact factor of JCR and SRJ as show [53, 76-78] [1–3], but in this case the correlation coefficient between h-index versus JCR and SRJ are 0.64 and 0.59 respectively. h-index is different from those of journals in the energy category, this result coincides with done by [79]. Continuing with the analysis, h-index increase in those as Astrophysical Journal, Journal of Geophysical Research Atmospheres, Journal of Geophysical Research Oceans, Monthly Notices of the Royal Astronomical Society and Journal of Climate.

Table 4. Top 30 journals where Mexican researchers publish.

Source Title	Items	JCR	SRJ	H-index	Total Refs	Country
Astrophysical Journal	569	5.909	3.266	325	18,889	England
Journal of Geophysical Research Atmospheres	443	3.318	2.310	263	13,215	USA
Atmospheric Environment	343	3.459	1.999	174	10,633	England
Atmospheric Chemistry and Physics	341	5.114	3.207	130	11,815	Germany
Journal of Geophysical Research Oceans	336	3.318	2.310	263	8307	USA
Monthly Weather Review	308	3.248	3.160	132	9841	USA
Monthly Notices of the Royal Astronomical Society	276	4.952	2.806	239	4702	England
Journal of Climate	274	4.850	5.000	204	12,357	USA
Continental Shelf Research	263	2.011	0.999	84	5328	England
Geophysical Research Letters	263	4.212	3.323	185	6630	USA
Astronomy and Astrophysics	248	5.185	2.446	214	3267	France
Marine Ecology Progress Series	211	2.361	1.554	141	6786	France
Estuarine Coastal and Shelf Science	208	2.335	1.094	94	4482	USA
Journal of Coastal Research	208	0.852	0.672	61	2969	USA
Geomorphology	205	2.813	1.441	108	5751	Netherlands
Plos One	178	3.057	1.395	181	1721	USA
Palaeogeography Palaeoclimatology Palaeoecology	175	2.525	1.501	112	6287	Netherlands
Renewable and Sustainable Energy Reviews	156	6.798	3.121	140	4695	England
Journal of Physical Oceanography	149	3.026	2.622	109	3975	USA
Proceedings of SPIE the International Society for Optical Engineering	145	0.028	0.216	109	38	USA
Marine Geology	142	2.503	1.489	98	4084	Netherlands
Science of the Total Environment	139	3.976	1.702	160	2805	Netherlands
Sedimentary Geology	139	2.236	1.513	79	3987	Netherlands
Journal of Marine Systems	131	2.174	1.092	78	3138	Netherlands
Renewable Energy	120	3.404	1.961	113	2928	England
Journal of the Atmospheric Sciences	116	3.578	3.227	129	4233	USA

Progress in Oceanography	113	3.512	1.762	99	5554	England
Advances in Space Research	112	1.409	0.606	65	653	England
Astronomical Journal	111	4.617	3.069	191	3164	USA
Journal of Arid Environments	111	1.623	0.833	80	3056	England

3.4 Author and index keywords analysis.

There are different definitions of keyword, e.g. a keyword is responsible for representing the content of the research in the most basic and concise way possible [80]; it is a term that captures the essence of the topic of a document. Index terms make up a controlled vocabulary for use in bibliographic records [81] or keywords represent the main research foci of one article and can help readers recognize the key research contents of one article [82]. An analysis of keywords in scientific research helps to identify trends in science, for tracking and searching the most frequents words [35, 83-87]. As a result, from this research, a total of 80,957 different keywords have been obtained since 1969 to 2016 within wind research in Mexico from Scopus database. Due to obtain similar keywords, e. g. Aerosol can be found as Aerosols, Algorithm as Algorithms, etc., the tool OpenRefine has been used. This platform is a powerful tool for managing data: data scrubbing, modifying format (http://openrefine.org/), which uses algorithms to facilitate text clustering and merging with some degree of similarity [88-91]. Table 5 shows the top 50 keywords from wind as topic. Once the software is used, 43,333 keywords were obtained, of this the most mentioned keyword is United States that in 3232 items was used and represents the 7.459% of the total, followed by the four most mentioned keywords, North America, Wind and Mexico, which represent the 3.644%, 3.644% and 3.605% respectively, the keyword Mexico was expected to be one of the most important keywords, it could observe that the research in Mexico has to be with Climate change, numerical models, computer simulation and oceans, about wind assessment the keywords as wind power, wind velocity, wind effects and wind turbine barely have 2.056%, 1.812%, 1.689% and 1.205% respectively.

