Low Carbon Emission Studies:
A Bibliometric Approach

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Abstract:- While nature avails us with resources, we must use them without degrading nature per se. One of the perils that persistently plague the twenty-first century Man is global warming and climate change instigated as a result of the emission of greenhouse gases (GHGs) including methane, nitrous oxide, ozone, chloro-fluoro-carbons and carbon dioxide; the last which is the major contributor to global warming emanates from many industrial and agricultural activities. Cleaner energy is pivotal to our continuous existence; hence world agencies and scientists are respectively promulgating and proposing methods and technologies wheeled towards the attainment of a low carbon universe. This paper quantitatively analyzes the volume of research outputs in this field using bibliometric methods. This analysis offers a comprehension of how low carbon emission as an environmental advance is progressively delved into globally, particularly amongst leading journals from Scimago. A bibliometric investigation was carried out on 47 documents published from 2011-2018 recovered from SCOPUS database with specific terms affiliated to Low Carbon Emission Studies. Results from analysis identified: the leading contributing authors and researchers; global distribution of research output; productive research institutions; leading publication outlets; funding sponsors; national contributions; and leading keywords affiliated to low carbon emission studies, with respect to the first three leading journals of 2017 extracted from Scimago. The publication trend shows exigency for a great deal of exploration with respect to low carbon emission in the leading journals used for the purpose of this study.

Keywords:- Carbon; Carbon Capture; Climate Change; CO2 Reduction; Bibliometrics.

I. INTRODUCTION

Since the inception of Industrial Revolution, the world has been experiencing a surge in the warming of the earth, termed global warming and appreciably synonymous with climate change, culminating from greenhouse effect- a phenomenon wherein greenhouse gases (GHGs) reabsorb a considerable amount of the exiting radiation and radiate virtually half of it to the earth surface again[5][9]. Amongst all greenhouse gases, atmospheric carbon dioxide is believed to be the major contributor to global warming, comprising three-fourths of the total GHGs[1]. Even though the natural sources pose no danger, anthropogenic sources of CO2 are a major threat to humanity, debilitating the ecosystem. These sources include but are not limited to combustion effluents, power generation, frequent transportation, cement and textile productions, refrigeration, and most industrial and agricultural activities. Carbon dioxide available in the atmosphere, emitted from biodegradation of biomass, is absorbed for the purpose of photosynthesis by forest dendrites, and more, especially during winter when they carry out more photosynthesis[4]. In fact, the largest anthropogenic source of CO2 discharged to the atmosphere is generated in power plants fueled with fossil fuels, and in 2007, it was recorded that Taiwan power plant emits the greatest amount of CO2 into the atmosphere annually, averaging over 30,000,000 tonnes[14].

According to NASA Goddard Institute of Space Science, the warmest year on record was 2016, while 2017 come next in the spectrum, and it is probable that 2018 will emerge as the warmest ever by the end of the year[10][11]. As a matter of fact, it is also estimated that the average temperature of the earth will increase by $1.5^{\circ}C$ between 2030 and 2052.

Highly populated countries like China and India are amongst the highest emitters of per capita CO2 annually owing to industrialization, and the quantity is increasing globally by about 2 ppm volume per annum[18]. Pathetically, intense weather conditions linked to climate change in the past two decades have exterminated more than 500,000 people and wreaked economic deficit estimated in millions of millions of dollars.

In recent years, efforts have been made to minimize the amount of carbon released in our quotidian existence. This incessant pursuit has led to the proposition of technologies and implementation of methods such as reforestation, carbon capture, storage and utilization by shifting from utilization and exhaustion of non-renewable energy sources- fossil fuels- to the usage of renewable energy sources such as solar, wind, biofuel, tides, waves and geothermal heat[7][13]. In fact, low carbon economy can be attained biologically, chemically and technologically either by reducing or sequestering emissions[7][8].

Since decarbonization has become the cynosure of socioeconomic development, many countries as well as top agencies such as European Union EU and United Nations UN have promulgated laws that will help the citizenry curb emissions[2]. In fact, Climate Action is amongst the Sustainable Development Goals SDGs set to be achieved by 2030[15]. As a result, industries would have to resort to selecting eco-friendly raw materials, utilizing cleaner energy, applying new energy-oriented technologies, using green packaging and instigating energy management programs. The progress of these industries will also be measured by the execution of the SDGs.

