Renewable energies: worldwide trends in research, funding and international collaboration.

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Abstract

The main aim of this study was to analyse scientific and energy production, funding, collaboration among countries and most cited papers on the renewable energies topic through bibliometric and social network study of articles included in the Web of Science database. 12,167 papers were recovered from 2007-2016. Wind power is the energy from which a greater number of articles have been published (n=3,930), followed by solar energy (n=2,570) and ocean energy (n=1,565). The United States leads the world production of articles (n = 2,320), followed by China (n=1,629), the United Kingdom (n=1007), Germany (n=730) and Spain (n=729). China is the leading country in financed works (80%), followed by South Korea (77%), Spain (61%) and the United States (59%). An important level of international collaboration has been identified, notably popping up the triangle made by United States, China and the European Union.

Key words: Scientific research; Renewable energies; International collaboration; Journals; Hot papers.

1. Introduction

Traditional fossil fuels are currently supplying about 80% of the energy consumed in the world. Emission of carbon dioxide among other pollutants into the atmosphere are a consequence of traditional fossil fuels combustion. Furthermore, some associated effects such as acid rain and smog became severe environmental issues [1-3]. Moreover, the demand for energy is steadily expanding. It has been reported that energy demand will triple by the end of the century [4].

Climate change has become one of the most important environmental challenges, with the consumption of fossil fuels as one of the major contributors to climate change. The development of renewable energies has been named as a significant measure to mitigate global climate change [5,6], trough mitigation of CO2 gas emissions. Moreover, it has been proved that an increase in the use of renewable energies improves the efficiency of the economies at macro-economic levels.

The definition of a renewable energy source includes a simple sustainable resource that will be available over the long term that does not imply high costs and that can be used for any application without negative side effects [7,8]. Moreover, a renewable energy source also implies minimal environmental impact and production of secondary side-wastes. Not less important its sustainability has to be based on current as well as future social and economic needs [9]. If all these conditions are met, the energy source is thus considered a clean source of energy. The use of renewable energy also holds several positive aspects. Within them, an increased energy supply options [7], net employment and the creation of export markets [10,11], in both developed and developing countries. Finally, the use of renewable energies implies an important reduction of greenhouse gas emission and consequently critically influences climate change [8,11-14].

The mitigation of climate change and the necessity of rapidly meeting increasing energy demands have been proposed as two of the most important worldwide challenges [15]. The development of renewable energy production and consumptions has been agreed by world key players (governments, commercial organizations and academic partners) as the best way to deal with the two aforementioned challenges. This may be achieved through the development of renewable energies, due to its economically rational, environmentally friendly and sustainable nature.

The power industry is decidedly looking towards increasing renewable energy production to meet energy demands following a sustainable development and thus mitigating climate change [16]. The sustainable development of renewable power is however dependant on several conditions, including economic factors (development and utilization costs), technological factors [17], social acceptance [18] and environmental constraints [19], among others [20].

On the other hand, the progression of renewable energies is of crucial importance for the development of the society. During 2015 the employment within the renewable energy sector was increased by 5%, which accounted for 8 million of jobs, including both direct and indirect employees [21]. However, the cost involved during the developmental stage of the renewable power applications is unfortunately acting as a solid barrier against scaling the technology to commercial uses [22-24]. On the other hand, most of the new renewable power application are still in its infancy and have not yet been commercialized

One of the factors that can foster the development and use of renewable energy sources is research. The main aim if this study is thus to perform a detailed analysis of the research efforts and trends in renewable energies. The goal will be accomplished through the examination of the number of indexed scientific journals and also through the investigation of the correlation between scientific productivity and impact, power production and funding on global renewable energies during the 2007-2016 period.

2. Methods

Records on publications, citations and funded papers were obtained from the Web of Science Core Collection (WOS) platform from Clarivate Analytics. A bibliometric analysis was performed to obtain indicators of scientific productivity, impact and funding, and its relation with energy production figures. The key words used for the search strategy in WOS were based on a previous work published by Rizzi, van Eck and Frey [25] and included: “biomass”, “geothermal”, “hydroelectric”, “solar”, “ocean” and “wind”, all of them combined with “energy*”. The generic term “renewable energ*” was also included in the search. The key words were truncated if necessary to obtain variants of the same term. To achieve greater accuracy in the results, the search was conducted in the title field of the registries. The study was restricted to original articles and, consequently, reviews, editorials, letters, abstract of conferences, bibliographical articles, reprints, book reviews and news were excluded. The search was thus limited to original articles within the 2007-2016 decade.

As indicators of scientific production it was estimated: annual evolution of funded and unfunded published papers; articles, citations and percentage of funded papers in each renewable energy; distribution of papers per countries; most productive journals with number of citations, impact factor, quartile and WOS subject category; most cited papers; world map of collaboration among countries. We also illustrated in several figures: the renewable energy production in GWh per class of energy; the energy production per type of energy with the number of funded articles; the number of citations per article for the different renewable energies; the number of funded and non-funded articles and the number of citations per article in the leading countries.

Impact factor numbers were extracted from the 2016 edition of the Journal Citation Reports. Data on funding were also extracted from WOS database. To analyse and drawn the collaboration patterns, a social network analysis (SNA) was also carried out to identify the number of co-occurrences between countries. Co-occurrences refer to all combinations of pairs of countries in each paper, which might also appear in other papers. To visualize the networks, we used the softwares Pajek and VOSViewer [26]. A threshold or minimum of papers written in collaboration between countries of 3 papers was applied in order to ensure proper network visualization. Analogous approaches have been used to map the knowledge structure in other fields such as environmental science [27], tsunamis [28] and deforestation [29], among others. Data renewable energies production per country were extracted from the International Energy Agency web page (www.iea.com).

