

# **Green Technology: A Scientometric Analysis from 2011-2020**

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## **ABSTRACT**

*This paper attempts to highlight the green technology research in global as per the number of publications appeared in the web of science database. During the period (2011-2020) a total of 18198 publications were published by the scientists in the field. The average number of publication per year was 1819.8. The highest numbers of publications (3470) were published in the year 2020. Authors from China have contributed maximum number of publications compared to other countries and India stood 3<sup>rd</sup> rank in terms of productivity in this field. This paper analysed the broad features of literature on green technology focusing on year wise growth of publications, most prolific authors, highly productive institutes, highly productive countries, language wise distributions of publications, high productive subjects and most preferred journals for publication.*

**KEYWORDS:** Green technology, Scientometrics, Relative growth rate and Doubling time.

## **1. INTRODUCTION**

Green technology deals with using science and technology in order to protect the environment. This technology is used to breathe life back into a damaged ecosystem. This technology ensures that the Earth remains healthy for all life to continue existing. Green technology helps manage and recycle waste material, purifying of water, purifying the air, conserving energy and rejuvenating ecosystems. Green technologies encompass various aspects of technology which help us reduce the human impact on the environment and create ways of sustainable development. Today the environment is racing towards the tipping point at which we would have done permanent irreversible damage to the planet earth. Green technology uses renewable natural resources that never depletes. Green technology uses new and innovative energy generation techniques.

To meet the needs of society in ways without damaging or depleting natural resources on earth is the main objective of green technology. By changing patterns of production and consumption, steps are being taken to reduce waste and pollution, as one of the important goals of green technology. It is essential to develop alternative technologies to prevent any further damage health and its advantages and their disadvantages of the green technology. This is clear from the scientometric evidence from 2011 to 2020, that the number of publications in the Web of Science database

was increased from 381 to 1512. Therefore the present study has been undertaken to know the growth and development of publications in the field of green technology.

## **2. OBJECTIVES FOR THE STUDY**

The main objective of this study is to analyse the global research performance in the field of green technology publication output during 2011-2020. In particular, the study focuses on the following aspects:

- Document types of publications
- Annual growth of publications
- Most prolific authors
- Geographical distribution of research output
- Highly productive institutes
- Language-wise distribution of publications
- Most preferred source titles for publication
- High productive subject areas

## **3. MATERIALS AND METHODS**

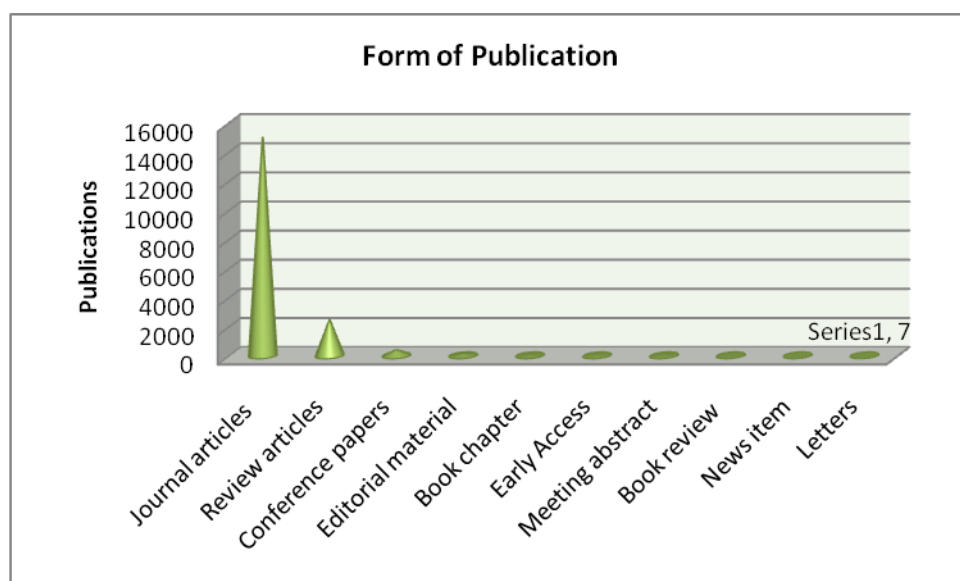
The Web of Science database was used for retrieving data on green technology in topic field. A total of 18198 publications were downloaded and analysed by using the Microsoft excels per the objectives of the study. The Web of Science database allows us to refine the results in terms of publication years, countries, institutes, authors, language, subjects and source titles.

