CHAPTER – I

INTRODUCTION: A BACKGROUND TO THE STUDY OF GREEN COMPUTING AND SCIENTOMETRICS

Computing technology plays a crucial role in our day to day activities. Subsequently the associated high volume of energy consumption has become a major concern both economically and environmentally. Green Computing is an emerging applications in computing technology that can reduce energy consumption effectively, which leads to significant CO$_2$ emission reduction. Green Computing has become an essential component that needs to be considered seriously by the next generation information and communication technology designers. Green Computing is to use computers and related resources in environment friendly ways. Such practices include the implementation of energy-efficient central processing units (CPUs), servers and peripherals as well as finding innovative ways of reducing resource consumption and proper disposal of electronic waste. Many IT manufacturers and vendors continuously invest in designing energy efficient computing devices, reducing the use of dangerous materials, and encouraging the recyclability of digital devices and printing paper. Green Computing practices were primarily introduced by the Environmental Protection Agency in 1992 with the launch of the Energy Star program.
Green Computing has become an innovative way on how technology and ecology converge together. With the recent years many industries and companies have turned their attention in realizing how going 'green' can benefit public relations, reducing costs, and lowering global emissions from industrial manufacturing. Though the term Green Computing covers a vast range of methods, from energy saving techniques, to the study of materials used in our lives, it all fundamentally breaks down to find ways not to damage or consume all of earth’s natural resources. Though ultimately Green Computing focuses on ways in reducing overall environmental impact, its main purpose is to find and promote new ways of reducing pollution, discovering alternative technologies, and creating more recyclable products (Gingichashvili, 2007).

1.1 Green Computing

Green Computing is the term used to denote efficient use of resources in computing. This term generally relates to the use of computing resources in conjunction with minimizing environmental impact, maximizing economic viability and ensuring social duties. Green Computing is very much related to other similar movements like reducing the use of environmentally hazardous materials like CFCs, promoting the use of recyclable materials, minimizing use of non-biodegradable components, and encouraging use of sustainable resources.
One of the spin-offs of Green Computing is EPEAT or Electronic Products Environmental Assessment Tool. EPEAT products serve to increase the efficiency and life of computing products. Moreover, these products are designed to minimize energy expenditures, minimize maintenance activities throughout the life of the product and allow the re-use or recycling of some materials.

The first manifestation of the Green Computing movement was the launch of the ENERGY STAR program back in 1992 and ENERGY STAR served as a kind of voluntary label awarded to computing products that succeeded in minimizing use of energy while maximizing efficiency. Indeed ENERGY STAR has been applied to products like computer monitors, television sets and temperature control devices like refrigerators, air conditioners, and similar items.

One of the first results of Green Computing is the Sleep mode function of computer monitors which place a consumer's electronic equipment on standby mode when a pre-set period of time passes when user activity is not detected. As the concept developed, Green Computing began to encompass thin client solutions, energy cost accounting, virtualization practices, and eWaste.

1.1.1 Green Computing Practices

Some common Green Computing practices include turning off the monitor when it is not in use or using more energy efficient monitors like LCDs instead of
traditional CRT monitors, volunteer computing or file sharing practices, virtualization of servers, using more energy efficient and less noisy cooling systems (like using liquid cooling systems instead of the conventional heat sinks and fans), temperature maintenance and regulation to reduce thermal shock wear and tear to computer parts, and increased online security measures through the use of firewalls, anti spyware and anti virus programs to reduce the increasing amount of eWaste on the Internet and on other networks.

1.1.2 Distinctive Features of a Green Computer

Green computer features help in determining whether the computer users buy is truly green or not. Most computer manufacturers have introduced a series of green PCs, but do not investigate the following features to ascertain how green their computers are.