3. Results and discussion

A number of 12,167 papers that received 185,410 citations were recovered from the search strategy. Fig. 1 shows the number of published articles (funded and unfunded) and the number of citations during the period under study (2007-2016). A steady increase in the number of publications was clearly identified. The number of published articles experienced an approximately fivefold increase in the last 10 years, from 462 publications in 2007 to 2330 in 2016, fact that highlights the importance of this research topic. The number of funded articles (orange bars) also shows a steady increase during the ten years' period under study. From 2012 the number of funded articles overcome the number of non-funded papers, following a constant progression with approximately 60% of the total number of publications being funded. Additionally, the number of citations has also experienced a steady increase during the first half of the period under study (up until 2011) with the exception of 2008 with a slight decrease in the number of citations. From 2012 an expected decrease in the citation numbers was observed.

The number of articles, citations and funded articles for each energy sub-class can be seen in Table 1. Wind power was the energy from which a greater number of articles were published (n=3,930), followed by solar energy (n=2,570) and ocean energy (n=1,565). The number of articles published on the other types of energy was found to be significantly lower. A considerable number of works have been published in the renewable energies topic in general, without specifying any particular energy sub-class (n=3,303). Moreover, the ratio citations per article was the highest for solar energy (n=17.89), followed by wind power (n=15.30) and biomass (n=14.9). The highest percentage of funded articles was found for ocean energy (65%), followed by solar energy (58%), wind power (48%) and geothermal energy (47%).

Table 2 presents data concerning the 15 countries that have published 300 or more articles. The United States leads the world production of articles (n = 2,320), followed by China (n = 1,629), the United Kingdom (n = 1007), Germany (n = 730) and Spain (n = 729). The same ranking was found for the number of citations received, however with Spain being ahead of Germany and Denmark in fifth place. The proportion of citations per article was highest for Denmark (n = 28.68), followed by United States (n = 20) and Canada (n = 17.99). The number of documents financed is almost similar in the United States and China (around 1,300), but China appeared as the leading country in terms of percentage of funded articles, with 80% of the works financed, followed by South Korea (77%), Spain (61%) and United States (59%). The specific data of these variables according to the type of energy will be analysed in the following sections. Additionally, data on types of renewable energies sub-classes by countries is provided in Supplementary information S1.

The articles obtained from the search strategy were published in 1829 different journals. Table 3 shows 16 journals with more than 100 published papers, including the country of publication, citations, citations per paper, impact factor, Web of Science subject categories and quartile. Journals publishing most papers have been *Renewable & Sustainable Energy Reviews* (n=1095), *Renewable Energy* (n=841) and *Energy Policy* (n=588). The ranking of journals according to the ratio citations per paper is headed by *IEEE Transactions on Energy Conversion* (C/A=39.79), followed by *IEEE Transactions on Power Systems* (C/A=35.52), *Applied Energy* (C/A=26.89) and *Renewable & Sustainable Energy Reviews* (C/A=24.03). Journals with higher impact factor were *Renewable & Sustainable Energy Reviews* (IF=8.050), *Applied Energy* (IF=7.182) and *IEEE Transactions on Power Systems* (IF=5.680). Most of journals are ranked in first quartile in Journal Citation Reports.

Fig. 2 shows the energy production in GWh on renewables per class of energy (biomass, geothermal, hydro power, ocean energy, solar energy, and wind power) as well as the number of published and funded articles. Different behaviours can be observed in Fig. 2 in terms of energy production and number of publications (funded and unfunded). China and United Stated stood out as the countries with the largest number of financed and unfinanced articles. However United States (leading country in terms of publications (2,320) energy production is more or less half (571,089 GWh) of that observed for China (1,294,214 GWh). The opposite behaviour can be identified for this later country (world leader in renewable energy production) with low article publication in comparison with energy production. Interestingly both countries showed similar number of funded publications, which indicates a high percentage of funded articles in China (80.23%). Moreover, a further group of four countries own a significant number of publications led by United Kingdom (despite the low renewable energy production) and followed by Germany, Spain and India. It is also worth mentioning the low number of publications observed for Canada notwithstanding his high energy production, taken almost exclusively by hydro power energy (second leading country). On the other hand, in terms of articles that received funding, in combination with China (second country in absolute numbers), Spain and South Korea seems to have a high percentage of funded articles (61,31 % and 77,42 %, respectively), followed closely by United States with almost sixty per cent of funded publications (59,27%).

A summary of renewable energy production per type of energy and countries can be seen in Fig. 3, together with the number of articles and number of funded articles. The figure is disaggregated into biomass, geothermal, hydropower, ocean energy, solar energy and wind power. The countries included in the figure correspond to those with more than 300 published articles within the period under study. United States, China, Germany and Japan, in this order, appeared as the leading countries in biomass energy production (GWh). Within these countries, Japan and China stood out with almost the totality of articles been funded (87,5%). Moreover, Germany also shows a high percentage of founded articles (63,64%), while on the other hand, the United States (leading country in biomass energy production) showed less than half of the articles financed (37,5%). In addition, Turkey presented a surprisingly high number of published articles (almost the totality not founded) with one of the lowest biomass energy production activities. In terms of geothermal energy production, United States, Germany and Turkey were observed as leading countries in number of publications, only in accordance with high-energy production for United States. In terms of funding, United States, China and Germany appeared as the leading countries (56.25%, 79.31%, 57.5%, respectively) with again Turkey showing low percentage of funded publications (30.43%). With regards to hydropower production China stood out as the prominent leading country (1,064,337 GWh), followed by Canada and United States (382,574 and 281.427 GWh, respectively). Moreover, China also presented high funding numbers with high percentage of financed articles (76.67%). On the contrary, Turkey again showed and important number of published articles with low funding activity (14.81%).

