

Research Advancement of Green Technologies

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Recently, green technology has become an attraction to researchers in engineering, manufacturing, material science, chemical engineering, environment science and energy areas. In this paper, six keywords such as, energy saving, energy consumption, green manufacturing, waste reduction, green products, and sustainable manufacturing which were the research fields discussed in the International Symposium on Green Manufacturing and Applications (ISGMA) 2013 were chosen to see the trend and status of green technologies in research area. In the last two decades, the number of journal articles related to the research area of green technology has significantly increased. Engineering is the most widely discussed research area covering the green technology. Also journals from five major research areas in green technology were analyzed with 5-years H-index and the number of journal articles published in recent 5 years.

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1. Introduction

Since energy consumption, environment concern, efficiency in manufacturing, etc. become important issues, green technology has become a significant research area to find solutions to these matters. As the third attempt to discuss the challenges toward green and sustainable manufacturing, this special issue covers multidisciplinary fields of green technology in the International Journal of Precision Engineering and Manufacturing (IJPEM).^{1,2}

The International Symposium on Green Manufacturing and Applications (ISGMA) 2013 was successfully held at Honolulu, Hawaii in USA from 25 to 29 June 2013 with topics of design and manufacturing of sustainable, energy saving and waste reduction process, new · renewable energy, light · eco-friendly materials and structure, and energy · environment management and policy within the scope of green manufacturing and applications. In ISGMA 2013, over 600 participants representing 17 countries and nationalities were hosted, and 27 distinguished plenary, keynote, and invited speakers from internationally reputed institutes aimed to present state-of-the-art research, development, and innovative advances and its related issues to our ever changing environment. Prof. David Dornfeld from University of California, Berkeley discussed about the matters of reduction of the consumption of energy, natural resources (including water) and other consumables and the impact of that consumption in manufacturing due

to societal, regulatory, economic and environmental considerations as a plenary speaker.³

Over 520 technical papers were presented in ISGMA 2013, and the number of selected papers from ISGMA 2013 and regularly submitted in green manufacturing were published in this special issue. Selected papers on the multi-directional approach towards applications, preparation and characterization of bio-based composites were published in Journal of Biobased Materials and Bioenergy (JBMB) as special issue.⁴ Some of the papers on composites were submitted to the Journal of Composite Materials (JCM). Other papers focusing on smart structure, smart materials, active materials, adaptive structures and adaptive materials related papers were submitted to Journal of Intelligent Material Systems and Structures (JIMSS).

In this paper, the current trend of green technology was analyzed through the research database based on the topics discussed in ISGMA 2013. To provide information and guidance of the research trend of green technology, recent 20 years of journal articles were categorically analyzed by country, research area, and represented journals.

2. Green Technology in the Research Database

In 21st century manufacturing, environmental shift and deficiency of energy and resources are two important challenges to consider. To

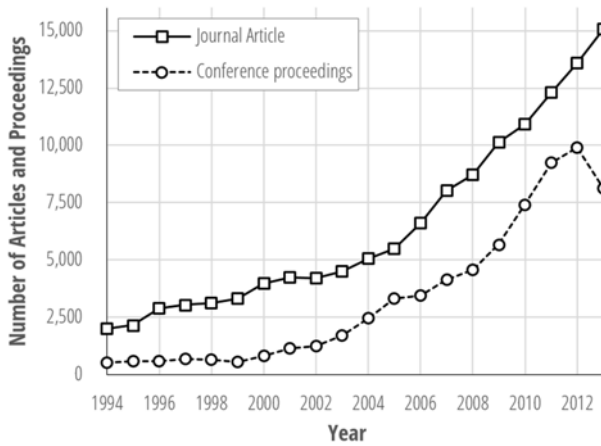


Fig. 1 Number of articles and proceedings published in green technology during 1994~2013

address these matters in the research area, following keywords were chosen from the topics mainly discussed during ISGMA 2013 in Hawaii, USA.

- Energy saving
- Energy consumption
- Green manufacturing
- Waste reduction
- Green products
- Sustainable manufacturing

These six keywords represent the major issues of current 21st century manufacturing. Journals and research areas in green technology were evaluated through categorization of journals from the research database into country and research area. The data source used in this paper was achieved from Scopus® database (Elsevier B.V.) since it represents the global scale of overall structure of world science (it covers most of the journals included in the Thomson Reuter’s Web of Science (WoS)).⁵⁻⁷

The database provides the information on business articles, conference review, note, book chapter, short survey, article in press, review, as well as journal articles and conference papers. However, only journal articles and conference proceedings were evaluated in this paper because the ratio of journal articles to total documents (263,891) was 59.4% while the ratio of conference proceedings to total documents was 27.8% in the last two decades (from 1994 to 2013).