Table 5. Top 50 keywords used on wind research in Mexico.

Keyword	Items	%
United States	3232	7.459

North America	1579	3.644
Wind	1579	3.644
Mexico	1562	3.605
Atlantic Ocean	1541	3.556
Climate Change	1410	3.254
Hurricanes	1322	3.051
Gulf Of Mexico	1175	2.712
Pacific Ocean	1170	2.700
Numerical Model	1129	2.605
Computer Simulation	1044	2.409
Priority Journal	1029	2.375
Storms	920	2.123
Oceanography	898	2.072
Seasonal Variation	893	2.061
Wind Power	891	2.056
Remote Sensing	878	2.026
China	835	1.927
Wind Velocity	785	1.812
Wind Effects	732	1.689
Animals	725	1.673
Climatology	720	1.662
Human	720	1.662
Eurasia	706	1.629
Air Pollution	699	1.613
Mathematical Models	688	1.588
Concentration (composition)	666	1.537
Nonhuman	655	1.512
Air Quality	654	1.509
Environmental Monitoring	648	1.495
Weather Forecasting	635	1.465
Meteorology	631	1.456
Sea Surface Temperature	618	1.426
Humans	586	1.352

Hydrodynamics	578	1.334
Particulate Matter	578	1.334
Atmospheric Temperature	574	1.325
Rain	557	1.285
Atmospheric Pollution	550	1.269
Ocean Currents	543	1.253
Aerosol	541	1.248
Forecasting	539	1.244
Tropical Cyclone	529	1.221
Wind Turbines	522	1.205
Ozone	505	1.165
Dust	500	1.154
Controlled Study	498	1.149

In fig. 8 shows the evolution of the 10 most used keywords on wind research used by Mexican authors. Wind is the four most mentioned keyword, we expected it was in the first three, as [92] found out in its study, where the sustainability-oriented innovation system analyses conducted to the first keyword are related to sustainable as subject; or [93] who used keywords about manufacturing productivity to find out trends in this category, the first places were all about it, e. g. automation, cost and energy all these referent to the principal subject; [94] did an overview of Chinese energy using bibliometric analysis based on information obtained from the Science Citation Index Expanded database from 1993 to 2012, where solar was an expected keyword, however, they results solar was not at the top of the keywords.

United States as keyword maintains its trend during the period analyzed, it could be because the country with more collaboration is United States and on the contrary North America since 2010 has not been used frequently.