Furthermore, South Korea and France appeared as the world leading countries in terms of ocean energy production (492 and 481 GWh, respectively). However, United States, China and United Kingdom were identified as the leading countries in number of articles (322, 228, 269, respectively) and funded publications (218, 191, 174, respectively). After this trio of countries, and despite the limited energy production, Spain showed up also with a significant number of publications (109) and funding received (82.57%). Moreover, South Korea and France showed almost the same number of publications (70 and 74, respectively) but with higher funding received by South Korean researchers (72.86%). On the other hand, a group of five countries stood out for solar energy production (GWh). Within them, United States was the leading country in terms of publications (681) followed by China with approximately half of its papers (339). The solar energy production was led by Germany, followed by China, United States, Japan and Italy (36,056, 29,229, 24,603, 24.506, 22,306 GWh, respectively). Interestingly a high percentage of funding seemed to be a common practice throughout the mentioned countries with the exception of Japan and Italy with 51.9% and 40.83% of funded publications. Finally, with regards to wind power, United States and China were the leading countries in terms of energy production (183,892 and 156,078 GWh, respectively), number of published articles (738 and 729, respectively) as well as funded publications (426 and 584, respectively). In addition to this fact, China also showed a high percentage of funded articles (80.11%) in agreement with what was observed in other sub-types of renewables investigated.

Fig. 4 presents the number of citations per article for the different identified sub-classes of renewable energies (including biomass, geothermal, hydro power, ocean energy, solar energy, wind power) as well as for the topic renewable energies. The third axis in Fig. 4 shows the total percentage of funded articles per country. As can be observed, Denmark stood out as the overall leading country in terms of articles impact i.e. number of citations per article. Denmark appeared as the leading country for geothermal (28), hydro-power (41), solar energy (27) and renewable energies (55). On the other hand, Canada was observed as the leading country for the biomass topic with approximately 45 citations per article, while United States did for ocean energy (17). Interestingly China and South Korea appeared as the two countries with higher percentage of funded articles with values of 80% and 77% respectively. In addition, Spain (61%), United States (59%) and United Kingdom (54%) showed also funded publications above the 50% threshold.

Fig. 5 illustrates a compilation of the number of funded and non-funded articles and the number of citations per article in the leading countries in biomass, geothermal, hydro power, solar and ocean energy, wind power and renewable energies scientific productivity (countries with more than 300 publications within the 2007-2016 period). United States (32), China (24) and Turkey (20) in this order are the countries with higher scientific productivity in terms of number of published articles. Additionally, a high percentage of funded articles was found for China (76,67%), fact that was not observed for the other two remaining countries. The articles published in Canada dealing with biomass (2) were found to be of exceptional quality (based on number of citations received per article) with an average of 45 citations per article. In terms of productivity and focussing in the above-mentioned three leading countries, United States, China and Turkey showed 19, 17 and 14 citations per article, also appearing as leading countries for this indicator with the mentioned exception of Canada and with the 21 citations per article observed for India.

Despite the low scientific productivity (number of publications), Denmark (3) and Iran (9) were observed as the countries which research received the highest number of citations per article with 28 and 23 citations per article, respectively. In terms of productivity (number of articles), Turkey, United Sates and Germany were the leading countries followed by China, Italy and Australia. All these countries presented a high percentage of funded articles (>50%) with the exception of Turkey (30.43%) and with China as the country with the highest percentage of funded publications (79,31%). Interestingly, these countries show very similar ratio citations per article, with an average approximate number of 12 citations per article. When referring to the hydro-power energy, Denmark appears again as the country with the highest ratio citation per article with 81 citations being received by two published articles. The total number of published articles was led by China (223) followed by Turkey (192) and United States (136). China and Turkey were again observed as the countries with the highest percentage of funded articles (76.67%) and one of the lowest funding percentage (14,81%), respectively.

United States appeared in first place in number of publications (322) and also in the number of citations received per article (17) for the ocean energy topic. United Kingdom (269) and China (228) showed also an important scientific productivity in number of publications. A high percentage of funded articles was also observed for the aforementioned countries with 68%, 65% and 84%, respectively. It is also worth mentioning the high impact (number of citations per article) and percentage of funded articles observed for Spain with 14 citations per articles (109 published articles) and 82,57% of funded articles. With regards to solar energy, United States appeared as the clear leader with double the publications (681) than the second most prolific country (China). This high productivity was also accompanied by a high citation per article ratio (25) and one of the highest percentages of funded publications (70,34%). Moreover, the research contributions published by Denmark and Germany showed also high number of citations per article with 27 and 24 citations per article respectively.

United States and China appeared again as the leading countries in wind power scientific publications (738 and 729 number of articles, respectively). However, the mentioned countries differed in the number of funded articles (with higher percentage showed by China (80.11%)) and in the number of citations per article (with United States showing 18 vs. 12 citations per article). Other countries with lower scientific productivity (number of articles) but high scientific impact (high citations per article) were Canada (23), Denmark (23), United Kingdom (22) and Spain (22). Finally, for the research topic “renewable energies”, United States appears as the leading countries in terms of number of publications (509) with almost double the numbers of the following countries (United Kingdom (302) and China (276)). The percentage of funded articles is below 50% for United States and United Kingdom while 73.19% of the articles published by Chinese researchers were funded. It is also important to highlight here the high citations per article observed again for Denmark (55) despite the lower total number of publications (80).

Fig. 6 shows the world map of 62 countries with more than 3 papers written in collaboration. The most prominent feature is the triangle of solid collaboration between United States, the European countries and China (for a better visualization, only the name of most European productive countries is displayed). The countries that have published the largest number of articles in collaboration were United States and China (n=216), United Kingdom and China (n=94) and United States and United Kingdom (n=82). Other collaborations that stood out are China with Australia (n=70), Spain and United Kingdom (n=60) and South Korea with United States (n=53).