Fig. 1 shows changes in the number of journal articles and proceedings from conferences in green technology. The numbers of journal articles and conference proceedings kept increasing year by year except 2013. The number of journal articles increased over 300% from 2004 to 2013.

Many researchers especially in engineering field are concerned about challenges mentioned above (see Fig. 2). Over 10 percent of journal articles were published in the area of environmental science during the same period. In the last two decades, the United States was the top contributor in this area followed by China in the total number of journal articles published (Fig. 3). An interesting trend in the number of journal articles related to green technology is that China maintains leading position for the last couple of years and the increment

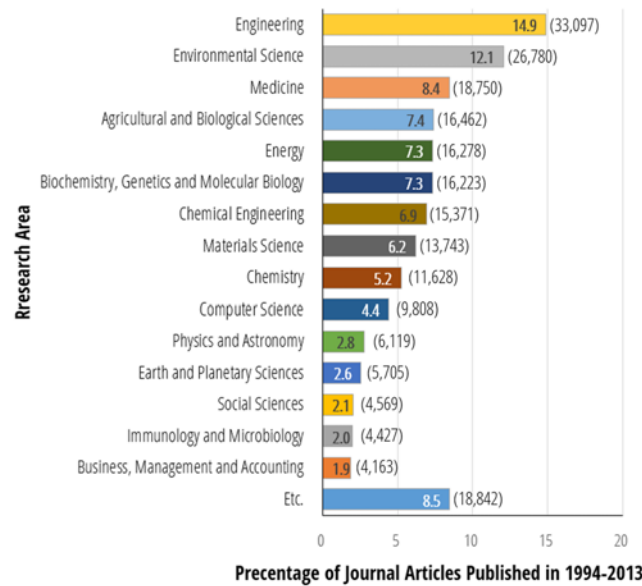


Fig. 2 Distribution of journals articles in green technology published in 1994-2013. The total number of articles are shown in parenthesis

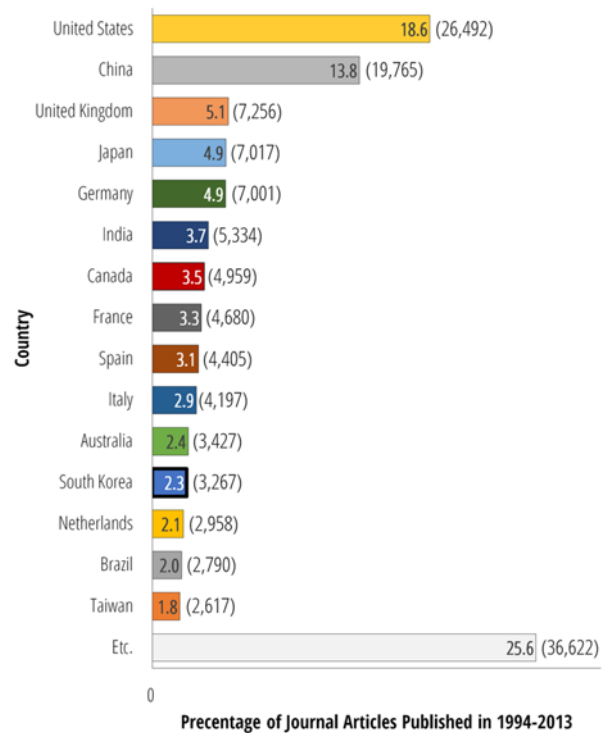


Fig. 3 Top 15 countries that lead green technology during 1994~2013. The total number of articles are shown in parenthesis

compared to 1994 was over 83.8 times (United States was only 4.6 times (Fig. 4)).

The number of journal articles of other countries such as United Kingdom, Japan, Germany, and India also increased significantly during the same period (7.0, 6.2, 4.9, and 20.2 times respectively) but the portion is not significant compare to China and United States. On the other hand, South Korea shows the remarkable increase of 205.7 times in the last 20 years (although it is not distinguishable in the Fig. 4

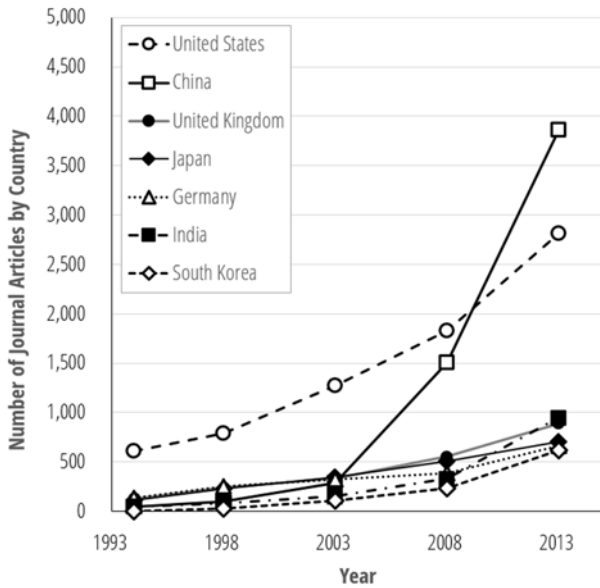


Fig. 4 Number of journal articles in green technology by country during 1994~2013

