Bulgarian Chemical Communications, Volume 48, Special Issue E (pp. 248 - 253) 2016

'Clean energy' vs. 'Green energy': Quantifying the online interest in USA & Australia

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This study examines the different modes that users of the World Wide Web employ to search for Renewable Energy. Up to this point, both terms –'Clean Energy' and 'Green Energy'- have been used. Our aim is to compare the terms' Google searches from January 2007 to December 2015 using data from Google Trends, a popular and powerful open tool for providing data on online search traffic. We calculate the ratios between the 'Clean Energy' and 'Green Energy' hits' normalized search volumes in the US and Australia, and analyze the quantified percentized hits. The results show that the 'Clean Energy' search volumes are higher in Australia, while, in the case of the US, 'Green Energy' is searched for more, consistent with the Worldwide trend. As is evident, the term 'Green Energy' is significantly more popular than 'Clean Energy' in online searches, contrary to the scientific community that uses the term 'Clean Energy' more often, judging by the number of documents in the Scopus database containing these terms in the titles. Results are further analyzed and compared with how these countries perform in terms of Renewable Energy consumption, in order to contribute to the discussion of choosing the term that best represents Renewable Energy.

Keywords: big data, clean energy, green energy, google trends, renewable energy

INTRODUCTION

According to the Australian Renewable Energy Agency (ARENA), Renewable Energy is defined as *"energy which can be obtained from natural resources that can be constantly replenished",* implementing technologies that use *"one or more renewable energy sources",* such as bioenergy, geothermal energy, hydropower, ocean energy, solar energy and wind energy [1].

USA's Environmental Protection Agency (EPA) defines Clean Energy as including *"renewable energy, energy efficiency and efficient combined heat and power"* [2]. Though Green Energy as a concept is not defined by EPA, the term 'Green Power' is defined as a subset of Clean Energy [3]. Based on the above, it is safe to assume that defining these terms is quite ambiguous, especially for those that have no special experience in the subject.

But how and in what volumes do researchers use these two terms? A search in the Scopus database shows that the number of documents containing the term 'Clean Energy' in the title is significantly higher than the ones containing 'Green Energy'. Table 1 consists of the two terms' total number of documents and their combinations in "Article Title" and "Article Title -Abstract- Keywords" as search fields until March 2016, and Table 2 consists of the number of documents for each year from 2007 to 2015 for the same combinations. It is evident that the academic community uses the term 'Clean Energy' more often.

Table 1. Scopus Total Number of Documents in Clean and Green Energy until March 2016

Search Term	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	Field
Clean Energy	904	893	815	721	641	529	425	367	317	271	T
Green Energy	630	624	555	461	382	302	247	195	156	123	T
Clean Energy + Green Energy	85	83	69	59	47	39	31	27	19	15	TAK
Clean Energy + Green Energy	0	0	0	0	0	0	0	0	0	0	T
Green + Clean + Energy	30	27	24	19	13	12	9	7	3	3	T
Green +Clean + Energy	1785	1754	1568	1364	1206	1011	858	701	547	423	TAK

T: Title, TAK: Title Abstract Keywords

Table 2. Scopus Number of Documents in Clean and Green Energy from 2007 to 2015

Search Term	2015	2014	2013	2012	2011	2010	2009	2008	2007	Field
Clean Energy	79	95	80	112	104	58	50	46	43	T
Green Energy	72	93	79	80	55	52	39	33	36	T
Clean Energy + Green Energy	15	10	12	8	8	4	8	4	1	TAK
Clean Energy + Green Energy	0	0	0	0	0	0	0	0	0	T
Green + Clean + Energy	3	5	6	1	3	2	4	0	1	T
Green +Clean + Energy	195	207	158	195	153	157	154	124	97	TAK

T: Title, TAK: Title Abstract Keywords

As definitions seem to differ, is the respective term attributed to the more suitable meaning? Why do people use the term 'Green Energy' when referring to 'Renewable Energy'? Is 'Clean Energy' the correct term? Keramitsoglou et al. [4] argue that the term 'Clean' is better than 'Green' when describing Renewable Energy Sources (RES).