## **4. DATA ANALYSIS AND INTERPRETATIONS**

### **4.1 Forms of publications**

**Table 1** Forms of publications

| <b>S. No.</b> | <b>Forms of publications</b> | <b>No. of publications</b> | <b>Percentage</b> |
|---------------|------------------------------|----------------------------|-------------------|
| 1             | Journal articles             | 14959                      | 82.20             |
| 2             | Review articles              | 2463                       | 13.53             |
| 3             | Conference papers            | 393                        | 2.16              |
| 4             | Editorial material           | 156                        | 0.86              |
| 5             | Book chapter                 | 68                         | 0.37              |
| 6             | Early Access                 | 67                         | 0.37              |
| 7             | Meeting abstract             | 58                         | 0.32              |
| 8             | Book review                  | 17                         | 0.09              |
| 9             | News item                    | 10                         | 0.05              |
| 10            | Letters                      | 7                          | 0.04              |
| <b>Total</b>  |                              | <b>18198</b>               | <b>99.99</b>      |



**Figure 1** Form of publications

The table 1 reveals that the major source of publications covered by web of science databases on green technology research is Journal articles with 6,830 publications (79.33%) followed by Review with 1236 publications (14.36%). Conference papers ranks the third position with 306 publications (3.55%), Editorial material with 94 publications (1.09%) and remaining forms are less than one percentage as seen in the table. The results indicate that the research outputs on green technology of the period covered by the study are mostly published in the form of journal articles.

#### 4.2 Annual Growth rate (AGR) of publications

Table 2 provides the AGR and CAGR of the number of documents for period 2011 to 2020.

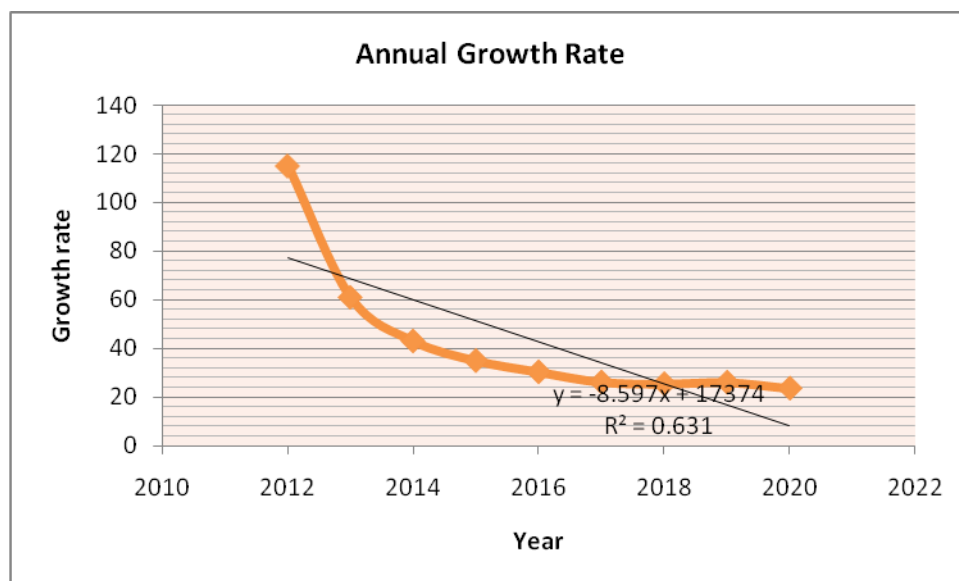
$$\text{AGR} = \frac{\text{End Value} - \text{First Value}}{\text{First Value}} \times 100$$

**Table 2** AGR and CAGR of Publications

| Year | No. of publications | Cumulative total | Annual growth rate (AGR) |
|------|---------------------|------------------|--------------------------|
| 2011 | 848                 | 848              | -                        |
| 2012 | 977                 | 1825             | 115.21                   |
| 2013 | 1114                | 2939             | 61.04                    |
| 2014 | 1265                | 4204             | 43.04                    |
| 2015 | 1469                | 5673             | 34.94                    |
| 2016 | 1718                | 7391             | 30.28                    |
| 2017 | 1931                | 9322             | 26.13                    |
| 2018 | 2366                | 11688            | 25.38                    |
| 2019 | 3040                | 14728            | 26.01                    |
| 2020 | 3470                | 18198            | 23.56                    |

During the period of 2011 to 2020, a total of 18,198 publications were published on green technology research. The highest number of publications is 3470 was published in 2020. The lowest publications of 848 are published in 2011. The average number of publications published per year was 1819.8. Table 2 shows that there has been a steady growth in research publications on green technology during the study period.