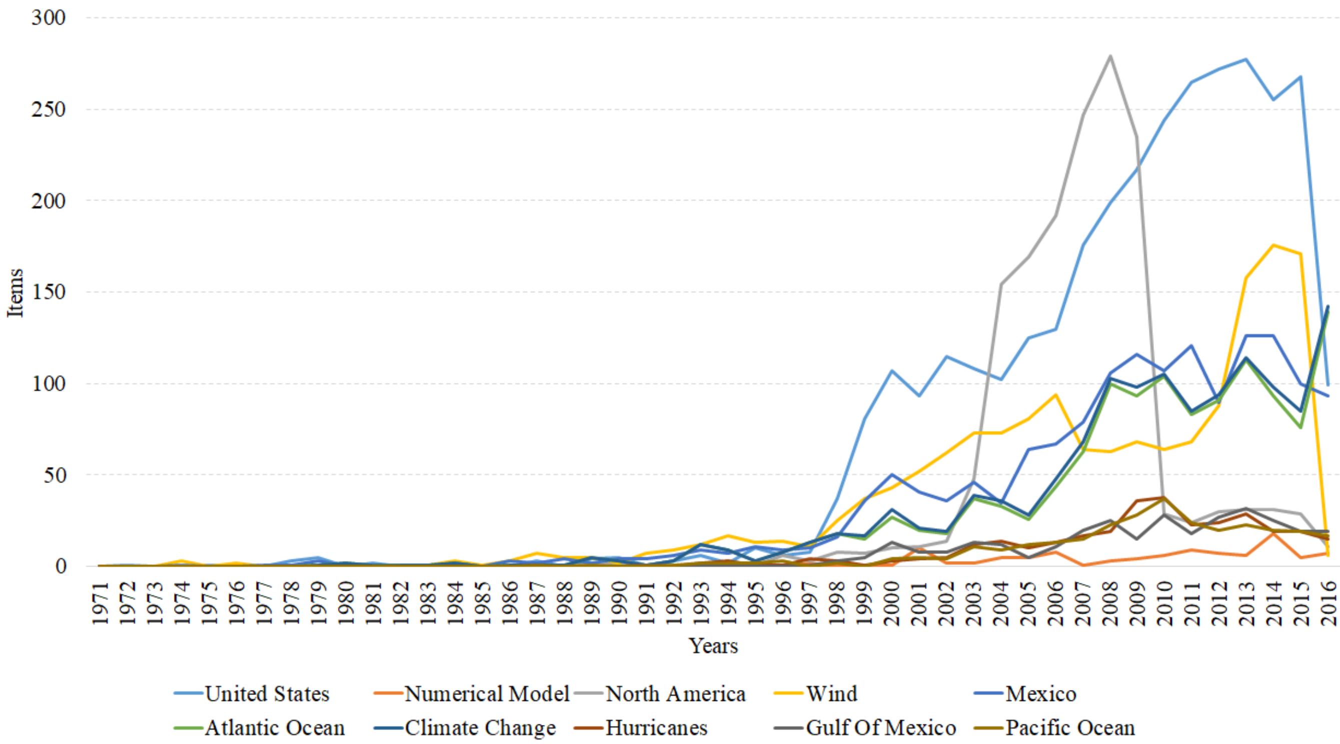


Fig. 8. Top 10 keywords evolution during 1971-2016.

In fig. 9 a linear regression has done to the top 10 keywords chart, that is presented in logarithm scale, in this analysis the keywords Climate Change and Atlantic Ocean are the most consistent even when they are not the most mentioned, their determination coefficient has been obtained, for Climate change (84.24%), followed by Atlantic Ocean (82.07%), Mexico (79.99%), United States (67.33%), Gulf of Mexico (66.53%), Pacific Ocean (63.64%), Wind (35.03%), Numerical Model (32.84%) and North America (0.098%). With this result it can observe that even United States is the most mentioned keyword, in the last years the number of times mentioned has not increased.