As the interest in Renewable Energy is growing, what kind of information does the public has easy

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access to when searching for these terms in Google? The first result for both 'Clean Energy' and 'Green Energy' is Wikipedia's page for Renewable Energy [5]. For 'Green Energy', the second result is the section "Green Energy and Green Power" in Wikipedia's "Sustainable Energy" page [6]. In the respective Wiki pages, 'Clean Energy' is defined as *"electricity or nuclear power, that does not pollute the atmosphere when used, as opposed to coal and oil, that do"* [5], while 'Green Energy' is defined as the energy *"that can be produced in a way that protects the natural environment, for example by using wind, water, or the sun"* [6]. Do these definitions bring even more confusion over which one is used for which term?

To address these questions, and in order to examine how the public views these two terms, large amount of information is needed. Handling such volumes of data requires new innovative tools. But in what way is it possible to obtain and analyze these vast amounts of data on online behaviour? A possible answer is Big Data; characterized by the three V's: 'Volume', 'Variety', Velocity', i.e. exponentially-increasing volumes [7], wide range of datasets, and high processing speed, respectively [8]. A trending Big Data tool is Google Trends [9], becoming all the more popular in academic research in several fields, such as medicine [10-11], economics and finance [12-14], politics [15-16], behaviour [17-19], and the environment [20-21].

We aim at quantifying and analyzing the public's online interest in the US and Australia in Clean and Green Energy, using data from Google Trends. Following this introduction, the rest of the paper is structured as follows: the next section covers the data collection and methodology, followed by the results and discussion of our analysis, and, finally, the overall conclusions are presented.

DATA AND METHOD

We analyze the normalized in the 'Clean Energy' and 'Green Energy' hits data provided by Google Trends in the US and Australia from 2007 to 2015; search volumes before 2007 are not large enough to be evaluated.

In our initial search, we observed that Australia was the only major English-speaking country where Google hits were more in 'Clean Energy' than 'Green Energy'. We chose USA to perform a comparative analysis, as they perform similarly in economic, social, and environmental issues.

Google Trends' data are downloaded online in '.csv' format and are normalized over the selected period: *"each data point is divided by the total searches of the geography and time range it represents, to compare relative popularity. The resulting numbers are then scaled to a range of 0 to 100"* [22].

For our search, Google Trends provide weekly data for the two terms, normalized over the selected period. We denote C_{t_i} and G_{t_i} as the weekly hits of the downloaded Google Trends' data for the search terms 'Clean Energy' and 'Green Energy' of the *i*-th week, respectively. For each week of our data, we percentize the hits in the two terms, and define $C_{t_{pi}}$ and $G_{t_{pi}}$ as the percentized weekly values of the normalized 'Clean Energy' and 'Green Energy' searches of the *i*-th week, respectively, with $C_{t_{pi}}+G_{t_{pi}}=1$ for each week. The percentized values are calculated using Equations (1) and (2).

$$C_{t_{pi}} = \frac{C_{t_i}}{C_{t_i}+G_{t_i}} \quad (1)$$

$$G_{t_{pi}} = \frac{G_{t_i}}{C_{t_i}+G_{t_i}} \quad (2)$$

For each year, we calculate the average of the weekly percentized hits for USA and Australia. Furthermore, we compare how the two countries perform in terms of production and use of Renewable Energy, in order to determine which term is used the most in the country performing better in Renewable Energy consumption. In addition, we examine if a relation exists between the number of documents in Scopus containing the terms 'Clean Energy' and 'Green Energy' in their titles and their affiliations, and the searches in Google for 'Clean Energy' and 'Green Energy' from 2007 to 2015.

RESULTS AND DISCUSSION

The first step is to examine how the Worldwide trend is changing in the use of the terms 'Clean Energy' and 'Green Energy'. Over the period 2007-2015, we see that the searches for the term 'Green Energy' are constantly and with significant difference above the ones for the term 'Clean Energy' (Fig.1). The weekly ratios of the 'Clean Energy' over the 'Green Energy' searches are always below the value '1', showing that search volumes for 'Clean Energy' are at no point above the ones for 'Green Energy' over the examined period. What is observed is that there are two peaks in 2009 and 2011 with a ratio over 0.8, meaning

that at those specific times, the use of the term 'Clean Energy' showed a sudden, but short-in-time, boost (Fig.2).

