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A Bibliometric Analysis of Global Research on Green Building Rating Tools.

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A Bibliometric Analysis of Global Research on Green Building Rating Tools.

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Abstract

The movement of green buildings started all over the world after the development of different rating tools for the assessment of green buildings. In the present study, the research trends in the area of green building rating tools (GBRTs) were analysed through the Scopus database from the year 2000-2020. By using the different combinations of keywords, relevant articles were found after refining the search results. In this study, 482 relevant articles from the first set of keywords were considered till the period 4th February 2021 for further analysis. Results reveal that research on GBRTs was majority done only on residential buildings. As per analysis, the USA and China depicted maximum publications in the area of GBRTs. The analysis also revealed that Building and Environment Journal is the leading Journal in publishing the GBRTs research followed by the Journal of Cleaner Production.

Keywords: green buildings; rating tools; analysis; research.

Introduction

According to a very recent report of the world resource institute, humankind is consuming more than 20% of natural resources than the earth can produce, and because of that production waste is increasing instead of increasing productivity (Ahmad et al., 2019). From all the available non-renewable resources, around half of the resources that humanity consumes going to use by the construction industry and it is called as least sustainable on the earth (Chi et al., 2020). Besides, the buildings are liable for almost 41% of worldwide consumption of energy, 12% of drinking water consumption, 40% of total solid waste generation, and the conventional buildings are the large source of greenhouse gas emission that is about 38% (Bano & Sehgal, 2018) (Polat et al., 2017). Hence, ignorantly, the construction and planning sector is liable for most of the environmental pollution happening in nature (Bansal et al., 2019) (Bansal et al., 2017) (Chandel et al., 2016). Therefore, there is a need to evolve the strategy to reduce energy use, to increase the usage of naturally available renewable resources, and to minimize environmental pollution so that we can reduce the cost of energy costs and the emission of greenhouse gases into the globe's atmosphere (Knobel et al., 2019) (Darko et al., 2019). From the ancient years, 'Green Buildings (GB)' is the word that continuously emerging attention in the mass media. Green building is the building, which is design, built, and functioned

to minimize the adverse environmental effects by improving the user's luxury and efficiency (Atanda & Olukoya, 2019) (Coma et al., 2016) (Illankoon et al., 2017) (Illankoon & Lu, 2020) (Kuo et al., 2016). For assessment of buildings, or to recognize the buildings that meet certain standards or green requirements, different rating tools were developed which is also known as the certification process (Majumdar, 2020) (Kumar et al., 2017). The main aim of these rating tools is to reward the organizations or the companies who builds and operates the green buildings to encourage them towards the sustainability by providing several tax benefits (Payyanapotta & Thomas, 2021) (Lazar & Chithra, 2020). They push the markets by setting some standards considering the government building codes, energy rules and regulations, or corporates strategies (Li et al., 2014). These rating tools are different for different countries as per their set standards.

The present study is the bibliometric analysis of available research on green building rating tools by using the major database Scopus. The analysis was done to recognize the past, present, and future research progress in the area of GBRTs. Scopus is considered the widely used authentic research database that covers a wide range of topics in various study areas (Patyal et al., 2020). By using several key aspects such as Documents by country, by authors, by Institution, by patents, and by citation, data collected on green building rating tools from the Scopus database as of 4th Feb 2021.

Data Collection and Methodology

The peer-reviewed academic literature obtained from the Scopus database contains the articles, review papers, conference proceedings, and patents from the year 2000 to 2020. In the Scopus database, the "green building" and "rating tools" or "assessment methods" was the first set of keywords, after that "Green Building" and "rating tools" and "residential Buildings" was the second set of keywords, the third set of keywords was "Green Building" and "rating tools" and "commercial Buildings" and fourth set of keywords is "Green Building" and "rating tools" and "Educational Campuses" to get the research publications in the title, abstract and keywords icon. By the first set of keywords, the total number of records obtained from the first search was 615, and results were further refined from source types by excluding the books, book series, and undefined sources. After that in refined search the number of documents limited to 482. The bibliometric analysis was done in detail for the first set of keywords. In the second set of keywords, the total relevant documents were 114, In the third set of keywords total relevant documents were 3, and in the fourth set of keywords total relevant documents were 0 as shown in Table 1. This type of different combination of keywords search reveals the research gaps in the particular field.

Table 1. The number of relevant documents for different combinations of Keywords.

