PROJECT REPORT ON:

CARBON EMISSION PRESENTATION

INDEX

ABSTRACT

The production of solar energy in cities is clearly a way to diminish our dependency to fossil fuels, and is a good way to mitigate global warming by lowering the emission of greenhouse gases. However, what are the impacts of solar panels locally? To evaluate their influence on urban weather, it is necessary to parameterize their effects within the surface schemes that are coupled to atmospheric models. The present paper presents a way to implement solar panels in the Town Energy Balance scheme, taking account of the energy production (for thermal and photovoltaic panels), the impact on the building below and feedback toward the urban micro-climate through radiative and convective fluxes. A scenario of large but realistic deployment of solar panels on the Paris metropolitan area is then simulated. It is shown that solar panels, by shading the roofs, slightly increases the need for domestic heating (3%). In summer, however, the solar panels reduce the energy needed for air-conditioning (by 12%) and also the Urban Heat Island (UHI): 0.2 K by day and up to 0.3 K at night. These impacts are larger than those found in previous works, because of the use of thermal panels (that are more efficient than photovoltaic panels) and the geographical position of Paris, which is relatively far from the sea. This means that it is not influenced by sea breezes, and hence that its UHI is stronger than for a coastal city of the same size. But this also means that local adaptation strategies aiming to decrease the UHI will have more potent effects. In summary, the deployment of solar panels is good both globally, to produce renewable energy (and hence to limit the warming of the climate) and locally, to decrease the UHI, especially in summer, when it can constitute a health threat.

1.INTRODUCTION

Renewable energy is seen as a necessary step toward sustainable energy development, diminution of the use of fossil fuels and mitigation of climate change, as stated for example by Elliott (2000): “With concerns about Climate Change growing, the rapid development of renewable energy technologies looks increasingly important.” However, the recent analysis of Nugent and Sovacool (2014) showed that, when their complete life-cycle is considered, renewable energies are not CO_2 sinks yet. Nevertheless their greenhouses gas emission rate per unit of energy produced is much less than for energy sources based on fossil fuels and slightly less than for nuclear power. They also “uncover best practices in wind and solar design and deployment that can better inform climate change mitigation efforts in the electricity sector.” Elliott (2000) underlines that renewable energy deployment requires a new paradigm, of decentralized energy production and small production systems. The implementation of renewable energy will need social and institutional changes, even if technology for these systems already exists (Gross et al., 2003, while still needing improvements and further research Jader-Waldau, 2007). Funding, incentive policies and statutory obligations on electricity suppliers may be needed to develop renewable energy faster. Lund (2007) demonstrates that, in Denmark, a transition toward 100% of renewable energy production is possible. Sovacool and Ratan (2012) conclude that nine factors linked to policy, social and market aspects favor or limit the development of wind turbines and solar energy, and explain why renewable energy is growing fast in Denmark and Germany compared to India and the USA.

Sims et al. (2003) show that most renewable energies can, in certain circumstances, reduce cost as well as CO_2 emissions, except for solar power, which remains expensive. However, Hernandez et al. (2014) review the environmental impacts of utility-scale solar energy installations (solar farms), which are typically implemented in rural areas, and show that they have low environmental impacts relative to other energy systems, including other renewables. Furthermore, solar power is also one of the few renewable energy sources that can be implemented on a large scale within cities themselves. Arnette (2013) shows that, compared to solar farms, individual rooftop solar panels are a very cost-effective means of increasing renewable energy generation and decreasing greenhouse gas emissions. So they conclude that solar panel implementation on roofs should be part of a balanced approach to energy production. Here, we aim to evaluate the environmental impacts on the local climate, of implementing such a strategy at city scale.