Papers receiving more than 300 citations are listed in Table 4. The most cited paper was published in 2007 by Kamat PV, a researcher of the Department of Chemical and Biomolecular Engineering of the University of Notre Dame (Indiana, United States) in the Journal of Physical Chemistry C (n=1467). The article discusses three major ways to utilize nanostructures for the design of solar energy conversion devices. The second most cited paper (n=916), was published in Angewandte

Chemie-International Edition in 2012 by Mishra A and Baurle P, from the Institute of Organic Chemistry II and Advanced Materials, University of Ulm (Germany). This paper investigated the design and development of molecular materials and their performance for future solar energy devices. Finally, another paper published by Cook TR et al. with nearly 900 citations published in Chemical Reviews discusses the needs of solar energy supply and storage.

4. Concluding remarks

This work describes the recent undertaken research on the renewable energy topic. The identification and discussion of research trends, most productive and cited journals, most cited papers, funded works and international collaboration was performed. The diffusion of knowledge and information related to renewable energies might contribute to promote a higher level of cooperation within the renewable energies community of researchers and to generate a constructive atmosphere for debate. Policy deliberations to advocate future research directions would be of high interest, operating thus as a starting point to monitor future improvements in the area [30].

Proof of the importance of renewable energies topic is that the number of published and funded articles has grown in recent years: in the last five years (2012-2016), almost three quarters of research papers (71.78%) and the 80.96% of funded articles have been published. On the other hand, many institutions at global and national level are funding or conducting research on the development of renewable energy. As an example of international funding, the World Bank Group has provided $49 billion since 2010 for the energy topic. Out of this amount $21 billion were assigned to renewable energy and energy efficiency projects. The total amount financed by the group made up $6.5 billion in FY15 (http://www.worldbank.org/en/topic/energy/projects). This seems to suggest a growing impulse from the research community towards diminishing society's dependence on fossil fuel energy and a sharp rise of scientific investments on renewable energies [31,32].

Additionally, USA played a central role owning the central position in the social network analysis in terms of academic cooperation on the alternative energy topic. It was observed that the countries with higher number of published papers tended to also carry out a more intense academic collaboration with other countries [32,33]. One fact that stands out is the large number of papers published by some countries outside the "scientific elite" like China, which ranks second in the ranking of producing countries, India (6th place), Turkey (9th place) and South Korea (11th place). It is also noteworthy the high percentage of funded papers of some of these countries, such as China (80%) and South Korea (77%). Therefore, the field of renewable energy appears to be characterized by different dynamics of scientific development, which on the other hand seems to be very different from those found worldwide for other sciences. This fact can be clearly identified specially in developing countries, which are making an intense effort to minimize energy dependence on non-sustainable sources [34].

The analysis of the country's renewable energy development showed that wind energy, solar energy and ocean energy received increased attention when compared to other energy types (i.e. biomass, geothermal or hydro power). Finally, it is noteworthy that reference to solar energy is in most of the frequently cited articles include in the alternative energy category, followed by wind energy. Topics in these articles are mainly related with nanostructures, semiconductors, storage, environmental protection, sustainable development and efficiency.

International institutions play a very important role in promoting research on renewable energies. For example, The International Renewable Energy Agency (IRENA), an international organization that aims to promote adoption and sustainable use of renewable energy, has a section devoted to renewable energy projects that aims to improve project quality, market visibility, access to finance, specially to support replicable, scalable and potentially transformative renewable energy projects in developing countries (Africa, Latin America, Asia, South-East Europe and the Small Island Developing States). IRENA also spread The Global Atlas for Renewable Energy, a web platform that allows finding maps of renewable energy resources for locations across the world. The initiative is intended at closing the gap between countries that have access to the necessary data and expertise to evaluate the potential for renewable energy deployment in their countries and those that lack these elements [35]. No less important are entities such as the International Network for Sustainable Energy (INFORSE), a worldwide spread network that consists of 140 non-governmental organisations present in about 60 countries and aiming to promote sustainable energy and social development. The organization gives priority to projects that increases access to sustainable energy to the poorest population groups and also focusses on developing regional capacity building programmes for NGOs and other key players [36].

Limitations and future research

The analysis shown in this paper was performed based on articles indexed in Web of Science database, which means that only journals covered in this database have been taken into account. Nevertheless, Web of Science is one of the most used and renowned databases for the analysis of scientific literature as it includes the most important journals with scientific impact factor [37]. The study could be complemented with an extended analysis, which could include critical information on the content of the papers provided by experts on renewable energies. Future research in this line could follow evolution research paters in this area, as well as evolution of networks of collaboration between countries complemented with citations as well as impact indicators. Another line of work might investigate whether interest in current topics remains in the future or are replaced by others, according to the evolution of the renewable energy research.

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Table

Table 1. Artícles, citations and funded papers in each renewable energy

Energy	Total					
	NA	%	NC	NC/NA	NFA	% NFA
Wind Power	3,930	32%	60,137	15.30	1,889	48%
Solar energy	2,570	21%	45,988	17.89	1,479	58%
Ocean energy	1,565	13%	18,102	11.57	1,016	65%
Geothermal	385	3%	3,736	9.70	181	47%
Hydro Power	264	2%	1,499	5.68	100	38%
Biomass	210	2%	3,128	14.90	81	39%
Renewable energies	3,303	27%	52,348	15.85	1,272	39%
Totals*	12,227	100%	184,938	15.13	6,018	49%

Table 2. Most productive countries (with more than 300 papers), citations and funded papers