Overall, we observe that the internet users worldwide search for the term 'Green Energy' in significant higher volumes than the term 'Clean Energy', which is in contrast to the scientific community, as shown in Table 1, i.e. the published papers containing the term 'Clean Energy' in their title over the last 30 years are about 40% more than the ones containing 'Green Energy'. Furthermore, we observe a periodic decrease in searches for both terms during Christmas vacations, which is an expected finding.

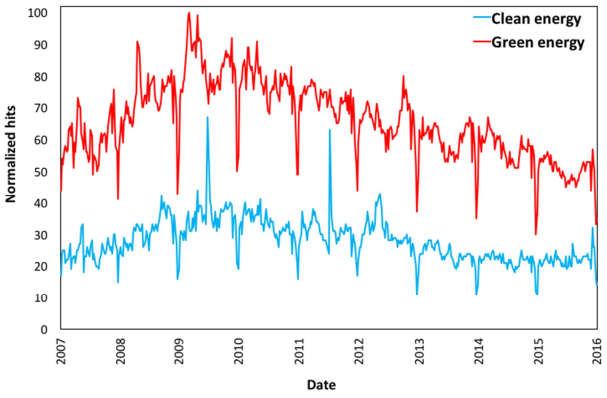

Fig.1. Worldwide Hits in Clean & Green Energy

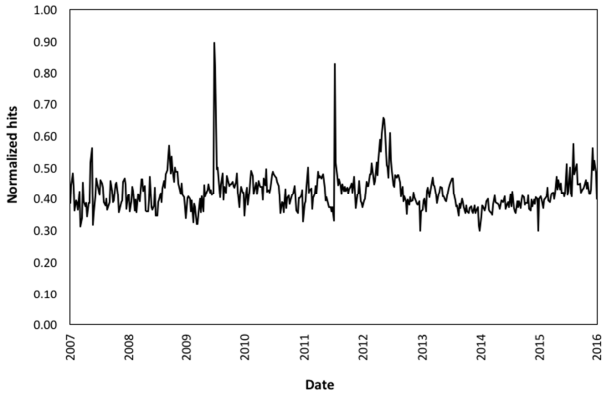

Fig.2. 'Clean Energy' per 'Green Energy' hits Worldwide

We proceed to analyze the online interest in Clean Energy and Green Energy in the US and Australia; Figures 3 and 4, respectively. In Google Trends, we select the period from January 2007 to December 2015 and search for the weekly hits in the terms 'Clean Energy' and 'Green Energy'.

For the US (Fig.3), the term that is mostly used is 'Green Energy'. In Australia, though up to 2010 the term 'Green Energy' was used more than 'Clean Energy', there is a shift in volumes (Fig.4), that reverses the percentages of the hits of 2009 and 2012. Up to this point, i.e. March 2016, the term 'Clean Energy' is searched for more in Google than 'Green Energy' in Australia.