The main impact of cities on the local weather is the Urban Heat Island (UHI). Cities are warmer than the surrounding countryside, and this can lead to a health crisis during heat waves, as was the case in Paris in 2003 with 15,000 premature deaths (Fouillet et al., 2006) or in Moscow with 11,000 premature deaths in 2010 (Porfiriev, 2014). It also has to be considered that, due to climate warming, the UHI impacts will become even larger than they are now (Lemonsu et al., 2013). Therefore, several strategies are being studied to reduce the UHI in summer. Gago et al. (2013) have reviewed several research works analyzing strategies to mitigate the UHI, including changes in green spaces, trees, albedo, pavement surfaces, vegetation, and building types and materials. Santamouris et al. (2011) have reviewed of several advanced cool materials systems usable to reduce the UHI. Such materials could be implemented on roofs in order to reflect more energy to the sky (high albedo, high emissivity) or to delay the heat transfer toward the inside the building (phase change materials). Masson et al. (2013) showed that changes in agricultural practices in the vicinity of Paris and the use of cool materials for roofs and pavement would decrease the UHI by 2 K and 1 K, respectively. However, the question of the ability of solar panels to contribute to the same goal is not addressed in these papers, and extremely few studies focus on, or even take into account, the effect of solar panels on the UHI.

It is thus necessary to analyze whether the two objectives of mitigating the global climate warming by increasing renewable energy production in cities, especially through solar panels, and of attenuating the UHI are compatible. Solar panels modify the nature of the rooftop and may thus influence the energy transfers to the atmosphere and the resulting UHI. The aim of this paper is then to evaluate the impact of solar panels, known to be good for global warming mitigation, on the local climate, especially the UHI.

2. Solar Panels into the Urban Canopy Model TEB

The objective of this section is to present how solar panels can be included in the Town Energy Balance (TEB, Masson, 2000) scheme, in terms of both energy production and interactions with the roofs below (shading, modification of the roof energy balance, etc.). The solar panels themselves can be either photovoltaic panels or thermal panels that heat water.

2.1. Modeling Strategy

The solar panel exchanges energy with the other components of the system. Very few parameterizations taking these exchanges into account exist in the literature. The level of detail depends strongly on the objectives of the authors. On the one hand, when looking at the building scale, it is possible to consider some implementation characteristics of the panels, as in Scherba et al. (2011), who modified the Energy+ software (software dedicated to building energetics) to improve its previous solar panel model (which only computed the energy production). Their solar panel model considers the tilting of the panels and associated sky-view factors. They then perform an analysis of the impact of several types of roofs on sensible heat fluxes toward the atmosphere, but are unable to link these fluxes to the UHI, which needs to take all the buildings of the entire city into account. On the other hand, Taha (2013) studies the impact of solar panels on the whole urban area of Los Angeles. To do this, he uses the very simplified approach of effective

albedo, which accounts for both the albedo and the solar conversion efficiency (linked to the energy produced). This approach estimates the impact on the UHI, but does not take account of the interactions with the urban canopy below (solar panel shadowing may lead to less cooling energy being used in buildings for example, leading to less waste heat outside).

In order to study the impact of solar panels implementations on the urban atmosphere and on the population and buildings, we need an approach that looks at both spatial scales: buildings and city. The TEB scheme is able to simulate the energy, water and momentum exchanges between cities and the atmosphere at a resolution as high as the urban block (say down to 100 m by 100 m). The energetics of buildings have also been included in TEB by Bueno et al. (2012) and Pigeon et al. (2014), to simulate the energy behavior of a typical building representative of the block. The focus is to keep the maximum of key processes, while making some approximations in the geometry that are pertinent at block scale (building shapes are averaged into road canyons, only one thermal zone is kept in the buildings, individual windows are averaged into a glazing fraction, etc.). Gardens and greenroofs modules have also been implemented (Lemonsu et al., 2012; DeMunck et al., 2013a). The modeling strategy chosen here for the implementation of solar panels is similar: key processes are kept while some geometrical assumptions are made to avoid unnecessary details of individual buildings.

In TEB, it is necessary to take account not only of the production of energy by the panels but also the influence of the panels on the underlying roofs. We must therefore calculate the complete energy balance of the panel to determine what is exchanged with the roof or the atmosphere. The TEB model will then be able to estimate the impact of solar panel implementation on the UHI at city scale, as well as the production of energy.

Modification of the Energy Balance of the Roof

For the energy balance of the roof, the most important key parameter will, of course, be the proportion of roof area occupied by the solar panels. As mentioned above, we only consider the projection of the panels onto the horizontal surface (it would be absurd to make accurate calculations taking the inclination of the panels into account—except as noted above for production—when it is already assumed in TEB that all roofs are flat). The fraction of the roof covered by solar panels is noted p_{anels}.