- **Low Use of Hazardous Elements:** A lot of hazardous substances are used in the production of a computer ranging from the more lethal ones like cadmium, lead, chromium, and mercury to the relatively less hazardous ones like flame retardants, pesticides, and chlorinated plastics. A green computer components should ideally be completely free of these lethal substances; thus IEEE environmental performance criteria requires the manufacturers of green computers to explicitly declare the percentage composition of these substances on the product. As for the less hazardous substances, the focus is on reduction of their use, since their elimination may not be completely possible.
• **Energy Efficiency** is one of the features of Green Computers that pleases not only the environmental enthusiasts but also the budget-conscious buyer. Every green computer will have an energy star rating on it, and the more the stars the more energy efficient the computer will be. Some green computers are also available with the option of running them on renewable energy like solar energy, for which the manufacturers will supply with all the required accessories.

• **Recycled Materials Used for Manufacturing:** A truly green computer will have most of its components, especially the plastic ones, made of recycled materials. Indeed the manufacturers are required to declare the percentage of recycled material used in the production of the computer and it should be with minimum thresholds at 10 percent. However, it is more environmentally friendly to opt for a computer built with more than 25 percent of recycled material. Ideally, printed circuit boards are the only things that may not contain recycled material.

• **End of Life Recovery:** The green computers are designed in such a way that at the end of their life their components can be easily reused, disassembled, or recycled. A minimum of 65% of the parts of the computer should be recyclable or reusable. Apparently, some of the better brands of green computers guarantee a minimum of 90% reusable or recyclable parts. Also, the parts that are hazardous should be marked accordingly for easy identification and expert handling.
• **Use of Renewable and Bio-Based Materials:** Another of the important green computer feature is the increased use of renewable or bio-based materials. Again a minimum of 10 percent of such materials should have been used in the production of the green computer components, and the same must be declared.

• **Longer Life:** Green computers come in modular and upgradeable designs with the idea of extending their life cycle. The manufacturers are required to provide a minimum of 3 years warranty or guarantee, and they must also ensure that the replacement parts will be made available to all buyers upto a minimum of five years and this is certainly a good reason to buy a green computer.

• **End of Life Take-back Facility:** Every green computer comes with a take-back policy, wherein the manufacturer provisions to take back the computer at the end of its life and offer the buyer a new purchase at a competitive price. Hence, it is mandatory to verify the brand of Green Computer in buying or taking back.

• **Manufacturer's Certification:** Before settle on a particular brand of green computers, must ensure that its manufacturer has ISO-14001 certification, which is the bare minimum for a manufacturer to qualify as environmental-policy compliant.

• **Packaging Material:** Further the question of the material used in recyclable packages too important. Hence checking the packaging material details is
essential to see that the material used is completely non-toxic and at least 90% of it is recyclable. It will be even better if the packaging is made of recycled material.

- **EPEAT Ratings:** Before making the final decision of the purchase a bit of research on www.epeat.net, where all green computers and laptops have been assigned a rating and this will clearly tell the buyers how Green the computer is and with this the buyer can find detailed reports on how each of these computers score on the different environmental criteria.

### 1.2 LIBRAMETRY TO INFORMATRICS: AN OVERVIEW

#### 1.2.1 LIBRAMETRICS

Application of quantitative techniques to library and bibliographical work was until recently known as statistical bibliography. Witting (1978) stated that the term ‘statistical bibliography’ was traced and found used by Hulme in 1923. Ranganathan (1948, 1969) announced the term ‘Librametry’ on the lines of biometry, econometry, and psychometry and illustrated with a few examples of the application of statistics to library science. P.C. Mahalanobis, the founder of the Indian Statistical Institute, Calcutta, stated that the statistics was the ‘key technology’ for all development and forecasting studies. The ‘bibliometric’ term was coined by Pritchard (1969) who described that bibliometrics was a simple statistical method of bibliography used to evaluate and quantify the growth of a subject. He also described the scope of the
Librametry and defined Bibliometrics as the “statistical distribution of the processes relating to establish a theory for the structural aspects of a library”. Garfield (1970) and he indicated that proper bibliometric analysis could identify the present focus of scientific research.