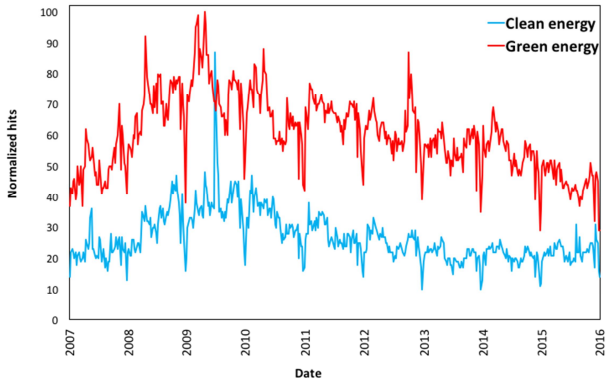

Fig.3. Hits in "Clean Energy" & "Green Energy" in USA

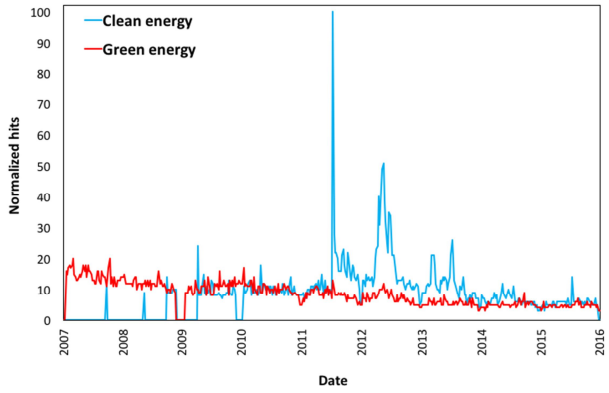

Fig.4. Hits in "Clean Energy" & "Green Energy" in Australia

Fig.5 and Fig.6 consist of the ratios of the 'Clean Energy' over 'Green Energy' hits in the US and Australia, respectively.

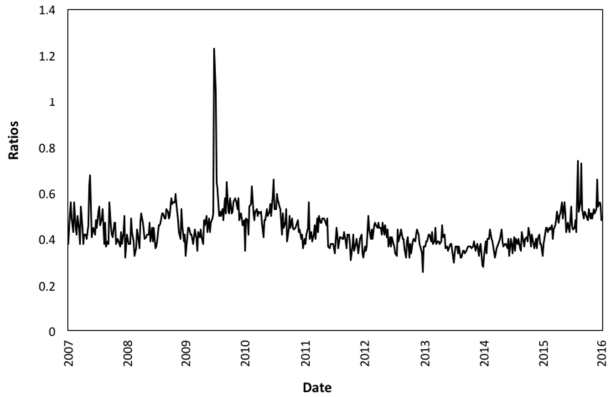

Fig.5. 'Clean Energy' per 'Green Energy' hits in USA

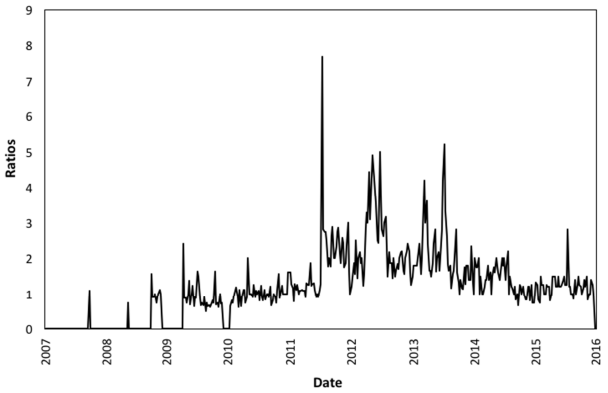

Fig.6. 'Clean Energy' per 'Green Energy' hits in Australia

In the case of the US, there is only one peak in 2009 with values above '1', for a two-week period (June 21th to July 4th), showing that the hits in 'Clean Energy' are over the ones in 'Green Energy'. Apart from this, all other weeks from 2007 to 2015 show that 'Green Energy' is searched for significantly more than 'Clean Energy'.

The analysis of the peaks is significant, as they could be attributed to important national or international incidents. We observe that the peak in the hits in the term 'Clean Energy' in the US in 2009 (Fig.5) influences the worldwide recording in the terms' hits. Google Trends can be useful in examining the reasons of this boost.

We see in the 'Region' field in Google Trends that the most searches occur in 3 countries, i.e. Australia (with a 100 score), USA (with a 74 score) and Canada (with a score of 50). There is a boost in the term's hits with the top searches in the 'Related Searches' field including *'clean energy act'* (100 score), *'American clean energy'* (90 score), *'clean energy power'* (50 score), *'green energy'* (45 score), *'clean energy council*' (35 score), and *'clean energy fund'* (35 score), suggesting that the aforementioned boost is attributed to the 'American Clean Energy and Security Act' of 2009.

In Australia, all ratios after 2010 are above '1', showing that the hits in 'Clean Energy' are more than the hits in 'Green Energy' at all times from 2010 to 2015.