The table 2 also provides that the annual growth rate of the total publications calculated year wise. AGR reveals that it has decreased from 115.21 in 2012 to 23.56 in 2020. There is a downward trend in the growth rate as seen in the figure 2.



**Figure 2** Annual growth rate of publications

**4.3 Relative Growth Rate (RGR) and Doubling Time**

The Relative Growth Rate (RGR) is the increase in number of articles or pages per unit of time. This definition derived from the definition of relative growth rates in the study of growth analysis in the field of green technology. The mean relative growth rate (R) over the specific period of interval can be calculated from the following equation.

Relative Growth Rate (RGR)

$$1 - 2R = \frac{\log W_2 - \log W_1}{T_2 - T_1}$$

Whereas

1-2 R- mean relative growth rate over the specific period of interval

Log<sub>e</sub> W<sub>1</sub> - log of initial number of articles

Log<sub>e</sub> W<sub>2</sub> - log of final number of articles after a specific period of interval

T<sub>2</sub>-T<sub>1</sub>- the unit difference between the initial time and the final time

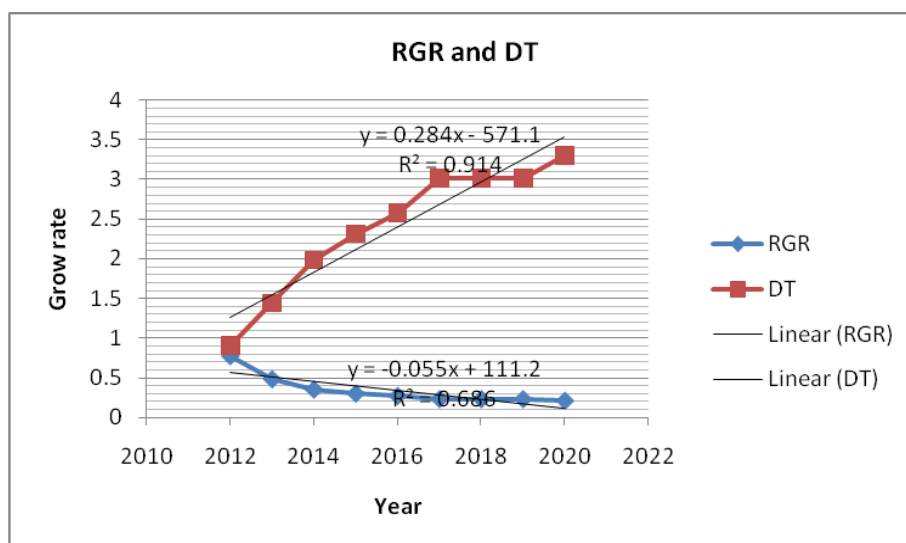
The year can be taken here as the unit of time.

Doubling Time (DT) = 0.693/R

**Table 3** Relative growth rate (RGR) and Doubling time (DT) of publications

| Year | No. of Publications | Cumulative Total | W1   | W2   | RGR  | DT   |
|------|---------------------|------------------|------|------|------|------|
| 2011 | 848                 | 848              | -    | 6.74 | -    | -    |
| 2012 | 977                 | 1825             | 6.74 | 7.51 | 0.77 | 0.9  |
| 2013 | 1114                | 2939             | 7.51 | 7.99 | 0.48 | 1.44 |
| 2014 | 1265                | 4204             | 7.99 | 8.34 | 0.35 | 1.98 |
| 2015 | 1469                | 5673             | 8.34 | 8.64 | 0.30 | 2.31 |
| 2016 | 1718                | 7391             | 8.64 | 8.91 | 0.27 | 2.57 |
| 2017 | 1931                | 9322             | 8.91 | 9.14 | 0.23 | 3.01 |
| 2018 | 2366                | 11688            | 9.14 | 9.37 | 0.23 | 3.01 |
| 2019 | 3040                | 14728            | 9.37 | 9.60 | 0.23 | 3.01 |
| 2020 | 3470                | 18198            | 9.60 | 9.81 | 0.21 | 3.30 |

The year wise RGR is found to be in the range of 0.77 to 0.21. It has been observed from Table 3 and figure 3 that RGR is downward trend from 2012 (0.77) to 2020 (0.21). The doubling time (DT) was upward trend from 2012 (0.90) to 2020 (3.30).