The following simplifying assumptions are made:

- An average temperature is still calculated for the roof, without distinguishing between the parts of the roof under or beside the panel. This is reasonable, in particular for flat roofs with inclined panels, because the shadows cast by the panels can modify the radiative contribution to the roof beside as well as below the panels.
- The coefficient for heat transfer from the roof to the sensible heat flux is not changed (it is already in a heterogeneous environment with a roughness length of 5 cm).
- The effect of humidity on panels is neglected: the water interception reservoir treating rainwater and evaporation concerns the whole surface of the roof.
- The effect of solar panels on snow is neglected. The snow mantel, if any, accumulates uniformly on the roof. Note that snow might change the energy produced by the solar panel (but this is not taken into account yet).

These assumptions allow us to change only the radiative contributions to the energy balance of the roof. Assuming that the surface area of the shadows is equal to the surface area of the solar panels, the incoming solar radiation on the roof is:

$$SW\downarrow roof=(1-fpanel)SW\downarrow sky \quad (6)SWroof\downarrow=(1-fpanel)SWsky\downarrow \quad (6)$$

The long-wave incoming radiation on the roof is modified by the long-wave radiation emitted downwards by the solar panels:

$$LW\downarrow roof=(1-fpanel)LW\downarrow sky+fpanelLW\downarrow panel$$
$$(7)LWroof\downarrow=(1-fpanel)LWsky\downarrow+fpanelLWpanel\downarrow \quad (7)$$

This way of implementing the interactions between solar panels and the roof below allows the considerations of the way the roof is built to be separated from the question of whether there are solar panels on it or not. For example, although it is not the case in this paper, it is possible to have greenroofs with or without solar panels. If there are solar panels, the vegetation of the greenroof will simply be more in the shade and receive slightly more infrared radiation.

Radiative Characteristics of Solar Panels

To establish the energy balance of the equivalent urban canyon, the TEB model needs the albedo (integrated between 0.4 and 2.5 µm) and the emissivity in the thermal infrared (integrated between 5 and 12 µm) for the following main areas: road, roofs, facades, glazing. The French Center for Aerospace Research (ONERA) laboratory maintains a current database of optical properties of urban materials. Specific measurements were made for emerging materials: rough white paints, photovoltaic solar panels, metal cladding, and glass (including low emissivity). The measurements for large samples of materials, e.g., for solar panels, were made using a goniometer

2.LITERATURE OVERVIEW

With green house gas emissions and global warming, Government is trying very hard and has taken considerable steps to preserve the environment, one of the steps being, the use of renewable, clean and green energy resource. In spite of its efforts to promote the use of solar energy products, various incentives and subsidies, there is marginal increase in the use of solar energy products. One needs to seriously think about the marketing strategies to promote the use of these products. Very less has been found and done in the area of marketing solar energy products. Thus there is not much literature available for review.

Critical Review Related to Environment Consciousness

Allaby, M. (1990) in his book Green Facts: The Greenhouse Effects & Other Key Issues, suggests that Nuclear power can be one of the best options for clean, and green energy. He further mentions that, Sunlight and solar heat can be used to generate electricity or for direct heating, but they are limited geographically. In Developing Marketing Strategies for Enhancing the Use of Solar Energy Products Anupamaa S Chavan 11 Britain, there may be too little warmth in the sunshine to provide useful amounts of heat in winter, although it can contribute to water heating in summer. He further states that installation is expensive, because heat is transferred by warming water; the plumbing is complex and needs maintenance. The suggestion made by the author for using Nuclear energy can be challenged, since you can get Nuclear energy only till you have uranium ore in the mines. Thus one needs to think of renewable energy, and Solar energy which is untapped fully becomes a very good source of energy. The efficiency of the system also relies on the location of the sun, although the latest technology has helped in overcoming this problem i.e. by installation of certain components which absorb the minimum sunlight to create energy. Though the initial cost is higher, there are no utility bills; and energy from Sun is practically free. In India Government also provides subsidy on solar energy products.