Set	Keywords	Conjunction	Relevant Documents
1	"Green building", "rating tools", "Assessment methods"	AND, OR	482

2	"Green Building", "rating tools", "Residential Buildings"	AND	114
3	"Green Building", "rating tools", "Commercial Buildings"	AND	03
4	"Green Building", "rating tools", "Educational Campuses"	AND	0

Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Table 1 clearly shows that the limited number of research in the area of green building rating tools done on residential buildings and very scare research done on commercial buildings. However, any researchers did not research green building rating tools particularly for Educational Campuses as the zero number of relevant documents were found for the fourth set of keywords as of 4th February 2021.

From the first set of keywords, in the "analyze search results" icon which is available on the Scopus search results page, the documents analyzed as several documents by authors, by year, documents by countries, and documents by institutions and universities. Different types of documents available on Scopus and from that the documents on green building rating tools considered for the bibliometric analysis are articles, review papers, patents, conference proceedings, and short survey documents. Table 2 shows the different types of publications along with their numbers. The largest contribution to the research was of research articles followed by conference papers, patents, reviews, and short survey documents. The largest contribution to the research publication was of articles and conference papers which counts almost 74.27% of the total database. The number of patents in the field is constantly increasing over the years which is shown in Figure 1 delivers the growth of research in this particular field.

Bibliometric Analysis and Results

Bibliometrics analyzes the research outputs impacts by giving the quantitative measures in the field green building rating tools (Patyal et al., 2020). Based on the Scopus database, the bibliometric analysis is the method to understand the growth trends in the area of GBRTs. Data obtained from the Scopus database was useful to evaluate the growth in the research field in terms of different institutes, countries, authors, and journals (Wuni et al., 2019).

Table 2. The types of Publications in Green Building Rating Tools

Publication Type	Number of Publications
Journal Article	210
Conference Paper	148
Patents	88
Review	28
Short Survey	8

Source:http://www.scopus.com (retrieved on 4th Feb 2021)

Basic Growth Trend

Data collected from the Scopus database revealed that the research in the area of green building rating tools is constantly increasing from years 2001 to 2020 which shows the current growth in the research field. Figure 1 shows the increasing trend of research publications per year in the area of green building rating tools from the year 2001 to 2020. Figure 1 also incorporates an overview of increasing patents in this particular area. Figure 1 shows the number of publications in the area of GBRTs was increased from 2 to 53 from the years 2001 to 2020 respectively. This shows that the constant increase in the number of publications and also increase in several patents delivers tremendous growth in this particular area of GBRTs (Ramachanderan et al., 2017). In Table 3, the information related to patent offices along with the patent numbers is given. In the area of GBRTs, the global scenario of research and innovations in different countries of the world was understood from the patent and paper analysis. As given in Table 2, the highest number of patents that is 87 patents were registered in the United States Patent and trademark office and after that 1 patent in the research, area is also from the European Patent office.

Table 3. Details of Patent office along with patents on Green Building Rating Tools.

Rank	Patent office	Number of Patents
1	The United States Patent & Trademark Office	87
2	European Patent Office	1

Source: http://www.scopus.com (retrieved on 4th Feb 2021)