Country	Total				
	NA	NC	NC/NA	NFA	%NFA
United States	2,320	46,390	20.00	1,375	59%
China	1,629	20,043	12.30	1,307	80%
United Kingdom	1,007	16,873	16.76	548	54%
Germany	730	11,627	15.93	334	46%
Spain	729	12,253	16.81	447	61%
India	571	7,465	13.07	167	29%
Canada	474	8,527	17.99	214	45%
Italy	452	7,256	16.05	168	37%
Turkey	445	6,543	14.70	92	21%
Australia	425	6,996	16.46	188	44%
South Corea	403	4,156	10.31	312	77%
France	366	5,971	16.31	167	46%
Denmark	357	10,240	28.68	174	49%
Iran	350	4,360	12.46	66	19%
Japan	321	3,739	11.65	142	44%

Table 3. Papers in most productive journals, citations, rate citations per article, impact factor, category (>100 papers)

Journal	Country	Nº of papers	Nº of citations	Citations/papers	Impact factor	Web of Science Subject category	Quartile
Renewable & Sustainable Energy Reviews	United States	1095	26316	24,03	8.050	Energy & Fuels Green & Sustainable Science & Technology	Q1 Q1
Renewable Energy	England	841	15184	18,05	4.357	Energy & Fuels Green & Sustainable Science & Technology	Q1 Q1
Energy Policy	England	588	14478	24,62	4.140	Environmental Studies Energy & Fuels Environmental Sciences	Q1 Q1 Q1
Energy	England	408	8192	20,08	4.520	Energy & Fuels Thermodynamics	Q1 Q1
Applied Energy	England	304	8175	26,89	7.182	Energy & Fuels Engineering, Chemical	Q1 Q1
Energy Conversion And Management	England	234	3465	14,81	5.589	Thermodynamics Mechanics Physics, Nuclear Energy & Fuels	Q1 Q1 Q1 Q1
Energies	Switzerland	193	1043	5,40	2.262	Energy & Fuels	Q2
Ieee Transactions On Sustainable Energy		192	3266	17,01	4.909	Engineering, Electrical & Electronic Green & Sustainable Science & Technology Energy & Fuels	Q1 Q2 Q1
Ieee Transactions On Power Systems	United States	179	6358	35,52	5.680	Engineering, Electrical & Electronic	Q1
Solar Energy	United States	159	2931	18,43	4.018	Energy & Fuels	Q1
Journal Of Renewable And Sustainable Energy	United States	149	415	2,79	1.135	Energy & Fuels Green & Sustainable Science & Technology	Q3 Q4
Iet Renewable Power Generation	England	148	1604	10,84	2.635	Energy & Fuels Engineering, Electrical & Electronic Green & Sustainable Science & Technology	Q3 Q2 Q3
International Journal Of Hydrogen Energy	England	123	2315	18,82	3.582	Electrochemistry Energy & Fuels Chemistry, Physical	Q2 Q2 Q2
International Journal Of Electrical Power & Energy Systems	England	115	1228	10,68	3.289	Engineering, Electrical & Electronic	Q1
Wind Energy	England	111	1333	12,01	2.725	Engineering, Mechanical Energy & Fuels	Q1 Q2
Ieee Transactions On Energy Conversion	United States	107	4257	39,79	3.808	Energy & Fuels Engineering, Electrical & Electronic	Q2 Q1

Table 4. Most cited papers in Renewable energies (> de 300 citations)

Authors	Title	Source	Citas ISI
Kamat, PV	Meeting the clean energy demand: Nanostructure architectures for solar energy conversion	Journal Of Physical Chemistry C 2007; 111(7): 2834-2860	1467
Mishra, A; Bauerle, P	Small Molecule Organic Semiconductors on the Move: Promises for Future Solar Energy Technology	Angewandte Chemie-International Edition 2012; 51(9): 2020-2067	916
Cook, TR; Dogutan, DK; Reece, SY; Surendranath, Y; Teets, TS; Nocera, DG	Solar Energy Supply and Storage for the Legacy and Non legacy Worlds	Chemical Reviews 2010; 110(11): 6474-6502	896
Granqvist, CG	Transparent conductors as solar energy materials: A panoramic review	Solar Energy Materials And Solar Cells 2007; 91(17): 1529-1598	806
Balzani, V; Credi, A; Venturi, M	Photochemical conversion of solar energy	Chemsuschem 2008; 1(1-2): 26-58	599
Kenisarin, M; Mahkamov, K	Solar energy storage using phase change materials	Renewable & Sustainable Energy Reviews 2007; 11(9): 1913-1965	454
Connolly, D; Lund, H; Mathiesen, BV; Leahy, M	A review of computer tools for analysing the integration of renewable energy into various energy systems	Applied Energy 2010; 87(4): 1059-1082	427
Falcao, AFD	Wave energy utilization: A review of the technologies	Renewable & Sustainable Energy Reviews 2010; 14(3): 899-918	408
Baetens, R; Jelle, BP; Gustavsen, A	Properties, requirements and possibilities of smart windows for dynamic daylight and solar energy control in buildings: A state-of-the-art review	Solar Energy Materials And Solar Cells 2010; 94(2): 87-105	367
Lund, H; Mathiesen, BV	Energy system analysis of 100% renewable energy systems-The case of Denmark in years 2030 and 2050	Energy 2009; 34(5): 524-531	354
Panwar, NL; Kaushik, SC; Kothari, S	Role of renewable energy sources in environmental protection: A review	Renewable & Sustainable Energy Reviews 2011; 15(3): 1513-1524	350
Lund, H	Renewable energy strategies for sustainable development	Energy 2007; 32(6): 912-919	347