**Figure 3** Relative growth rate for research output

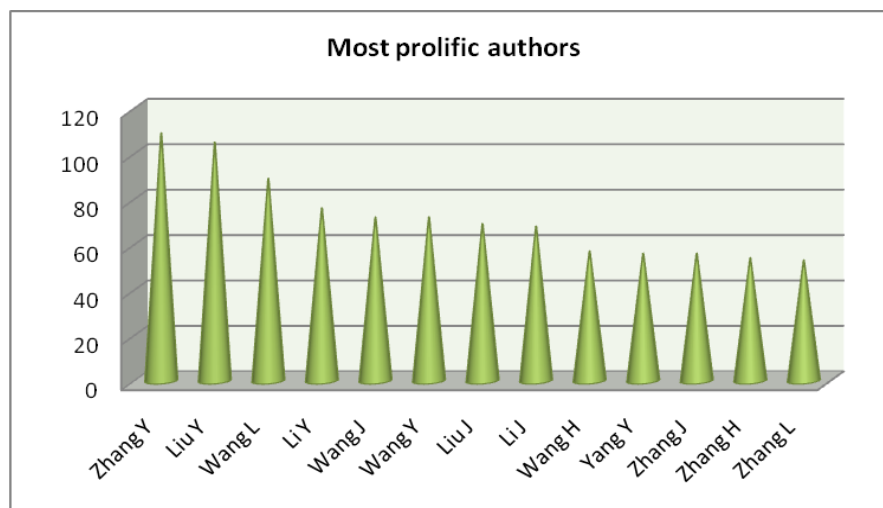
#### 4.4 Most prolific authors

**Table 4** Most prolific authors

| S. No. | Author  | No. of publications | Percentage |
|--------|---------|---------------------|------------|
| 1      | Zhang Y | 109                 | 0.60       |
| 2      | Liu Y   | 105                 | 0.58       |
| 3      | Wang L  | 89                  | 0.49       |
| 4      | Li Y    | 76                  | 0.42       |
| 5      | Wang J  | 72                  | 0.40       |
| 6      | Wang Y  | 72                  | 0.40       |

|    |         |    |      |
|----|---------|----|------|
| 7  | Liu J   | 69 | 0.38 |
| 8  | Li J    | 68 | 0.37 |
| 9  | Wang H  | 57 | 0.31 |
| 10 | Yang Y  | 56 | 0.31 |
| 11 | Zhang J | 56 | 0.31 |
| 12 | Zhang H | 54 | 0.30 |
| 13 | Zhang L | 53 | 0.29 |

Zhang, Y is the most productive author with 109 (0.60%) publications followed by Liu, Y with 105 (0.58%) publications, Wang, L with 89 (0.49%) publications, Li, Y with 76 (0.42%) publications, Wang, J with 72 (0.40%) publications, Wang, Y with 72 (0.40%) publications, Liu, J with 69 (0.38%) publications and Li J with 68 (0.37%) publications respectively. And a total of 28,837 authors are contributed entire research output of the period under study. Table 4 provides the most prolific authors who have contributed 50 or more publications.



**Figure 4** Most prolific authors

**4.5 Highly productive institutions**

**Table 5** Highly productive institutions

| Rank | Institutions   | Country | No. of Publications |
|------|--|---------|---------------------|
| 1    | Chinese Academy of Science                             | China   | 585                 |
| 2    | University of California Systems                       | USA     | 308                 |
| 3    | Centre National de La Recherche Scientifique CNRS      | France  | 271                 |
| 4    | Indian Institute of Technology                         | India   | 210                 |
| 5    | University of Chinese Academy of Science               | China   | 168                 |
| 6    | Tsinghua University                                    | China   | 167                 |
| 7    | Consejo Superior de Investigaciones Científicas (CSIC) | Spain   | 148                 |
| 8    | Consejo Superior De Investigaciones Cientificas        | Spain   | 147                 |
| 9    | Zhejiang University                                    | China   | 143                 |
| 10   | University of London                                   | UK      | 137                 |