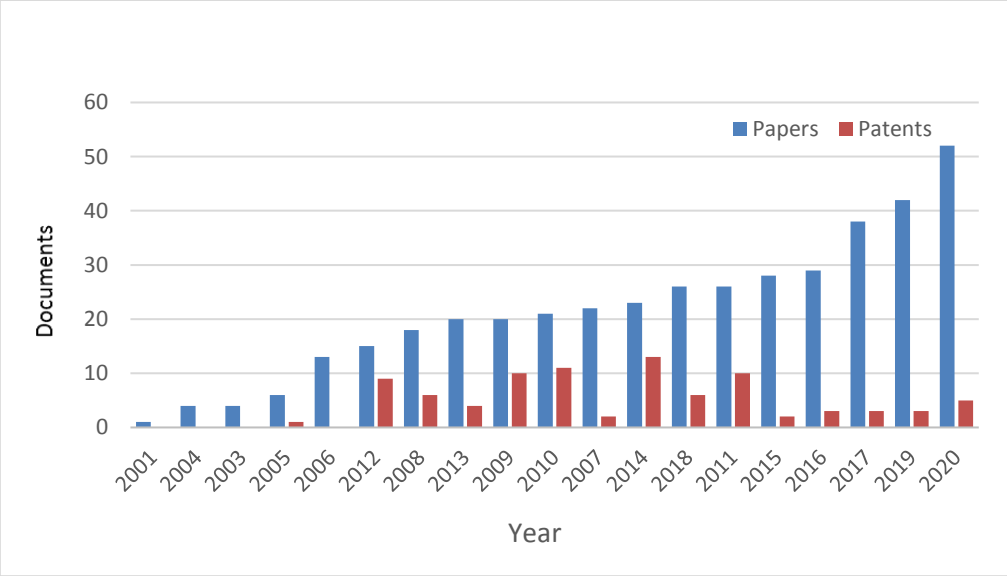

Figure 1. The yearly distribution of publications and patents on green building rating tools. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Geographical regional analysis

The different number of publications in the entire world given in Figure 2 along with their geographical locations. The shown map is drawn by using the application known as iMapBuilder. The highest number of publications in the area of green buildings are from the United States followed by China, Australia, and other countries as shown in Figure 3. The total top fifteen leading publishing countries is shown in Figure 3. This accounts together almost 84% of total (out of total 482) documents available on green building rating tools in the Scopus database

Figure 2. Geographic locations of green building rating tools studies. Source: https://www.imapbuilder.net/

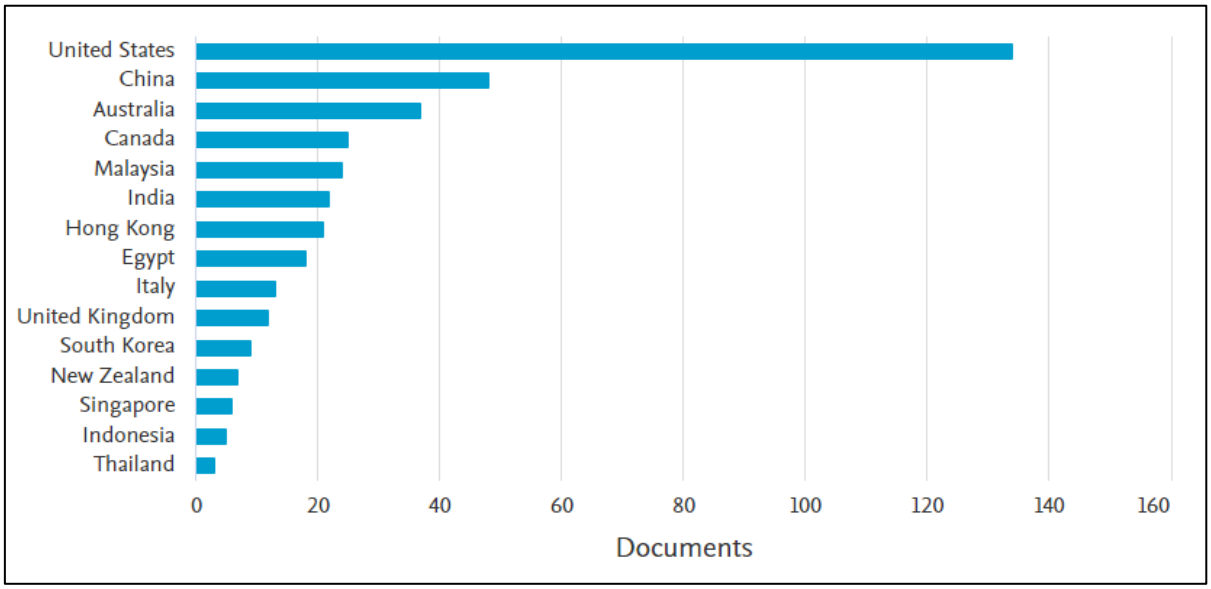

Figure 3. The top 15 countries based on the number of publications on the green building rating tools. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

In this analysis, United States was found as the major contributor to this particular area of research on GBRTs having 136 publications out of 482 publications. China is in the second rank having 49 publications followed by Australia and other remaining countries. Only 22 publications are available from India and other developing countries. The United States and China together account for almost 45% of total publications. The remaining twelve countries shown in Figure 3 has a very less number of publications in the last two decades from the year 2001 to 2020.