Authors	Title	Source	Citas ISI
Lund, H; Kempton, W	Integration of renewable energy into the transport and electricity sectors through V2G	Energy Policy 2008; 36(9): 3578-3587	332
Pospischil, A; Furchi, MM; Mueller, T	Solar-energy conversion and light emission in an atomic monolayer p-n diode	Nature Nanotechnology 2014; 9(4): 257-261	329
Chen, XB; Li, C; Gratzel, M; Kostecki, R; Mao, SS	Nanomaterials for renewable energy production and storage	Chemical Society Reviews 2012; 41(23): 7909-7937	329
Hetzer, J; Yu, DC; Bhattarai, K	An economic dispatch model incorporating wind power	Ieee Transactions On Energy Conversion 2008; 23(2): 603-611	315
Zhu, XG; Long, SP; Ort, DR	What is the maximum efficiency with which photosynthesis can convert solar energy into biomass?	Current Opinion In Biotechnology 2008; 19(2): 153-159	313
Jacobson, MZ; Delucchi, MA	Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials	Energy Policy 2011; 39(3): 1154-1169	312
Morfa, AJ; Rowlen, KL; Reilly, TH; Romero, MJ; van de Lagemaat, J	Plasmon-enhanced solar energy conversion in organic bulk heterojunction photovoltaics	Applied Physics Letters 2008; 92(1): 0-0	311
Feng, J; Qian, XF; Huang, CW; Li, J	Strain-engineered artificial atom as a broad-spectrum solar energy funnel	Nature Photonics 2012; 6(12): 865-871	309
Abbey, C; Joos, G	Supercapacitor energy storage for wind energy applications	Ieee Transactions On Industry Applications 2007; 43(3): 769-776	304
Peng, KQ; Lee, ST	Silicon Nanowires for Photovoltaic Solar Energy Conversion	Advanced Materials 2011; 23(2): 198-215	303

Figure

Figure 1. Number of published papers and citations per year

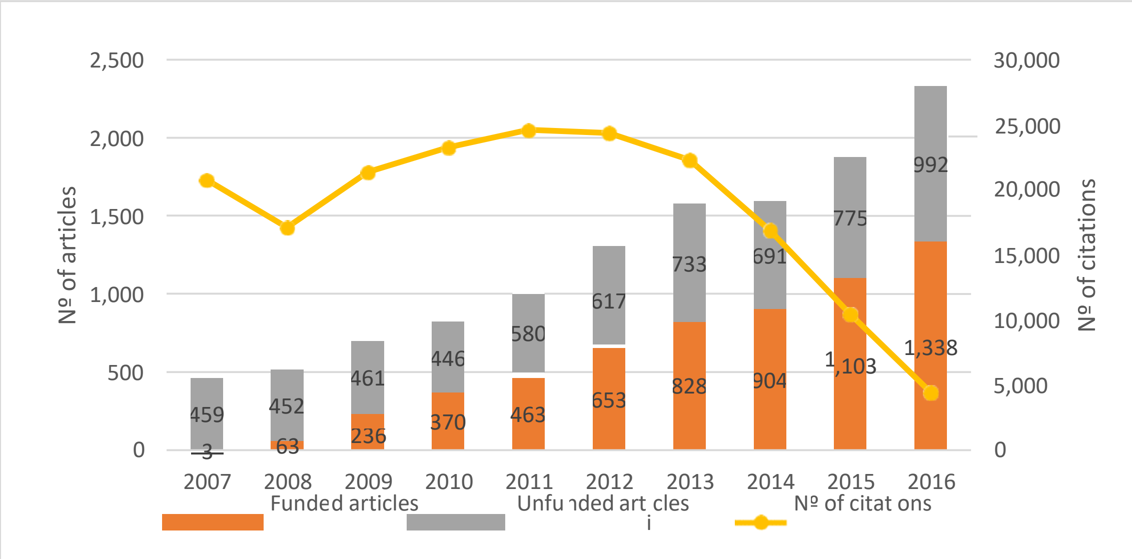

Figure 2 Energy production (GWh) on Renewable energies, published articles (NA) and funded papers (NFA)

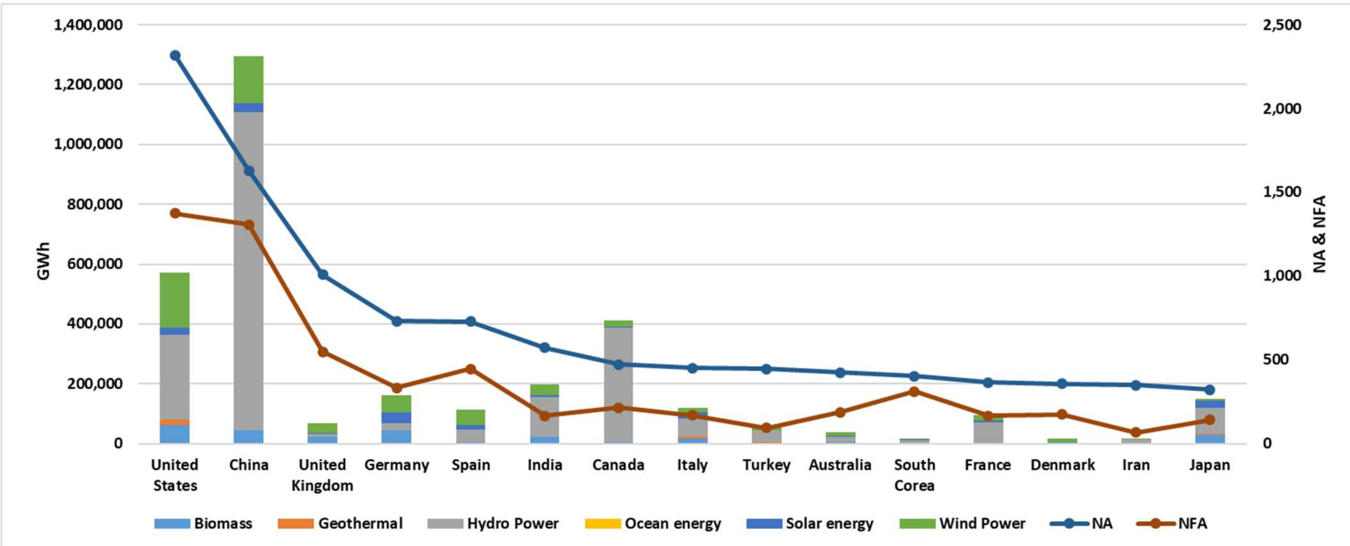

Figure 3 Energy production (GWh) on Renewable energies, including biomass, geothermal, hydro power, ocean and solar energy and wind power in combination with published articles (NA) and funded papers (NFA).