Similarly, there is a peak in Australia in 2011 in 'Clean Energy'. An in-depth worldwide search for this year shows that the countries with the most hits on the term, in the 'Region' field in Google Trends, are Australia (100 score), and, with lower contribution, USA (26 score) and Canada (24 score). The top searches in the 'Related Searches' field include: *'clean energy council'* (100 score), that could be attributed to the 'Clean Energy Council' in Australia, *'clean energy solar'* (85 score), *'clean renewable energy*' (60 score), *'clean energy future'* (55 score), *'clean green energy*' (55 score), *'green energy'* (55 score), and *'clean energy act'* (40).

Table 3 consists of the yearly averages of the weekly percentized hits in 'Clean Energy' and 'Green Energy' in the US, Australia and Worldwide from 2007 to 2015.

Table 3. Yearly Averages of the Percentized Hits: 'Clean Energy' & 'Green Energy' Hits

	Worldwide		USA		Australia	
Year	Clean(%)	Green(%)	Clean(%)	Green(%)	Clean(%)	Green(%)
2007	28.90	71.10	30.96	69.04	1.00	95.15
2008	29.68	70.32	30.97	69.03	10.41	79.97
2009	29.96	70.04	33.28	66.72	30.23	65.93
2010	29.67	70.33	32.87	67.13	48.69	51.31
2011	30.11	69.89	28.98	71.02	61.17	38.83
2012	31.19	68.81	28.53	71.47	68.38	31.62
2013	28.29	71.71	26.96	73.04	65.47	34.53
2014	27.56	72.44	27.68	72.32	56.18	43.82
2015	30.44	69.56	33.12	66.88	52.37	47.63

We observe that USA closely follows the percentages of the Worldwide trend, with the hits in 'Green Energy' being above the ones in 'Clean Energy' with a percentage around 70% for all examined years. Australia, though starting with a percentage of 1% in 2007 for the 'Clean Energy' hits, interest in this term rises continuously till the peak in 2012, with almost reversed percentages of the hits in 'Clean Energy' over the ones in 'Green Energy'. Hits in 'Clean Energy' start declining afterwards, with a percentage of 52.37% in 2015. From 2010 to 2015, the average online interest in Australia in 'Clean Energy' is 58.71%, while in 'Green Energy' it is 41.29%.

Fig.7 consists of the chart pies of the Google Trends' hits in 'Clean Energy' and 'Green Energy' compared to the Scopus' publications with the two terms in their titles from 2207 to 2015. While in the scientific community the term 'Clean Energy' is used in larger volumes (55%) compared to 'Clean Energy' (45%), the public prefers the term 'Green Energy' (70%) over 'Clean Energy' (30%), with statistically significant difference (Z=3.576, p<0.001).

Fig.7. Google Trends' hits vs. Scopus Publications terms for 'Green Energy' and 'Clean Energy'

A possible reason for the difference between Google Trends (public) and Scopus (scientific community) is the way that RES are communicated to the general public by the media, politicians, and other organizations, private or public. Since 'green' is mostly a 'folksy' word for the clean environment and all drivers related to it (e.g. green funds, green economy, green development etc), it is generally more 'trendy'. On the other hand, scientists and engineers are more orthological on average, thus refer to energy with more real or clear adjectives. In sense, energy is not 'green'; actually it is colorless, thus the term 'clean' is more rational than the term 'green', as the former is related to the production technology rather than a color of nature.

But how do researchers from Australian and USA report energy in their publications? To address this question, we ran two *scopus* searches with the terms 'Clean energy' and 'Green energy' in the title of the published hits. We included an additional term for the affiliation of the authors to be from Australia or USA. The comparison is shown in Fig.8. Though the portion of papers published in Australia with the term 'Clean energy' in their title is considerably higher, this is not statistically significant compared to those published in USA (X^2=2.3943, p=0.1218).

What is observed is that Australia's public's interest in the two terms agrees with what the scientific community suggests, i.e. 'Clean Energy' is used in larger volumes than 'Green Energy'. This could be attributed to the overall wording that is used in the country, that could be influenced by several factors, such as important political statements or events.