Renewable energy projects in the form of solar, wind and hydropower generated electricity are the keys to provide rural area with energy where power is in short supply. Authors further state that in the absence of co-ordinated government efforts, including stricter enforcement, air pollution is likely to continue to worsen in coming years. Government is trying hard to curtail pollution and is encouraging the use of Developing Marketing Strategies for Enhancing the Use of Solar Energy Products Anupamaa S Chavan 12 solar and wind energy by giving various incentives such as financial assistance and subsidies, but still there is no substantial increase in their use. It is required to further investigate and find out the reasons and take necessary steps to enhance the use of clean energy.

Critical Review related to Marketing Strategies

Uberoi, (2007) in his book on Environmental Management states that, Energy is an essential need for human existence. There is shortage of energy due to fast depletion of fossil fuels and the increase in demand for energy due to the increase in population and the growth of industry. The energy demands are increasing while conventional energy sources are diminishing at a much faster rate. The rising energy demand has resulted in the setting up of more power plants which are based primarily on fossil fuel (coal, oil, gas). The fossil fuels based plants not only emit green house gases like Carbon dioxide (CO_2) but also generate fly-ash which is dangerous to human health. The emission of CO_2 the main green gas, is expected to surpass that of the Organization for Economic Co-operation and Development (OECD) countries by the year 2015. Hydro plants have also been installed to generate energy but these plants also create problems like human displacement and are damaging the ecosystem. The nuclear option comes with its own set of problems. Uncertainties surrounding the safety and economics of radioactive waste disposal and decommissioning remain. The mishap at Tokaimura, Japan in September 1999 shows that the danger of a nuclear accident is still very real. The use of biomass again should be equated with rate of consumption. The use of solar energy can be another very good option for renewable energy resource. It is freely available and a very clean and quiet source of energy generation. The author further states that the Government at the centre and at the State level and their agencies should become proactive vis-à-vis environment. The environmental problems cannot be tackled without a sound proactive policy by the Government. Intervention of the Government is required on continuing basis and not on one-time legislation and its implementation. Corporate behaviour can be regulated or altered through state policies. The policies of Government can shape the role of companies and that of the managers for the larger interest of society. The corporate world in India, under new economic order of liberalization and globalization has to Developing Marketing Strategies for Enhancing the Use of Solar Energy Products Anupamaa S Chavan 19 increase its share of world trade and in this effort one major impact of rising trades would be on environment and resources. The business world internationally has begun to acknowledge that environment is playing an important role in all facets of business. A survey by Mckinsey and company (2009) revealed that: (1) 92% of CEO‟s believe that environment should be top management priority; (2) 35% CEO‟s believe that their companies have adopted strategies to anticipate impacts of environment on business. Thus environment management is gaining a lot of momentum in today’s corporate world. The author stresses more on Government regulations for use of clean and green energy, but already Government is doing its level best. India is the first nation to have a separate ministry for new and renewable energy.

Critical Review related to Government Action & Support

MEDA (Maharashtra Energy Development Agency), (2005), in its Strategic Energy Conservation Action Plan (Final Report) - states that more electricity is required as Maharashtra is one of the largest states in the country with close to 3.08 Lakhs square kilometre of area coverage with a population density of 314 per sq. km. Total population of 96,752,247 is divided into 43.4% and 56.6% in urban and rural sector respectively. Maharashtra being a leading industrial state in India with almost 29,000 registered factories,