Journals Analysis

The top ten journals in the area of GBRTs are given in Table 4. These journals accounted for almost 41% of total research in the area of GBRTs and arranged along with the highest to lowest number of publications in the research field. Journal of Building and Environment and Journal of Cleaner Production, these two Journals have a maximum number of publications of around 22 and 15 publications respectively in the research area. Other remaining Journals are also at the pick level of publishing the research in the area of green building rating tools.

Table 4. Journals for green building rating tools with publication count.

Rank	Journal	Number of publications
1	Building and Environment	22
2	Journal of Cleaner Production	15
3	HPAC Heating Piping Air conditioning Engineering	13
4	Journal of Green Buildings	13
5	Sustainability Switzerland	13
6	Sustainable Cities and Society	8
7	Applied Mechanics and Materials	7
8	ASHRAE Journal	7
9	Building Research and Information	6
10	Civil Engineering and Architecture	6

Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Figure 4 indicates the pattern of year-wise publications in the top journals from the year 2007 to 2020 of publishing the research in the area of GBRTs. In the year 2013, Sustainable cities and society were at the top level of publishing the research in the area of green building rating tools. From the year 2014, the Journal of green buildings is attracting much more attention in publishing the research related to green buildings as the journal is pure of green buildings. The highest number of publication s in the recent year 2020 was from Building and Environment Journal.

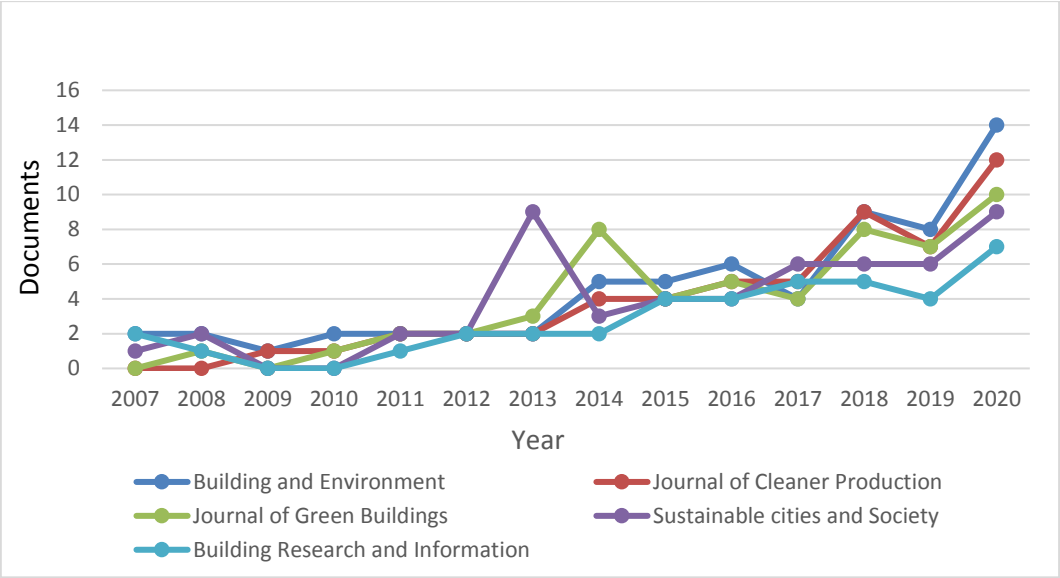

Figure 4. The trend in Publication of top five journals in Green Building rating tools. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Subject Area Analysis

Categorization of Subject wise Research in the area of GBRTs have shown in Figure 5. The figure shows that the highest number of publications are from an engineering background that is 34.6% of total research. After that, the highest second number of research has carried out under the Environmental Science background that is of 16.5% of total research. It means almost 51% of research has done under these two categories and remaining 48.9% of research publications were under the subject areas of Social Science, Energy, Business Management, Computer Science, material science and other interdisciplinary subject categories.