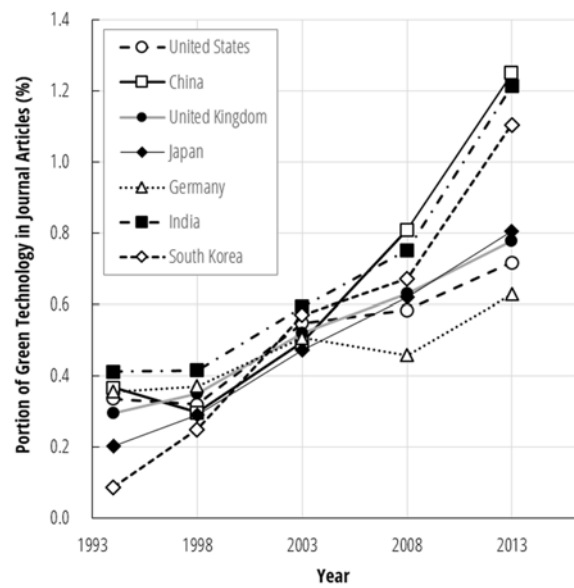


Fig. 6 Changes of portion of green technology in last 20 years (2009~2013)

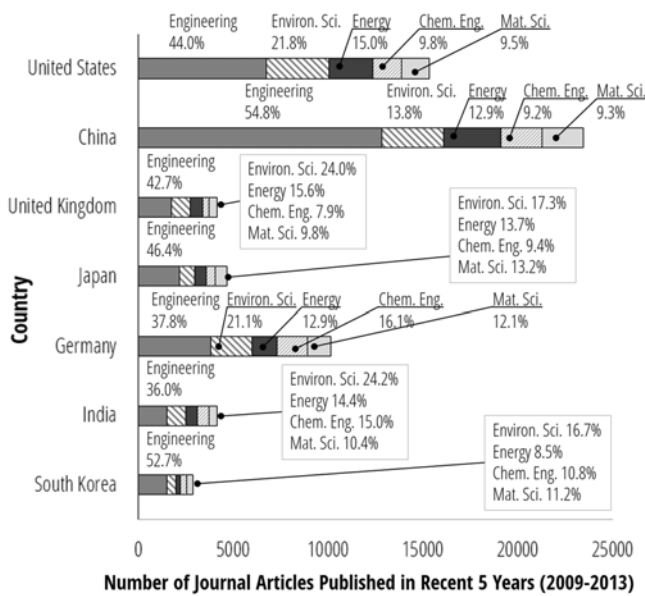


Fig. 5 Comparison of number of journal articles in green technology with research area by research leading countries

compare to United States and China since the total number of journal is relatively small to these countries).

Five research areas (engineering, environmental science, energy, chemical engineering, and material science) covered by countries leading in research (countries were chosen from the source of Fig. 4) as in Fig. 5.

Similar to Fig. 2 almost 50% of journal articles were from engineering area as in Fig. 5. China shows the highest portion (54.8%) of engineering in entire research area compared to other countries. On the other hand, the number of journal articles in material science area showed the smallest portion among 5 research areas. China and South Korea (52.7%) have over 50% of contribution in engineering area.

Changes related to green technology in last two decades are shown in Fig. 6. In the last 20 years, green technology has gradually grown. While the portion of green technology in South Korea was smallest among 7 representative countries in 1994, it increased 12.9 folds in 213. It is the highest increment compared with other countries (India (2.9 times), China (3.4 times), Japan (4.0 times), United Kingdom (2.6 times), Germany (1.8 times), and United States (2.1 times)). Especially, as in Fig. 6, green technology has more attraction recently to researchers in Asian continent (China, Korea, and India) than in other continent.

Commonly, the impact factor (IF, ratio of the cited number of papers to the total number of published papers) is used to evaluate the quality of journals. IF can be easily affected by number of articles and some selected highly cited articles might affect the result of the journal IF. Review papers in general, have higher citation than original research papers. H-index, on the other hand, is an index to measure the 'productivity' and 'impact' of the published articles.^{8,9}

The comparison and evaluation of each journal related to green technology in different research areas were compared graphically as in Fig. 7. Three to five journals in the green technology area were chosen based on the total number of journals articles. The horizontal axis of the graph is the 'importance' of the journal and vertical axis represents the 'attention' by researchers.⁸ Fig. 8 show the five regions corresponding to the research areas drawn from data points (selected journals) of Fig. 7. The engineering region shows the characteristic trend line with the equation $y = 36.39\ln(x) - 234.02$ where x is the number of journal articles published in 2009-2013 and $-y$ is the 5 year H-index of journal articles. In the same way other regions show the values of trend lines as in Fig. 8 (Δ is gradient of trend line). All the research areas do not show much difference in the attention or importance by different research area except chemical engineering.