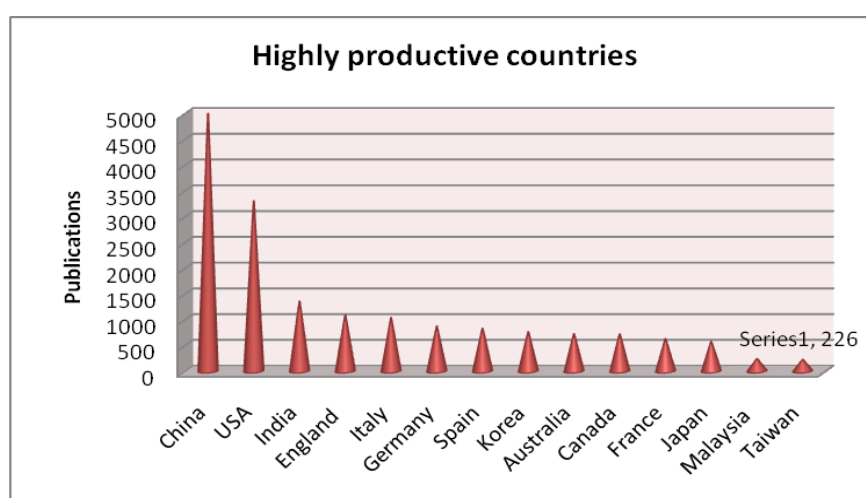
In all there were 6987 institutions involved in research activity on green technology. Table 5 presents the top 10 institutes that have contributed 130 or more publications on during 2011-2020. Chinese Academy of Science, China topped the list with 585 publications followed by University of California Systems, USA with 308 publications, Centre National de La Recherche Scientifique CNRS with 271 publications, Indian Institute of Technology, India with 210 publications, University of Chinese Academy of Science, China with 168 publications and Tsinghua University, China with 167 publications.

#### 4.6 Geographical distributions of research output

**Table 6** Geographical distribution of publications

| S. No. | Country | Total Publications (%) | S. No. | Country   | Total Publications (%) |
|--------|---------|------------------------|--------|-----------|------------------------|
| 1      | China   | 4996 (27.45%)          | 8      | Korea     | 762 (4.19%)            |
| 2      | USA     | 3300 (18.13%)          | 9      | Australia | 722 (3.97%)            |
| 3      | India   | 1354 (7.44%)           | 10     | Canada    | 721 (3.96%)            |
| 4      | England | 1085 (5.96%)           | 11     | France    | 628 (3.45%)            |
| 5      | Italy   | 1038 (5.70%)           | 12     | Japan     | 575 (3.16%)            |
| 6      | Germany | 869 (4.78%)            | 13     | Malaysia  | 242 (1.33%)            |
| 7      | Spain   | 830 (4.56%)            | 14     | Taiwan    | 226 (1.24%)            |

There were as many as 174 countries involved in carrying out research in the field of green technology and produced 18198 publications. Table 6 list of countries whose share in the research output is more than 1% of the output. China topped the list among all the countries with 4996 publications followed by USA with 3300 publications, India with 1354 publications, England with 1085 publications, Italy with 1038 publications, Germany with 869 publications, Spain with 830 publications, Korea with 762 publications, Australia with 722 publications, Canada with 320 publications, France with 628 publications and Japan with 575 publications and the remaining countries are publishing less than 3% of the research output in this study period. However, China and USA together accounts for 45% of world green technology research publications. India ranks 3<sup>rd</sup> among the countries publishing green technology publications



**Figure 5** Highly productive countries

**4.7 Language wise distributions****Table 7** Language wise distribution of publications

| S. No. | Language   | No. of Publications |
|--------|------------|---------------------|
| 1      | English    | 17908 (98.41%)      |
| 2      | Chinese    | 168 (0.92%)         |
| 3      | German     | 25 (0.14%)          |
| 4      | Spanish    | 25 (0.14%)          |
| 5      | Portuguese | 21 (0.12%)          |
| 6      | Japanese   | 10 (0.05%)          |
| 7      | Polish     | 10 (0.05%)          |
| 8      | French     | 6 (0.03%)           |
| 9      | Croatian   | 4 (0.02%)           |
| 10     | Italian    | 4 (0.02%)           |
| 11     | Turkish    | 4 (0.02%)           |