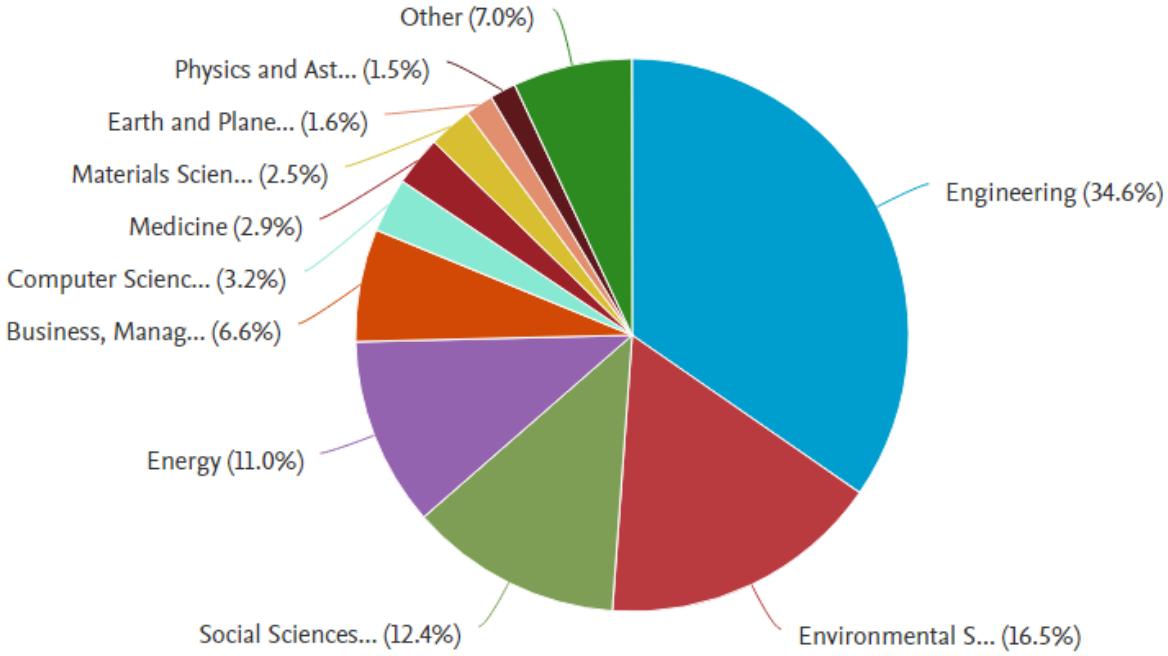

Figure 5. Subject area-wise distribution of available literature on green building rating tools. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Performance of Institutions

The top fifteen institutions or universities or organizational affiliations of publishing the research in the area of GBRTs are pointed out in Figure 6. The figure shows that the majority of research was done in Shenzhen University followed by Hong Kong Polytechnic University. Out of the top five Universities, the three universities are remarkably from China, which means China is one of the leading countries in publishing the research on GBRTs.

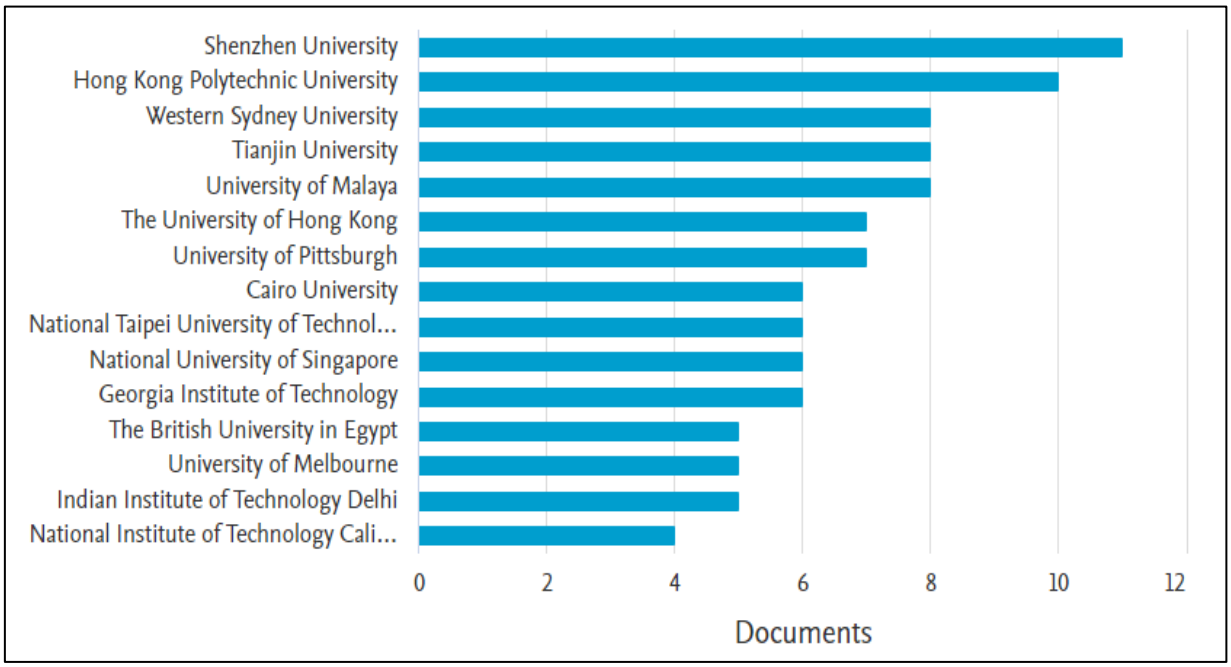

Figure 6. Details of top fifteen universities in terms of maximum productivity. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Authorship