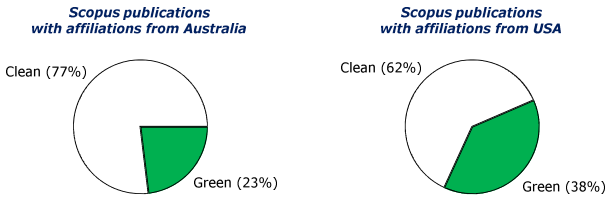

Fig.8. USA and Australia affiliations in Scopus Publications containing the terms 'Green Energy' and 'Clean Energy' in the title

Fig.9 shows the yearly percentages in Renewable Energy Consumption (% of total final energy consumption) in the US and Australia from 1990 to 2013 (data obtained from the World Bank [23]). Apart from the years between 2008 to 2011, Australia's percentages in Renewable Energy consumption are higher than USA's from 1990 to 2013. A *Z*-test calculated per year (Fig.9) shows that Australia was better performing up to 2002. From that point on, including our selected study period i.e. from 2007 on, we cannot claim statistically significant better performance of one over the other country.

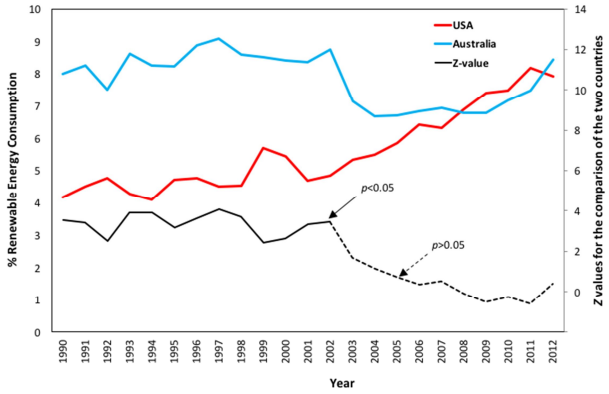

Fig.9. Yearly Percentages of Renewable Energy Consumption from 1990 to 2013 in USA and Australia

Based on the above, it is evident that both countries are actively concerned about environmental issues and promote the production and use of Renewable Energy. In the US, apart from the Environmental Protection Agency that is responsible for all environmental issues and legislation, there are the 'National Renewable Energy Laboratory' [24] and the 'Department of Energy' [25]. The most important Renewable Energy policy is the "US Climate Action Plan" (2013) [26]. In Australia, though the Department of the Environment by the Australian Government is the main agency responsible for environmental issues, there is also the 'Australian Renewable Energy Agency' [27]. The key Renewable Energy policies in force are the 'Australian Renewable Energy Agency' (2012) and the 'Renewable Energy Target' (2010) [26]. A key policy that has ended is the 'Clean Energy Future Plan' (2012) [26].

CONCLUSIONS

This study aimed at examining the online interest in the terms 'Clean Energy' and 'Green Energy' for the US and Australia from 2007-2015. Using data from Google Trends, we quantify the normalized search volumes over the selected period and explore each country's selection in terminology for Renewable Energy. We find that, though USA follows the worldwide trend, i.e. uses the term 'Green Energy' in higher volumes, Australia shows

an increasing use of the term 'Clean Energy' from 2007 to 2010, and the percentages in 'Clean Energy' searches are dominant over the 'Green Energy' ones from 2010-2015, with significant difference.

Comparing the performances of the two countries in terms of Renewable Energy, as long as the implementation of policies and projects are concerned, it is evident that both countries are actively concerned for and promote Renewable Energy. This could be attributed to the fact that USA and Australia have been integrating all the more Renewable Energy issues in their way of governance. In addition, we observed that the scientific community uses the term 'Clean Energy' significantly more than 'Green Energy' in terms of containing these terms in the title of the published papers.

Google Trends as a tool has been shown to be useful and effective in assisting us to elaborate on the different use of the terms 'Clean Energy' and 'Green Energy'. This, compared to the use of these terms in published papers, shows a different approach from academics compared to the public, thus contributing to the discussion of redefining Renewable Energy, as 'Clean Energy' could be a more suitable term for describing it.

This paper provides ground for further research on redefining Renewable Energy, as the same methodology could be applied to other countries of interest. Further research could be especially applied to developing countries, so as to examine the relation between the public's change in online interest in Renewable Energy with other economic and social factors, like per capita income, industry levels, human development, social progress, and environmental performance.

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