Ravichandra Rao (1981) stated that the information process and handling of information in libraries and information centres were done by quantitatively analyzing their characteristics and behavior of documents by library staff and library users. The British Standards Institution defines ‘bibliometrics’ as the study of the use of documents and patterns of publications in which mathematical and statistical methods have been applied. According to Howkins (1981) the term bibliometrics implied the “quantitative analysis of the bibliographical features of the body of a literature”. More recently Sengupta (1973) has defined this term as the “organisation, classification and quantitative evolution of publication pattern of all micro and macro level communication along with the authorship pattern by mathematical and statistical calculus”.

1.2.2 BIBLIOMETRICS

Bibliometrics means literally "book measurement" but the term is used about all kinds of documents (with journal articles as the dominant kind of document). What are measured are not the physical properties of documents but statistical patterns in variables such as authorship, sources, subjects, geographical origins, and citations. "The definition and purpose of bibliometrics is to shed light on the process
of written communications and of the nature and course of a discipline (in so far as this is displayed through written communication) by means of counting and analyzing the various facets of written communication. (Pritchard, 1969.)" (Here quoted from Nicholas & Ritchie, 1978). Egghe & Rousseau (1990) write:

"Historically, bibliometrics developed mainly in the West, and arose from statistical studies of bibliographies. Earlier to the term "bibliometrics" proposed by Pritchard (1969), the term "statistical bibliography" was in use. According to Prichard (1969), it was Hulme (1923) who initiated the term "statistical bibliography". Hulme used the term to describe the process of illuminating the history of science and technology by counting documents. Pritchard's timely proposal caught on immediately, but the content of the term remained somewhat of a problem (Broadus, 1987). According to Prichard, “bibliometrics means the application of mathematics and statistical methods to books and other communication media”.

Bibliometrics is particularly related to research in scientific communication. Schmidmaier (1984) discusses the history of bibliometrics and demonstrates its relation to the concept "the science of science", which is traced to lectures given by Carl Christian Friedrich Krause in 1829. In the former USSR it was G. M. Dobrov's investigation of the science of science from 1966 a pioneer work. Cole and Eales, who analyzed books published between 1550 and 1860 with regards to developments in subject matter, published the first genuine bibliometric investigation in 1917.
Investigations by P. L. K. Gross in 1927 and H. H. Henkle in 1938 on biochemical literature together with later works by S. R. Ranganathan (1969) and Solla Price (1976) belong to the foundational literature of bibliometrics (Ranganathan proposed the term 'librametrics' in 1948). In European information science journals bibliometric investigations began to be popular in the 1970’s and 1980’s. Hungary, Eastern Germany and Switzerland belong to the countries, which early started to do research in bibliometrics.

Bibliometrics is an LIS research method. It is a quantitative study of the literature on a topic and is used to identify patterns of publication, authorship, and secondary journal coverage to get an insight into the growth of knowledge on that topic. This leads to better organization of information resources which is essential for effective and efficient use. Bibliometrics has attained a sophistication and complexity, and has a national, international, and interdisciplinary character. The present study focuses attention on the bibliometric analysis of publication in the area of ecology.

The term “Bibliometrics” was coined by Pritchard in 1969, and its practice can be traced back to the second decade of the 20th century. A very early example of a bibliometric study was a “statistical analysis of the literature” of comparative anatomy from 1543 to 1860, which counted books and journal article titles, and grouped them by countries of origin within periods. In 1923, Hulme conducted a study on the history of science. His analysis was based on the seventeen sections of the English International Catalogue of Scientific Literature.
A third study was the pioneering work of Gross and Gross, reported in 1927. They counted and analyzed the citations in articles in the *Journal of the American Chemical Society*, and produced a list of significant journals in chemical education. Another prominent work was Bradford (1934) on the distribution of lubrication research. This research formed the backbone of the theoretical foundation of the bibliometric study, known as the “Bradford's Law of Scattering.”