An umpteenth number of works has been done in the context of literature documenting vivid scenarios and innovations leveraged towards the attainment of a low carbon economy.

This paper quantitatively analyzes the volume of research outputs in this field using bibliometric methods. This analysis offers a comprehension of how low carbon emission as an environmental advance is progressively delved into globally, particularly amongst leading journals.

The remaining part of this paper is structured in sections. The section that follows contains the reviews of related works and bibliometric studies targeted at low carbon emission. In section III, the objectives of the study are delineated. In section IV contains the methodology used in this study is given. The results and discussion are highlighted in section V, and section VI underscores the drawback of this study and the conclusion.

II. RELATED WORKS

Wu et al. (2018) presented a bibliometric review on urban environmental governance, with the primary aim of tackling climate change[17]. Employing a total of 1697 publications from 1997 to the next two decades retrieved from Web of Science, this study offered significant policy insights into alleviating the overall greenhouse gas emission. Oliveira Neto, Pinto, Amorim, Giannetti and Almeida (2018) analyzed published articles from Special Volumes of the Journal of Cleaner Production (SVJCP) derived from the International Workshop Advances in Cleaner Production

(IWACP), and consultations with experts. It was observed that one of every twenty of such publications were akin to Strong Sustainability. It also ideated actions that are specifically directed towards effective sustainability[12]. Viebahn and Chappin (2018) vetted the authenticity and sufficiency of trending research in proffering solutions aimed at achieving minimization in the discharge of greenhouse gas, particularly using carbon capture and storage. The analysis showed major dominance of technical research compared to approximately 30% addressing non-technical issues[16]. In the same study, the development of more and efficient carbon capture and storage strategies was recommended[16]. Li et al. (2017) performed a bibliometric study on a decade-long atmospheric pollution sources from 2006 using Web of Science as the database. The study also provided an in-depth comprehension of futuristic investigation with respect to atmospheric pollution sources[6]. However, at present, this study is the first to conduct a bibliometric analysis on low carbon emission studies with respect to the three leading journals of Scimago Journal Ranking (SJR) for a particular year.

III. STUDY OBJECTIVES

In order to fulfill the purpose for which this paper exists, the following objectives were not unmet: to ascertain the leading contributing authors and researchers in low carbon emission studies; to scrutinize the annual worldwide distribution of research efficiency in low carbon emission studies; to distinguish the most active research-oriented institutions on low carbon emission studies; to distinguish the publication outlets that extensively published low carbon emission studies; to identify the funding institutions involved in low carbon emission studies; to specify the national contributions of countries to low carbon emission studies; and to enumerate the leading keywords used in low carbon emission studies, with respect to the first three leading journals retrieved from Scimago.

IV. METHODS

Scimago Journal Rankings was used to pinpoint the top three journals for 2017, specifying the subject area and subject area category as environmental science and environmental chemistry respectively, within all regions/countries. The journals: Energy and Environmental Science, Chem and Global Change Biology with respective h-indexes of 240, 18 and 204 and journal impacts of 14.590, 5.295 and 4.731 spearheaded all others. Bibliometric data of the documents affiliated to these journals exploited in this study were retrieved from SCOPUS, a leading indexed academic database[3], using meticulously selected search query. Search strings comprising "low carbon emission", "carbon capture", and "CO2 reduction" were used to acquire germane documents and the publication years was restricted to 2011-2018 while the data procured was used to respond to the objectives established in this study.

A total of 47 research papers were retrieved from the search made and documents were used for bibliometric analysis and as such details such as source title, authors name, affiliation, and country year were examined.

Only documents in line with the domain of study, that is, low carbon emission studies, were included in the corpus. To achieve this, the title, abstract and keywords of each document was reviewed for words such as carbon, carbon sequestration and climate change. However, all 47 documents still formed the corpus used for this study. All documents were written in English. The corpus was exported as a Comma Separated Version (CSV) file format for ease of analysis on MS-Excel. The part of the data that were considered in the study included Year, Author Name, Subject Area, Document Type, Funding Sponsor, Keywords, Affiliation, Countries and Language.