The authors' analysis of the top 14 authors in the area of GBRTs research is as shown in figure 7. These authors analysis is helpful to the researchers in the field, for finding the impacts of some significant authors and their research contribution. Figure 7 represents that Sami G. Al-Ghamdi is the top author in publishing the research in the area of GBRTs, followed by Bilec M.M. Interestingly both of these two authors are from University of Pittsburgh that is located in the United States. It means major publishing authors are from the United States. The third leading author is I.M. Chethana S. Illankoon. She is from the University of Newcastle, Australia. Hence, the United States and Australia are the top leading countries as per Figure 3 and verified in Figure 7. Jha K.N. and Vyas G.S. are the Indian authors in publishing the research in the area of GBRTs. Their contribution is

appreciating and most suitable for the Indian region (Vyas & Jha, 2017) (Vyas & Jha, 2018).

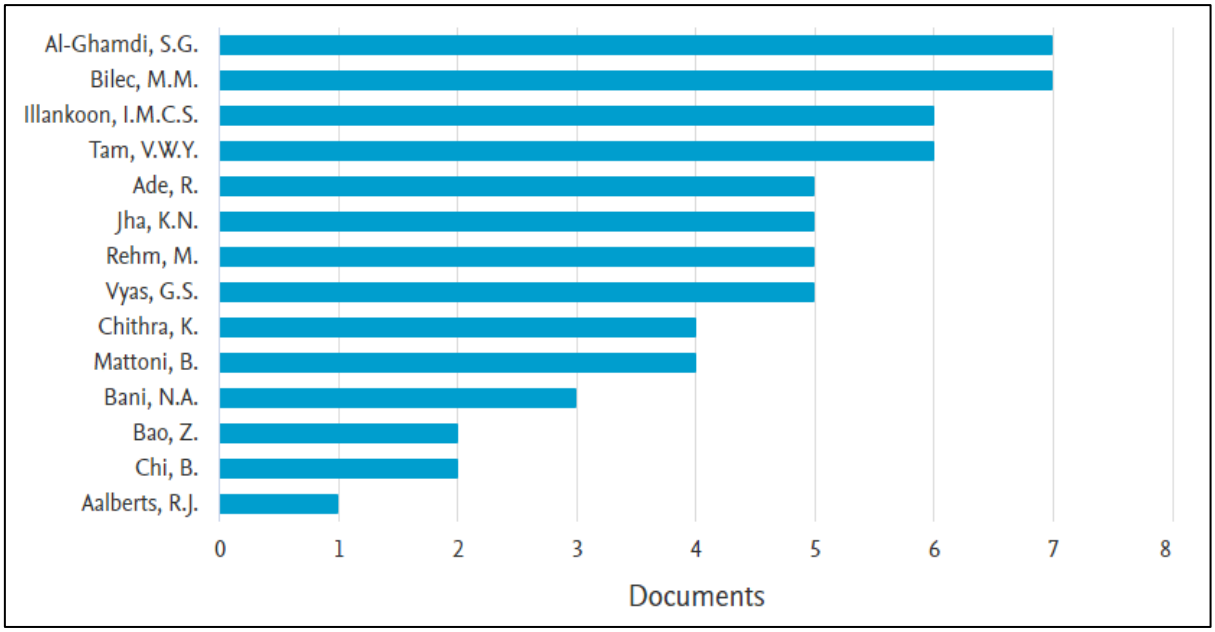

Figure 7. Top 14 authors in the area of green building rating tools with a maximum number of publications. Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Citation analysis

Year-wise citation distribution in the research domain from the year 2001 to 2021 presented in Table 5. The total citation count is 3489 of 482 publications retrieved on 4th February 2021.