Publications on green technology are spread over 20 languages. The study reveals that the maximum number of publications have been published in English language with 17908 (98.41%) publications, followed by Chinese language with 168 (0.92%) publications, German language ranks third position with 25 (0.14%) publications, Spanish language with 25 (0.14%) publications, Portuguese language with 21 (0.12%) publications, Japanese language with 10 (0.05%) publications and Polish language with 10 (0.05%) publications. The most predominant language used for communication was English in every year in total productivity on the subject during the study period.

**4.8 Most preferred source titles****Table 8** Source Title of Publications

| S. No. | Source Title                                 | No. of Publications | Percentage |
|--------|--|---------------------|------------|
| 1      | Journal of cleaner production                | 647                 | 3.55       |
| 2      | Sustainability                               | 446                 | 2.45       |
| 3      | Renewable sustainable energy reviews         | 298                 | 1.64       |
| 4      | Green chemistry                              | 153                 | 0.84       |
| 5      | Energy policy                                | 142                 | 0.78       |
| 6      | Environmental science and pollution research | 139                 | 0.76       |
| 7      | ACS Sustainable chemistry engineering        | 133                 | 0.73       |
| 8      | Energies                                     | 131                 | 0.72       |
| 9      | RSC Advances                                 | 124                 | 0.68       |
| 10     | Science of the total environment             | 119                 | 0.65       |

Table 8 provides the leading journals with number of publications. The scientific literature on green technology is spread over 2942 different web of science source journals. It reveals that Journal of cleaner production the list with the highest number of publications 647 (3.55%) followed by Sustainability with a share of 446 (2.45%) publications.



Renewable sustainable energy reviews occupies the third position with 298 (1.64%) publications. The fourth highest source title is Green chemistry with 153 (0.84%) publications, Energy policy with 142 (0.78%) publications and Environmental science and pollution research with 139 (0.76%) publications.

#### 4.9 High productivity subject areas

**Table 9** High productivity subject areas

| Rank | Subject                               | No. of Articles | Percentage |
|------|---------------------------------------|-----------------|------------|
| 1    | Engineering                           | 4651            | 25.56      |
| 2    | Environmental sciences ecology        | 3538            | 19.44      |
| 3    | Science technology                    | 3441            | 18.91      |
| 4    | Chemistry                             | 3400            | 18.68      |
| 5    | Materials science                     | 2069            | 11.37      |
| 6    | Energy fuels                          | 1833            | 10.07      |
| 7    | Physics                               | 1176            | 6.46       |
| 8    | Business economics                    | 1002            | 5.51       |
| 9    | Biotechnology applied<br>microbiology | 831             | 4.57       |
| 10   | Agriculture                           | 783             | 4.30       |

Table 9 shows high productivity subjects which are contributing more than 500 articles. It is found that Engineering has highest number of articles with 4651 (25.56%) followed by Environmental sciences ecology contributing 3538 (19.44%) articles. Science technology occupies the third position with 3441 (18.91%) articles. The fourth highest articles belonged to the subject Chemistry with 3400 (18.68%), Materials science with 2069 (11.37%) and Energy fuels with 1833 (10.07%) articles respectively.

## CONCLUSIONS

The present study attempted to highlight the growth and development of research publication on green technology. A total of 18198 publications were published during 2011-2020 and the average number of publication per year was 1819.8. There was a steady growth of publication during the study period. China topped the list with highest share (27.45%) of publications followed by USA with 18.13% share of publications, India with 7.44% share of publications and England with 5.96% share of publications. Chinese Academy of Science, China topped the list with 585 publications followed by University of California Systems, USA with 308 publications, Centre National de La Recherche Scientifique CNRS with 271 publications, Indian Institute of Technology, India with 210 publications. The most prolific authors, high productive subjects and also the most preferred journals which they publish have also been identified. The single most prevalent type of publications is the journal article, in which 82.20% of the total publication is published. This shows that green technology scientists preferred medium of communications is journal article. A large number of researchers are pursuing their research in the field of green technology, giving hope that more publications would be published on the subject from all over the world in upcoming years.

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