Bibliometrics has been known by other names, including “statistical analysis of the literature” (Cole and Eales 1917), while Hulme used the term “statistical bibliography” in 1923.

In 1948, the great library scientist S.R. Ranganathan coined the term “librametry”, which referred to measurement used to streamline library services. “Bibliometrics” is analogous to Ranganathan's librametrics, the Russian concept scientometrics, FID's infometrics, and to some other well established sub-disciplines such as econometrics, psychometrics, sociometrics, biometrics, technometrics, chemometrics, and climetrics, where mathematics and statistics have been systematically applied to study and solve problems in a given field. The term “scientometrics” is currently used for the application of quantitative methods to the history of science, and obviously overlaps with bibliometrics to a considerable extent.

Bibliometrics is a type of research method used in library and information science. It utilizes quantitative analysis and statistics to describe patterns of
publication within a given field or body of literature. Researchers may use bibliometric methods of evaluation to determine the influence of a single writer, for example, or to describe the relationship between two or more writers or works. One common way of conducting bibliometric research is to use the Social Science Citation Index, the Science Citation Index or the Arts and Humanities Citation Index to trace citations.

1.2.3 SCIENTOMETRICS

Scientometrics is a branch of library and information science. Scientometric tools can be used to measure and compare the scientific activities at various levels of aggregation including institutions, sectors, provinces and countries. They can also be used to measure research collaborations, to map scientific networks and to monitor the evolution of scientific fields. Scientometric indicators give policy-makers objective, reproducible and therefore verifiable information that goes beyond the anecdotal. Scientometrics empirically describes the constantly changing relationship between science, technology and the research productivity. This consequently sheds more light on the structure of subject literature and better organization of information resources which can ultimately be effectively used for various purposes including regeneration of information. Scientometrics is concerned with the quantitative features and characteristics of science and scientific research. Emphasis is placed on investigations in which the development and mechanism of science are studied by statistical mathematical methods.
Scientometrics is a discipline, which uses statistical and computational techniques in order to understand the structure and dynamics of science. Nalimov and Mulchenko (1969) of USSR defined scientometrics as the quantitative methods which deals with the analysis of science viewed as an information process. According to Beck (1978) scientometrics is defined as the quantitative evaluation and inter-comparison of scientific activity, productivity and progress.

Tague-Sutcliffe (1992) defined scientometrics as a “study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy making. It involves quantitative studies of scientific activities including, among others, publication, and so overlaps bibliometrics to some extent. Bookstein (1995) defined scientometrics as “the science of measuring science”. Scientometrics is also considered as bibliometrics measurement for evaluation of scientific development, social relevance and impact of application of science and technology.

Scientometrics is the science of measuring and analysing science. In practice, scientometrics is often done using bibliometrics, which is a measurement of the impact of (scientific) publications. Modern scientometrics is mostly based on the work of Derek J. de Solla Price and Eugene Garfield. The latter founded the Institute for Scientific Information, which is heavily used for scientometric analysis. Methods of research include qualitative, quantitative and computational approaches. One significant finding in the field is a principle of cost escalation to the effect that achieving further findings at a given level of importance grow exponentially more
costly in the expenditure of effort and resources. Related fields are the history of science and technology, philosophy of science and sociology of scientific knowledge.

Scientometrics--the quantitative study of scientific communication--challenges science and technology studies by demonstrating that organized knowledge production and control is amenable to measurement. Scientometrics is the science of measuring and analysing science. In practice, scientometrics is often done using bibliometrics, which is a measurement of the impact of (scientific) publications. (Wikipedia)

Scientometrics is the science of measuring and analyzing science. In practice, scientometrics is often done using bibliometrics that is measurement of (scientific) publications. Scientometrics means literally "measurement of science". In reality it means the application of statistical indicators (especially bibliometric indicators) as a mean for the evaluation of scientific productivity. "The term "scientometrics" (derived from the Russian "naukometria") was used mainly in the East and is defined as the study of the measurement of scientific and technological progress. This also explains the foundation in 1978 and the title of the journal Scientometrics in Hungary. For more information on the history and the contents of these names, we refer the reader to Egghe (1988f) Scientometrics deals mainly with science policy applications." (Egghe & Rousseau, 1990).