The analysis encapsulates the research outputs per annum, academic publishers, top funding sponsors and the citation count as well as leading institutions and authors. It also includes both subject area and keywords affiliated to the trends of research in Low Carbon Emission Studies.

V. RESULTS AND DISCUSSIONS

The aim of the study is to quantify and analyze the volume of research outputs in the domain of low carbon emission studies. The subsections that follow respond to the research question posed in this study.

A. Most Productive Authors

The first research question identifies the leading contribution authors to low carbon emission studies worldwide. The analysis proved that there are a total of 160 authors for all 47 publications harnessed in this study. Table I shows the five leading most productive authors, with at least three articles, affiliation and country. Mac Dowell, Niall of Imperial College London in United Kingdom emerged as the top author with five articles, whereas Anthony, Edward J., Fennell, Paul S., Scott, Stuart A. and Smit, Berend had three publications each.

Author	Number of Articles	Affiliation	Country
Mac Dowell, N.	5	Imperial College London	United Kingdom
Anthony, E.J.	3	Cranfield University	United Kingdom
Fennell, P.S.	3	Imperial College London	United Kingdom
Scott, S.A.	3	University of Cambridge	United Kingdom
Smit, B.	3	Swiss Federal Institute of Technology	Switzerland

Table 1:- Affiliation and Country of Leading Authors in Low Carbon Emission Studies

B. Global Distribution of Research Output

The second objective aims to determine the yearly global distribution of research productivity in low carbon emission studies. The trend of publication over the years (2011-2018) based on the number of publications is shown in Fig. 1. It is obvious that the number of publications released in 2012 was the highest in all while 2016 emerges as the second with 13 and 10 papers respectively. The lowest number of publications released was in 2011. This trend shows inconsistency in research output in low carbon emission studies with respect to the leading journals used for this work.
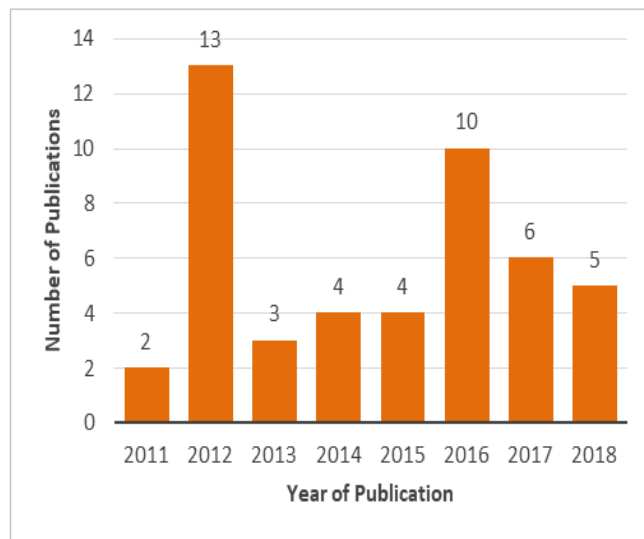

Fig 1:- Annual Publication Spread (2011-2018)