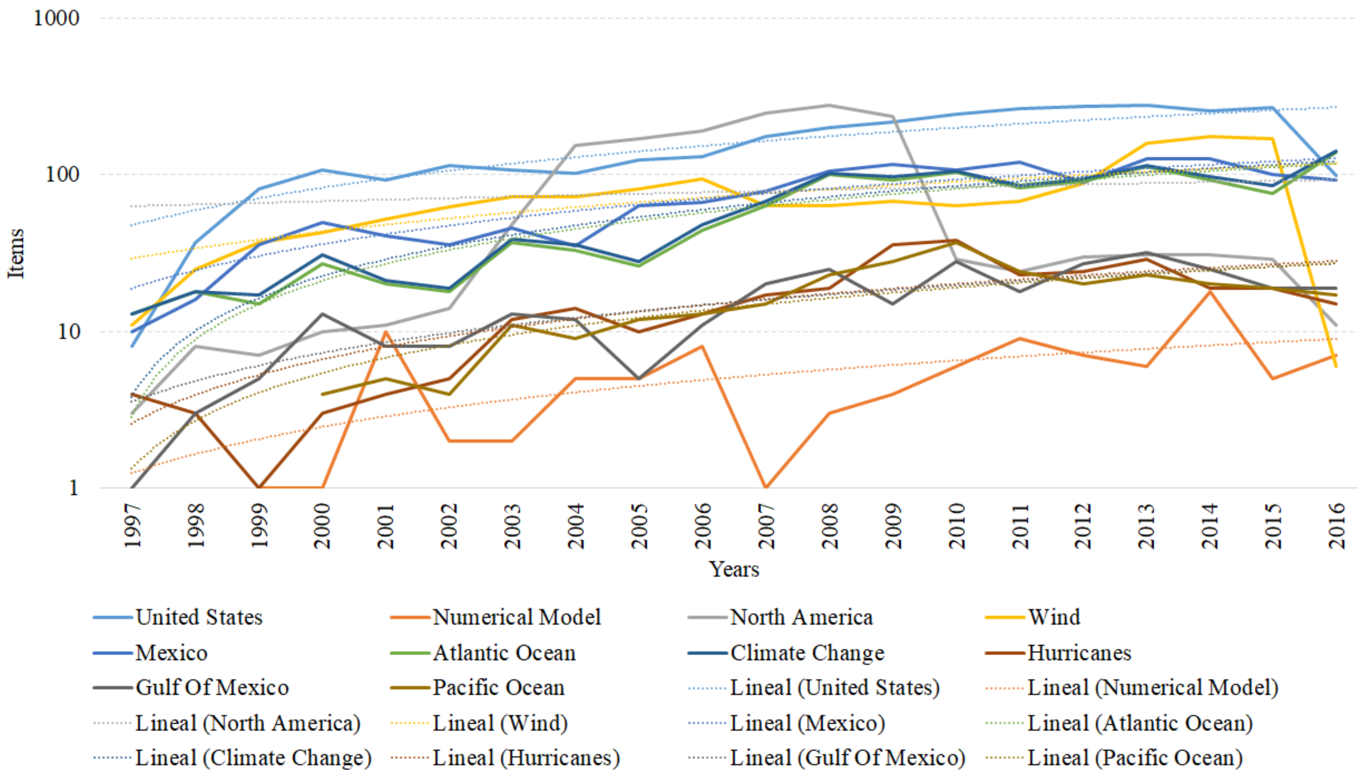


Fig. 9. Linear regression for the top 10 keywords..

Conclusion

An analysis of Mexican research on wind as topic during 1969-2016 have given interesting results, it has found 31,890 documents, most of them are articles (75.5%) and the most language used in the research is English (96.92%), this could be because Mexican researchers collaborate with US researcher in almost the 50% of the documents published. The research on wind maintain an increase trend since 1969, however the worst variation where between 1979-1980 when passed of 76 documents publish to 44, this decrease represented -42%, even though the trend is positive. An analysis of GPD per State versus documents published were done, Mexico City with the highest GPD has the lowest relationship with 0.29 which represents that even if has the highest GPD no necessary is the firsts one in publications. The institution with more documents published is UNAM with 2354 which represents the 55.8%, has been showed the h-index by institutions, the highest belong to UNAM with an h-index of 16 and the lowest has it the INEEL with 2. The evolution of the 15 most productive Mexican institutions showed that UNAM published in average 150 documents per year, INECOL presented the last year a decreased because in 2015 published 39 documents and 1 in 2016. Mexican researchers collaborate with researches from 180 different countries, the most collaboration is with United States. The subject where are more publications are Environmental Science, Agricultural and Biological Sciences, Engineering with 7672, 7553 and 3764 documents respectively. The principal journals where Mexican publish are Astrophysical Journal (569), Journal of Geophysical Research Atmospheres (443) and Atmospheric Environment (343). The analysis done by keywords showed that United States, North America, Wind and Mexico were the most mentioned keywords in the documents, although Atlantic Ocean and Gulf of Mexico are the most consistent. Analyzing the ratio between the publication date and category of the journal, the evolution in themes as Environment and Climate have increased during the period studied. As reflection the state of Oaxaca is widely known as the zone with the highest wind resource in Mexico, the research about this zone has been increased, as recommendation the studies must be directed on others states with proven wind potential as Tabasco and Chiapas. This study represents a complete guide for researchers on wind, to identifying new trends in Mexico.

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