Scientometrics are used to quantify scientific activities. Generally quantification of scientific activities is measurable by producing statistics on
scientific publications indexed in indicator databases such as SCOPUS and Web of Science. Scientometric data can be useful to measure research collaborations among scientific environments and to monitor the evolution of special scientific subjects and fields. Also decision and policy-makers are going to be interested in scientometric indicators.

Scientometrics is “the study of the measurement of scientific and technological progress” (Garfield, 1979). Its origin is in the quantitative study of science policy research, or the science of science, which focuses on a wide variety of quantitative measurements, or indicators, of science at large. Typically input and output of science programs correspond to two major categories of indicators. Input indicators include the amount of research grants awarded to institutions and the number of people receiving scientific degrees; output indicators include the number of scientific articles published, the number of citations to each article, and the number of patents granted. Science policy and program evaluation studies have used such indicators to measure the scientific strength of various countries, regions, or research institutions. Domain analysts have used such indicators to describe the intellectual structure of a knowledge domain. Scientometrics is the demographics of the worldwide scientific community. As Garfield put it, “One can follow the growth or decline of various fields or identify where the action is.” (ibid.)
1.2.4 INFORMATRICS

The most recent metric term ‘Informatrics’ which comes from German was first proposed in 1979 by Nacke and described it as to cover all parts of information science, dealing with the measurement of information phenomenon and the application of mathematical methods to the discipline’s problems to parts of the information retrieval theory and bibliometrics.

In the second international conference on ‘bibliometrics, scientometrics and informatics’ held at Canada, Hemalatha Iyer, (1987) pointed out that the late B.C. Brooke’s suggestion about the term ‘informatrics’ was most meaningful to represent bibliometrics, scientometrics and many other quantitative studies related to information science. In the third conference held at Bangalore, India in 1991, the term informatrics was used as a generic term and was described as “use and development of a variety of measures to study the several properties of information in general and documents in particular”. Obviously this covers bibliometrics and scientometrics.

1.3 LAWS AND TOOLS OF BIBLIOMETRICS AND SCIENTOMETRICS

One of the main areas in bibliometric research is concerned with the application of bibliometric laws. The three most commonly used laws in bibliometrics are: Lotka's Law of Scientific Productivity, Bradford's Law of Scatter, and Zipf's Law of Word Occurrence.
1.3.1 LOTKA’S LAW

Lotka's Law describes the frequency of publication by authors in a given field. It states that "... the number (of authors) making n contributions is about 1/n^2 of those making one; and the proportion of all contributors, that make a single contribution, is about 60 percent" (Lotka 1926, cited in Potter 1988). This means that out of all the authors in a given field, 60 percent will have just one publication, and 15 percent will have two publications (1/2^2 times .60). 7 percent of authors will have three publications (1/3^2 times .60), and so on. According to Lotka's Law of scientific productivity, only six percent of the authors in a field will produce more than 10 articles. Lotka's Law, when applied to large bodies of literature over a fairly long period of time, can be accurate in general, but not statistically exact. It is often used to estimate the frequency with which authors will appear in an online catalog (Potter 1988).