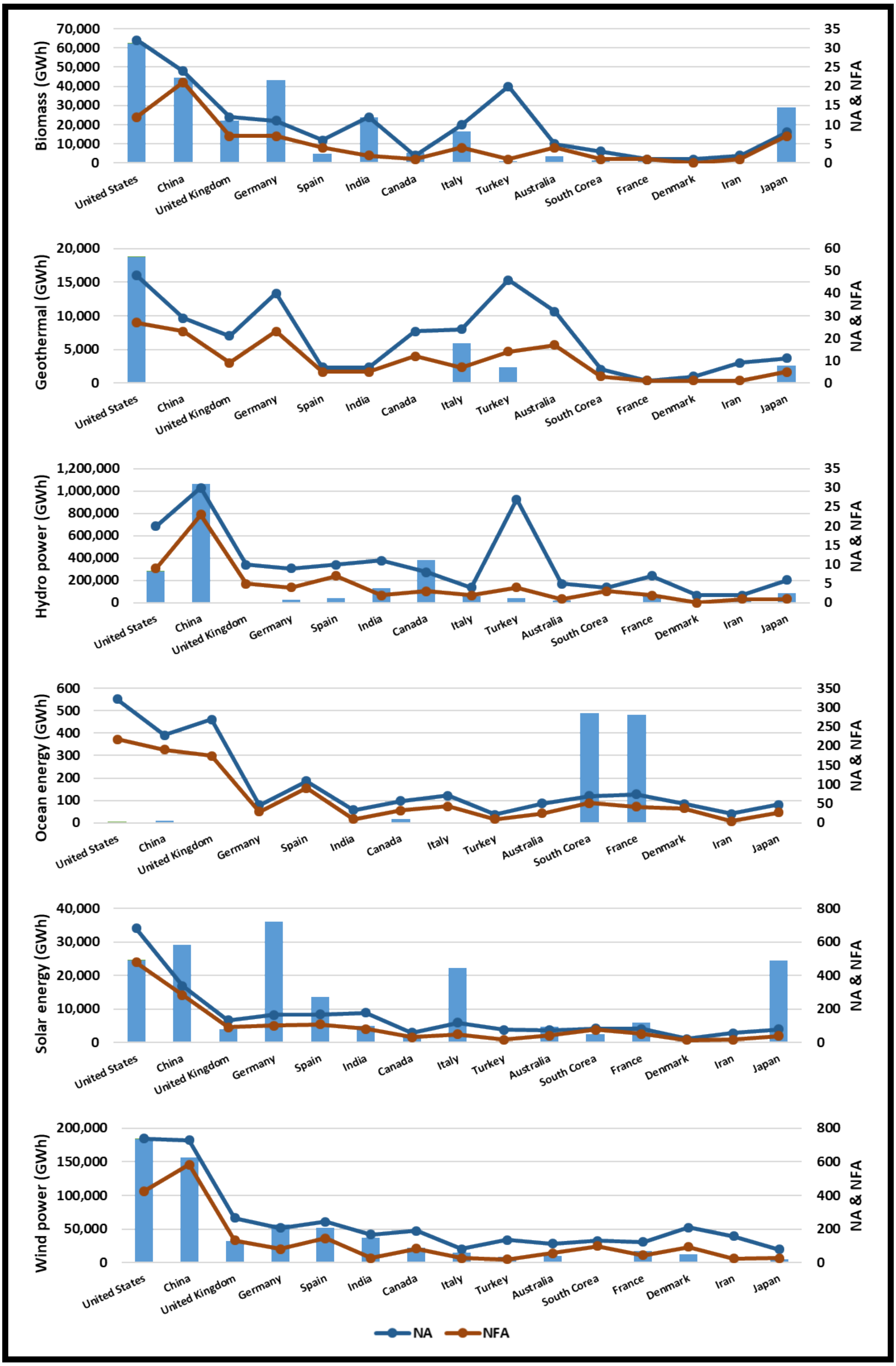

Figure 4 Number of citations per article and percentage of funded publications in the world leading renewable energy production countries.