C. Productive Research Institutions

Analysis derived from this study showed that there are 17 institutions that have contributed to low carbon emission studies. Fig. 2 describes the top eight institutions with Imperial College London leading with 7 publications out of all 47 publications (14.89%). This is closely followed by University of California, Berkeley and Lawrence Berkeley National Laboratory with 6 (12.77%) and 5 (10.64%) publications respectively; Cranfield University and Swiss Federal Institute of Technology, Lausanne both have 4 (8.51%) publications each while University of Cambridge, Ohio State University and University of Sheffield have 3 (6.38%) publications respectively.
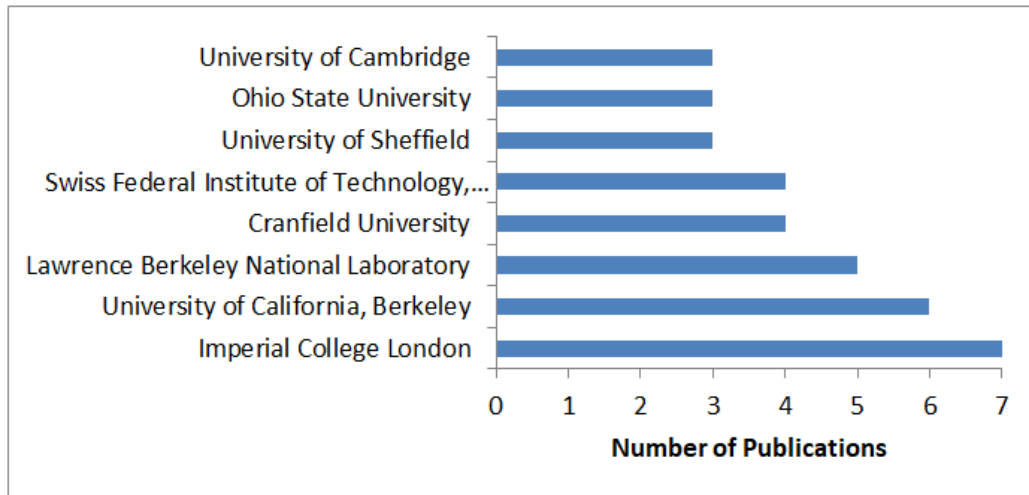

Fig 3:- Countries Contributing to Low Carbon Emission Studies

D. Leading Publication Outlets

The goal of this analysis is to uncover the various outlets where low carbon emission studies have been relatively published. We profiled and ranked the publication outlets in terms of the number of documents published. The publications in the domain area of focus of this study belong to the following categories: article, review, article in press, and short survey. Table II shows the spread of this document types over the years of publication (2011-2018), with Article being the most type of publication with 33 documents (70.21%); followed by Review having 12 documents (25.53%). One document each was classified as Article in Press and Short Survey.

	2011	2012	2013	2014	2015	2016	2017	2018	Total
Article	2	5	3	2	3	10	5	3	33
Review	0	8	0	2	1	0	0	1	12
Article in Press	0	0	0	0	0	0	0	1	1
Short Survey	0	0	0	0	0	0	1	0	1
Grand Total	2	13	3	4	4	10	6	5	47

Table 2:- Document Types Published Per Annum (2011-2018)

E. Top Funding Institutions Distribution

Table III unleashes the various funding sponsors affiliated to the publication of low carbon emission studies in the leading journals. Engineering and Physical Sciences Research Council (EPSRC) spearheaded this category with 6 publications; Natural Environment Research Council (NERC), Office of Science (SC), U.S. Department of Energy (DOE) have 3 publications; Australian Research Council (ARC, Basic Energy) Sciences (BES), Lawrence Berkeley National Laboratory (LBNL) and National Natural Science Foundation of China (NSFC) have 2 publications each.

Funding Sponsor	Number of Publications
Engineering and Physical Sciences Research Council (EPSRC)	6
Natural Environment Research Council (NERC)	3
Office of Science (SC)	3
U.S. Department of Energy (DOE)	3
Australian Research Council (ARC)	2
Basic Energy Sciences (BES)	2
Lawrence Berkeley National Laboratory (LBNL)	2
National Natural Science Foundation of China (NSFC)	2

Table 3:- Top Funding Institutions (2011-2018)