1.3.2 BRADFORD’S LAW

Bradford's Law serves as a general guideline to librarians in determining the number of core journals in any given field. It states that journals in a single field can be divided into three parts, each containing the same number of articles: 1) a core of journals on the subject, relatively few in number, that produces approximately one-third of all the articles, 2) a second zone, containing the same number of articles as the first, but a greater number of journals, and 3) a third zone, containing the same number of articles as the second, but a still greater number of journals. The
mathematical relationship of the number of journals in the core to the first zone is a constant \( n \) and to the second zone the relationship is \( n^2 \). Bradford expressed this relationship as \( 1:n:n^2 \). Bradford formulated his law after studying a bibliography of geophysics, covering 326 journals in the field. He discovered that 9 journals contained 429 articles, 59 contained 499 articles, and 258 contained 404 articles. So it took 9 journals to contribute one-third of the articles, 5 times 9, or 45, to produce the next third, and 5 times 5 times 9, or 225, to produce the last third.

As may be seen, Bradford's Law is not statistically accurate, strictly speaking. But it is still commonly used as a general rule of thumb (Potter 1988).

### 1.3.3 ZIPF’S LAW

Zipf's Law is often used to predict the frequency of words within a text. The Law states that in a relatively lengthy text, the "list of the words occurring within that text in order of decreasing frequency, the rank of a word on that list multiplied by its frequency will equal a constant. The equation for this relationship is: \( r \times f = k \) where \( r \) is the rank of the word, \( f \) is the frequency, and \( k \) is the constant (Potter 1988). Zipf illustrated his law with an analysis of James Joyce's Ulysses. "He showed that the tenth most frequent word occurred 2,653 times, the hundredth most frequent word occurred 265 times, the two hundredth word occurred 133 times, and so on. Zipf found, then that the rank of the word multiplied by the frequency of the word equals a constant that is approximately 26,500" (Potter 1988). Zipf's Law, again, is not statistically perfect, but it is very useful for indexers.
1.3.4 WEB APPLICATIONS OF BIBLIOMETRICS

Recently, a new growth area in bibliometrics has been in the emerging field of webmetrics, or cybermetrics as it is often called. Webmetrics can be defined as using of bibliometric techniques in order to study the relationship of different sites on the World Wide Web. Such techniques may also be used to map out (called "scientific mapping" in traditional bibliometric research) areas of the Web that appear to be most useful or influential, based on the number of times they are hyperlinked to other Web sites.

1.3.5 BIBLIOGRAPHIC COUPLING

Bibliographic coupling occurs when two works reference a common third work in their bibliographies. It is an indication that the two works treat a related subject matter. Measuring bibliographic coupling can be useful in a wide variety of fields since it helps researchers find related research done in the past, though its exact interpretation may vary depending on the field, since different fields have different citation practices. There are various metrics of bibliographic coupling, usually calculated using citation indexes. The coupling strength of two given documents is higher the more citations they have in common. The co-citation index is the number of times two works are cited together in subsequent literature. The concept of "bibliographic coupling" was first introduced by M. M. Kessler of MIT in a paper published in 1963, and has been embraced in the work of the information scientist
Eugene Garfield. Others have questioned the usefulness of the concept, pointing out that the two works may reference completely unrelated subject matter in the third.

1.4 STATEMENT OF THE PROBLEM

As an emerging topic in IT management, “Green IT” practices are drawing high interest among IT organizations as well as suppliers, manufacturers and service providers. With the rapid run up of energy costs and a broadening awareness of the impact of global climate change, IT organizations are looking for strategies to offset rising costs and use technology in ways that reduce their environmental impact. By keeping this view in mind, the researcher intends to undertake the study on “Mapping the Research Productivity of Green Computing: A Scientometric Study”. This study attempts to analyse the performance of researcher working in the field of Green Computing in terms of growth rate, areas of research concentration, authorship pattern, scattering of articles in different sources, institution wise distribution and so on.
1.5 CHAPTERIZATION

The thesis is divided into five chapters.

- The first chapter presents the Introduction about Scientometrics and Green Computing.
- The second chapter discusses the related Review of Literature and its impact on the present research.
- The third chapter describes the Research Design of the study.
- The fourth chapter presents the detailed Data Analysis and Discussions.
- The fifth chapter reports the findings, suggestions and Conclusion.
REFERENCES