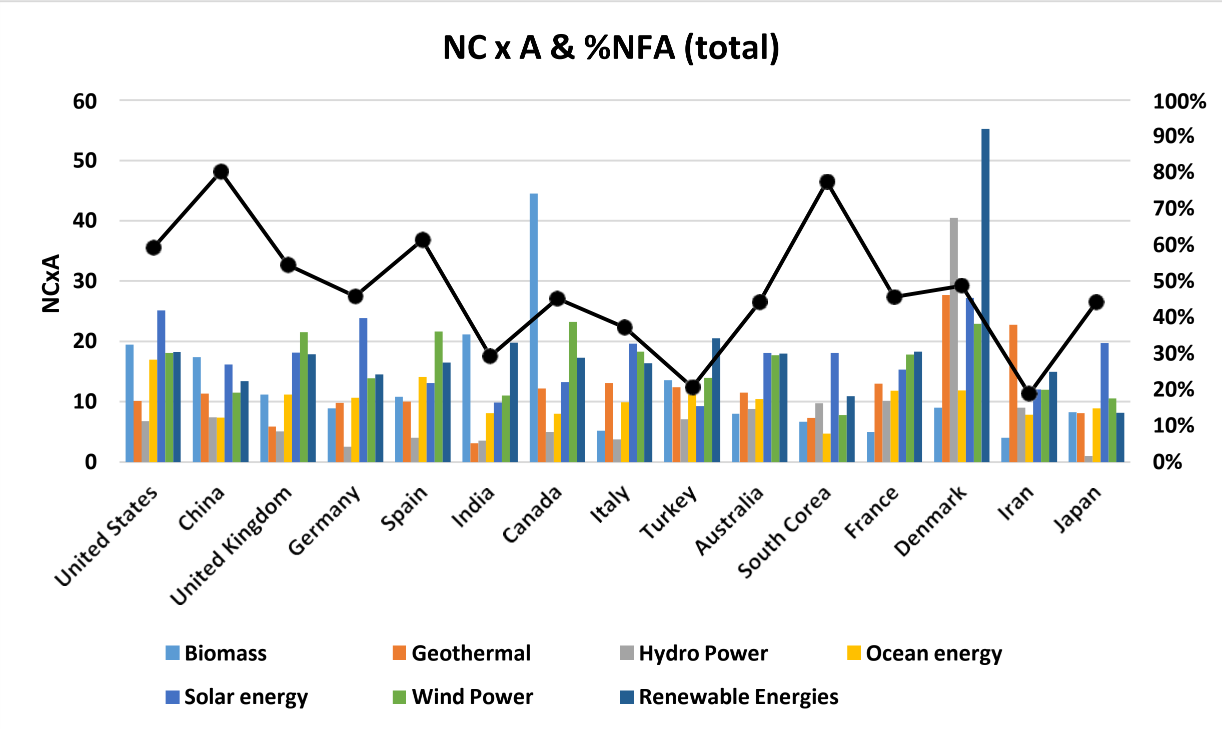

Figure 5 Number of funded and non-funded articles and number of citations per articles in the world leading countries in renewable energies research topics.

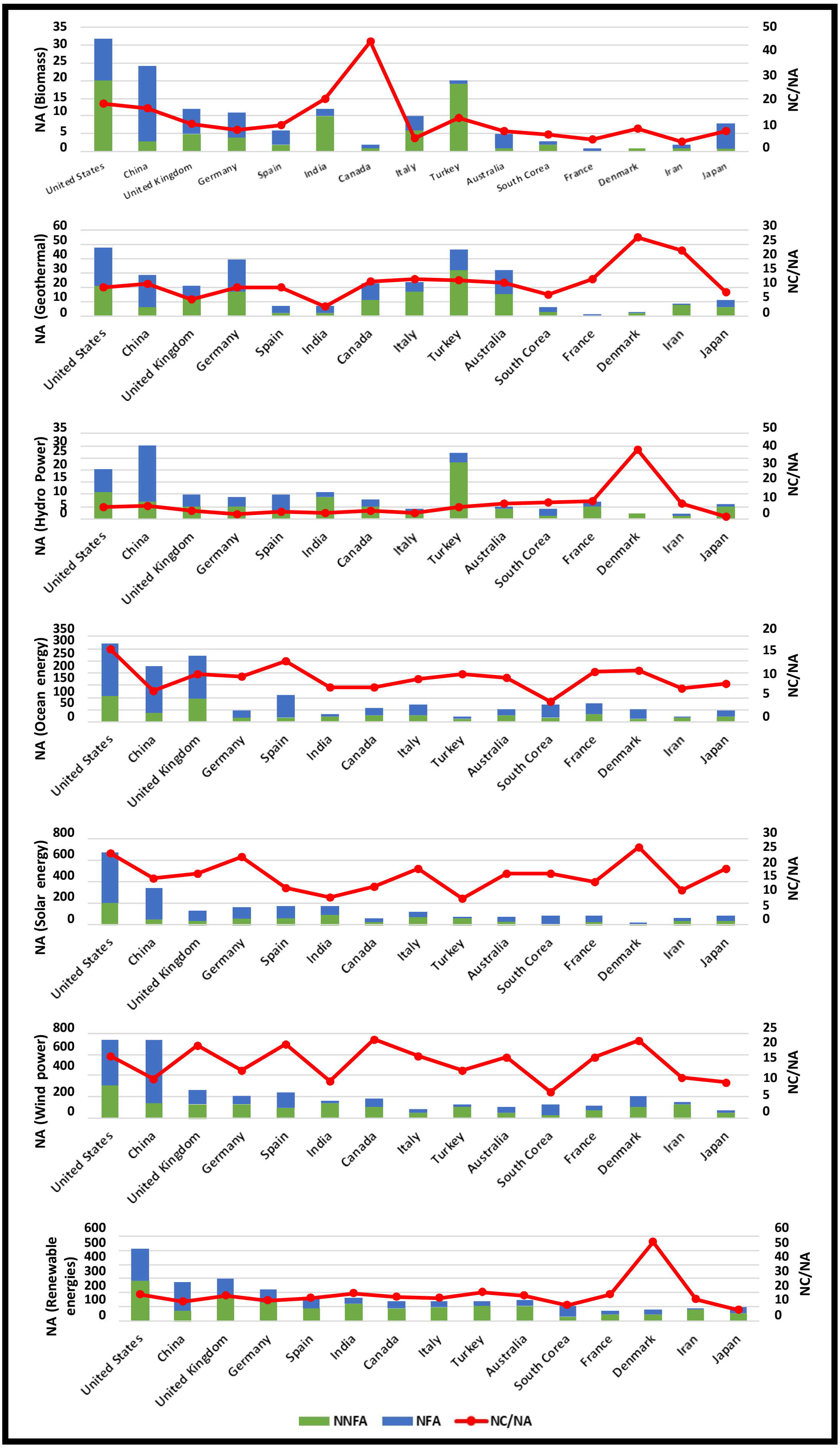

Figure 6. World map of collaboration among countries