Per capita income in the state is approximately Rs.17, 295 as compared to the national average of Rs. 10,771. This state contributes almost 14.7% of India's gross domestic product and 15.1% of the national income. Evidently, the electricity supply in the industrial and domestic consumer sectors is important to the growth in the national income as it contributes to the production in the state and is likely to increase the purchasing power of the population, clearly indicated by the higher per capita income. Thus from the above, it is known that sufficient amount of electricity is required to meet the increasing demand and one has to think of various alternative sources of energy for sustainable development. The Karnataka Government has made it mandatory to use solar water heaters, as we know water heaters require more power. International Energy Agency (IEA), (2006) World Energy Outlook published by, IEA which is an autonomous body established in November 1974 within the framework of the Organization of Economic Co-operation and Development (OECD) to implement an international energy programme. IEA aims at improving the world's energy supply and demand structure by increasing the efficiency of energy use. It basically stresses Developing Marketing Strategies for Enhancing the Use of Solar Energy Products Anupamaa S Chavan 28 more on how to improve system for coping with oil supply disruptions. The book states that the world is facing twin energy- related threats; that of not having adequate and secure supplies of energy at affordable prices and that of environmental harm caused by greenhouse gas emissions by consuming too much of it. The current pattern of energy supply carries the threat of severe and irreversible environmental damage including change in global climate .It also states that reconciling the goals of energy security and environmental protection requires strong and co-ordinated Government action and public support. Thus IEA stresses more on the use of non – conventional use of energy resource thus, solar energy being one of them becomes inevitable.

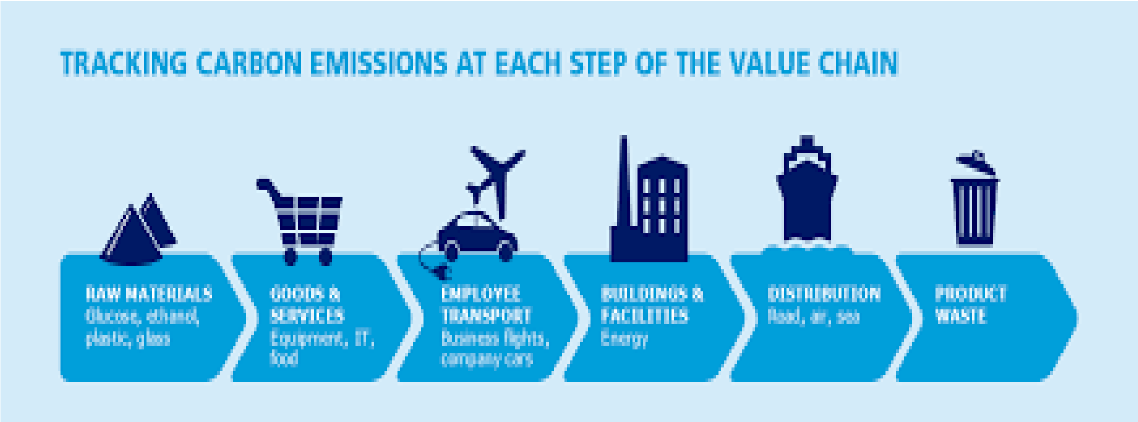
Critical Review related to Solar Power & Solar Energy Products

Vipradas (2001) in Renewables - Products and Markets a compilation of papers edited by him in his paper Product and Market development process in renewables states that wide acceptance in the society regarding the interlinkages among environment, poverty, and sustainable development forces our attention to technological solutions that address the needs of today without producing any negative externalities. It is in this regard that Renewable Energy Technologies (RET) have gained immense popularity. The editor further emphasizes that technology and installations have to be provided with due regard to replication and integration into long-term development strategies. This, in turn, necessitates the spread of these technologies through market channels requiring the provision of a maintenance and after-sales servicing infrastructure. Another paper presented by Amit Kumar on Solar pond: experience and barriers in developing indigenous technology in India states that solar pond technology is one such renewable energy option that offers various cost-effective end-uses without endangering the environment. Salinity gradient solar ponds in suitable locations are essentially low-cost solar collectors with integrated storage and, hence are potentially cheaper alternatives to flat plate collector system. Developing Marketing Strategies for Enhancing the Use of Solar Energy Products Anupamaa S Chavan 35 Solar ponds are not as much popular as other solar energy products. Solar energy products are comparatively costly, and if solar ponds can curtail the cost one should opt for it, but again feasibility is an issue that needs attention. Thus cost and after sale service are important factors in the field of RET. The Energy Resource Institute i.e.