F. National Contribution to Low Carbon Emission Studies

A total of 17 countries have contributed to Low Carbon Emission Studies from 2011 to 2018. Fig. 3 captures the host countries of researchers in this domain. From the analysis shown in Fig. 3, United States spearheads the category with 22 publications out of 47, amounting to 29% of all publications in the period under review. United Kingdom comes next with 19 publications (25%), followed by China with 6 publications (8%). Both Australia and Germany have 5 publications (7%), and are the next in line after China but before Switzerland with 4 publications (5%). France, Singapore, South Korea and Sweden share same position with two publications (3%) respectively.
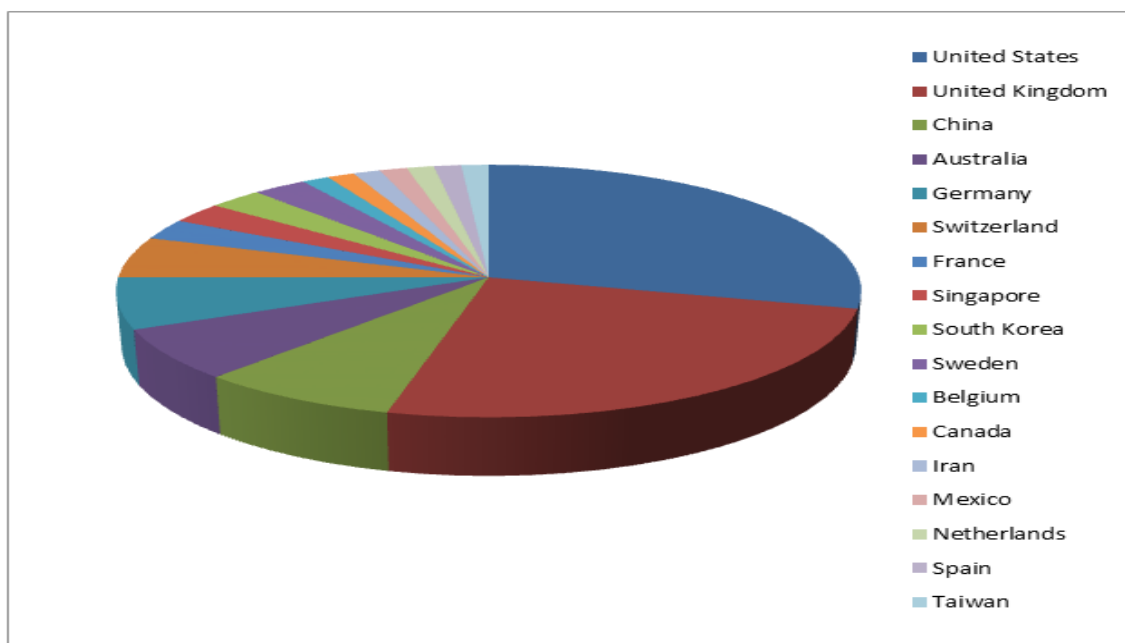

Fig 3:- Countries Contributing to Low Carbon Emission Studies

G.

Research Trend in Low Carbon Emission Studies

Here, we explore the trend of Low Carbon Emission Studies by examining subject area and keywords of publications available in this context. Analysis showed that Low Carbon Emission Studies is classified into 7 subject areas namely Biochemistry, Genetics and Molecular Biology, Chemical Engineering, Chemistry, Energy, Environmental Science, Materials Science, Medicine. Table IV shows the seven subject areas and the number of publications in each category.

Subject Area	Publication Count
Biochemistry, Genetics and Molecular Biology	1
Chemical Engineering	1
Chemistry	1
Energy	39
Environmental Science	47
Materials Science	1
Medicine	1

Table 4:- Seven Subject Classification of Low Carbon Emission Studies

H. Top Twelve Keywords

A total number of 550 keywords from 47 publications were acknowledged. The leading keywords used in the publications retrieved in this domain are featured in Table V. The analysis evinced that most research publications focused a lot on how carbon dioxide can be minimized. It also gives inkling on why carbon capture is the very now superlative method for decarbonization.

Keywords	Publication Count
Carbon Dioxide	38
Carbon Capture	26
Carbon Sequestration	23
Carbon	19
Climate Change	10
Carbon Capture And Storage	9
Carbon Emission	9
Adsorption	8
Fossil Fuel Power Plants	8
Combustion	7
Emission Control	7
Fossil Fuel	7

Table 5:- Top 12 Keywords Used in Low Carbon Emission Studies

VI. CONCLUSION

SCOPUS database served as the source for retrieving the data utilized in this paper, with definite search terms on the titles, keywords and abstracts of documents. This study reveals the authors, countries, funding sponsors and institutions affiliated to research work in Low Carbon Emission Studies. It is probable that a distinct set of results could have been retrieved using data from other electronic databases viz Web of Science or EBSCO. On the basis of the bibliometric analysis carried out in this study, there lies an inconsistency in production of papers in Low Carbon Emission Studies from 2011-2018. Consequently, there is a need for a great deal of exploration with respect to low carbon emission studies in the leading journals used for the purpose of this study. Hopefully, low carbon emission is attainable if we keep exploring and effectively redesigning and exploiting the resources available to us, sustainably.

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