Table 5. Citation details of top ten publications in green building rating tools

Year	<2017	2017	2018	2019	2020	>2021	Total
Number of Citations	1147	465	669	1051	1106	198	3489

Source: http://www.scopus.com (retrieved on 4th Feb 2021)

A list of the top 10 papers along with their citation details received in citation analysis is shown in Table 6. Most of the papers related to sustainability assessment of buildings (Ali & Al Nsairat, 2009), sustainability criteria for residential building (Pulselli et al., 2007), Annual Energy Consumption (Castro-Lacouture et al., 2009), and New Green Building Rating Tools for residential buildings. As per the results shown in Table 6, research related to the Sustainability assessment of Buildings was the most carried research from the year 2000-2020 that has the maximum number of citations as of 297 citations. After that, 174 and 167 citations respectively in sustainability criteria for residential building and Annual Energy Consumption fields as per the information retrieved on 4th February 2021 from Scopus database.

Table 6. Details of top five most cited publications in the area of green building rating tools.

Rank	Authors	Year	Journal	Total Citations
1	Ali H.H., Al Nsairat S.F.	2009	Building and Environment	297
2	Pulselli R.M., Simoncini E., Pulselli F.M., Bastianoni S.	2007	Energy and Buildings	174
3	Castro-Lacouture D., Sefair J.A., Flórez L., Medaglia A.L.	2009	Building and Environment	167
4	Doan D.T., Ghaffarianhoseini A., Naismith N., Zhang T., Ghaffarianhoseini A., Tookey J.	2017	Building and Environment	146
5	Chen X., Yang H., Lu L.	2015	Renewable and Sustainable Energy Reviews	122
6	Newsham G.R., Birt B.J., Arsenault C., Thompson A.J.L.	2013	Building Research and Information	101
7	Mattoni B., Guattari C., Evangelisti L., Bisegna F., Gori P., Asdrubali F.	2018	Renewable and Sustainable Energy Reviews	93
8	Wu P., Low S.P.	2010	Journal of Professional Issues in Engineering Education and Practice	92
9	Illankoon I.M.C.S., Tam V.W.Y., Le K.N., Shen L.	2017	Journal of Cleaner Production	90
10	Jalaei F., Jrade A.	2015	Sustainable Cities and Society	87

Source: http://www.scopus.com (retrieved on 4th Feb 2021)

Conclusions

The study presents the trend of an increasing number of publications and patents in the area of GBRTs in the last twenty years. It implied that researchers are actively taking interest in this particular research area of GBRTs recently as the demand for sustainable environments along with the construction of green buildings is increasing over years. It replicated the strong concern for the green buildings movement. It also highlights the increasing demand for natural resources by constructing healthier green buildings. By considering the demands for green buildings, different rating tools developed as per their set standards for their own countries (Kuo et al., 2016). These set standards need some modifications and researchers are seeking their attention to reframing these rating tools by developing the new framework or by refining the existing GBRTs (Wuni et al., 2019). Growth figures explained in the present study are for understanding the increasing demand for research in the area of GBRTs leading to a necessity of the most sustainable GBRT. Data of publications extracted from Scopus database, the primary language used in scientific documents was English. This analysis revealed that Building and Environment Journal is the leading Journal in publishing the GBRTs research followed by the Journal of Cleaner Production.

The Massive research gaps found out from the study after giving different combinations of keywords to the Scopus database as follows. 1) Very scarce research has done on commercial buildings in the area of GBRTs, as the number of relevant documents

in the field was very less in numbers. 2) None of the documents found for the research in GBRTs for Educational Campuses. However, It is required to adopt the green ratings for educational campuses as a large number of resources are consumed by every campus for the provision of all the facilities to students and staff working in that particular Campus. Hence, there is a need to evolve a new rating framework for educational campuses.

Countries that contributed significantly to this area of research are United States (28.2%), China (18.4%), Australia, Canada, Malaysia, India, and Hong Kong. China is one of the leading countries in publishing research on GBRTs. The United States and China together account for almost 45% of total publications in the last two decades. Researchers around the globe are consistently working to come up with Sustainable and Smart solutions for the construction industry by providing occupants comfort and a healthier lifestyle in Buildings. It has steadily going forward from the core subject areas of 'Engineering", "Environmental Science" and "Social Science" to another interdisciplinary approach resulting in an additional increase in the research in green building rating tools with the development of new frameworks for different types of green building and refinement of existing green rating systems.

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