Although the H-index and the number of journal articles of engineering area show lowest portion among the research areas, the gradient of trend line is the highest. Environmental science, material

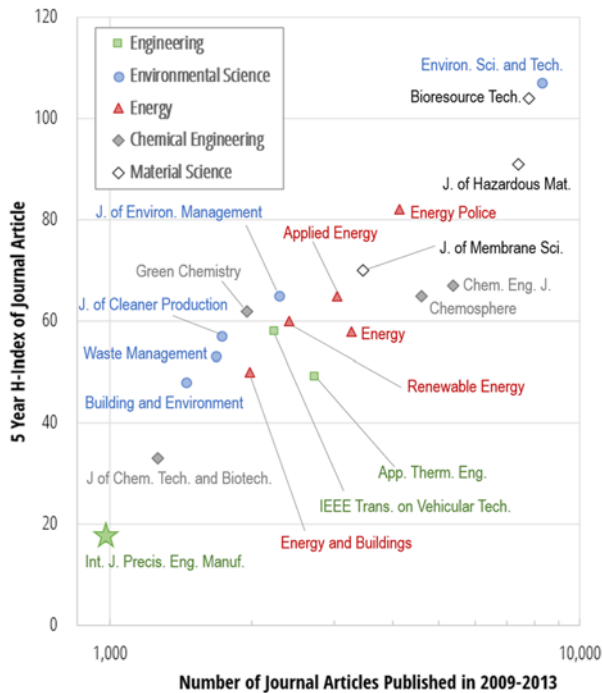


Fig. 7 Comparison of journals from 5 different research areas in green technology

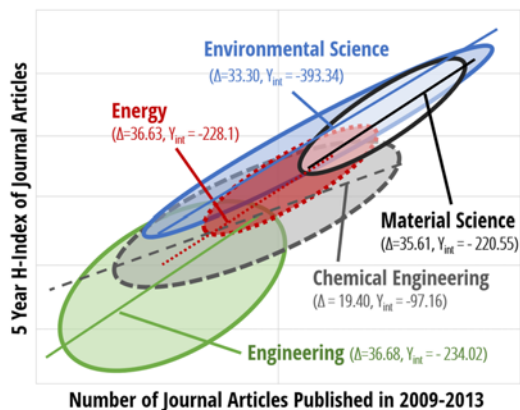


Fig. 8 A schematic diagram of the location of journal articles in different research areas. The gradient of trend lines are calculated by the method in reference 8 and shown in parentheses

science, and energy areas have more attention and thus increase in the number of papers and active researchers.

Green technology research in the area of engineering occupies 6.43% as shown in Fig. 9. Engineering related to green technology has recently gained attention compared to other research areas. Whereas engineering as a whole contributes the highest percentage of publications (14.9%), it can be expected that the attention of green technology will increase in the coming years.

3. Conclusions

As importance and attention to minimize energy consumption,

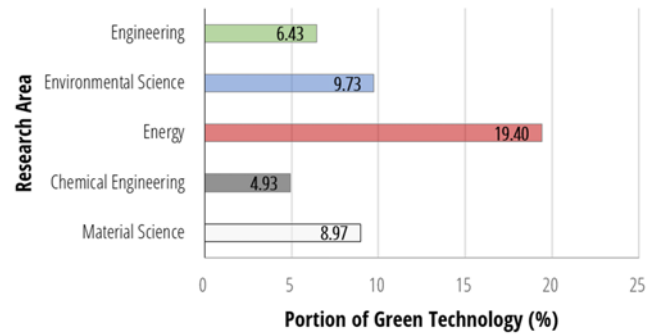


Fig. 9 Portion of green technology by research areas in recent 5 years (2009~2013)

environment concerns, and efficiency in manufacturing are increasing, green technology will be a key issue in the manufacturing related research areas. The trend of the green technology was summarized for the last two decades by research area and country. In the last 20 years, green technology was led by United States but China gained more strength in this area recently. Asian countries have gained more interest in green technology and journal articles from Korea increased over 200 times compared to 1994 in the same field. Representative journals were compared with its 5 year H-index and engineering area showed most attention or importance to researchers compare to other research areas in engineering. From the previous research trend, we can conclude that the importance and attention of the green technology is increasing.

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