TERI, (2007) Energy Data Directory year book elaborates on the development of the Energy resources in India, that Photovoltaic (PV) technology was initially developed during the late 1950s to provide long term reliable power for satellites. Companies began to offer PV technology for commercial application in the mid- 1970s. India has a PV manufacturing history of more than two decades. Production of Solar Photovoltaic (SPV) cells has grown at an average rate of 28%per annum during 1996-2005, while solar module manufacturing has grown at an average rate of 30% during the same period. The SPV systems are being promoted in India primarily for rural and remote applications. A 2.9-MW system based on SPV is feeding power to the grid. The decentralized systems are solar power plants, with mini grids, solar home lighting systems, solar lanterns, and solar street lights. However in terms of contribution , the percentage of total amount of electricity generated in India is very small owing to very small installed capacity – about 87MW compared to total power generation capacity of 12,736 MW. The target for Eleventh Five – year Plan period, that is till 2012, is to add about 50 MW of SPV systems (includes both off grid and grid-connected SPV systems). Financial assistance is provided as per the provisions under various schemes by Ministry for Non Renewable Energy (MNRE).

3. MEHODOLOGY

Science mapping, which is defined as “a generic process of domain analysis and visualization”, can detect the intellectual structure of a scientific domain [38]. This method is useful in visualizing trends and patterns of a large body of bibliometric data, allowing researchers to make discoveries related to a particular scientific domain. Several scientific methods, such as content analysis [39], latent semantic analysis (LSA) [40], literature reviews [41], bibliometric techniques [42–44] and scientometric analysis [45] have been used by researchers in different research areas, such as building information modelling (BIM), green building and innovation and energy and sustainability. However, a scientometric analysis provides several advantages over the other analytical techniques by providing a broader approach to identify the insightful patterns and trends of a large bibliometric dataset [46]. This study, therefore, adopted a scient metric analysis technique to analyze the large body of literature available on global carbon emissions. Accordingly, the research methodology consisted of the selection of science mapping tool, data collection, data analysis, visualization, and interpretation of the results. This study adopts a scientific and visual representation (illustrative diagrams and maps) with a qualitative (descriptive) research approach for global literature review [47]. To explore the characteristics and productivity of global research with the research objective of providing an in-depth review of carbon emission research [48,49]. The descriptive and visual representation was adopted considering its ability to analyze and discuss academic research within the entirety of scientific purview comprehensively [50–52]. Scientometric review with descriptive and visual illustration is described as one of the most adopted methods of evaluating and assessing research trends by researchers, academics, institutions, countries, and journals. As adopted in this study, it helps to understand the structure (cluster), research areas and trends in carbon emission better than and other studies.



3.1. Selection of Science Mapping Tool

There are several science mapping tools available to analyze insightful patterns and trends of a scientific domain. These tools possess their own pros and cons when performing a scientific analysis. It is therefore important to select the best suitable tool to analyze a scientific domain. Among various tools available, CiteSpace and VOSviewer were identified as the two most suitable tools to perform this analysis. VOSviewer provides basic software tools for exploring, analyzing and visualizing bibliometric data. CiteSpace offers more visualized analytical options, providing more opportunities to address important elements of a research domain, such as links between publications and major components of the domain. Compared to VOSviewer, CiteSpace has the ability to analyze a larger bibliographic dataset. Accordingly, CiteSpace was selected as the science-mapping tool for this research.

3.2. Data Collection

The selection of a scientific database is a critical step in a review study as there are multiple scientific databases, such as Scopus, Web of Science (WoS) and Google Scholar. Apart from these major databases, core journal publishers also possess their own databases, such as Emerald, ElsevierScience Direct, Wiley Online, Taylor and Francis, IEEE Explore and Springer Link. However, following the previous researchers the Web of Science core collection database was selected for this review. The WoS core collection consists of the most influential and related journal records and combined with WoS scientific robustness, this database provides a wider range of bibliographic data to the user. Moreover, CiteSpace enriches with several data sources, such as WoS, Scopus, and PubMed, and converts those data, from different sources to WoS format prior to processing. Thus, to prevent losing data from the conversion process, the WoS core database collection was selected as the source of data for this review. The data source and retrieval strategy adopted was based on the best techniques that will achieve the established aim, objectives and the identified methodology of this study. The source of data includes journal articles published from 1980 to June 2019. Journal papers are significant and reliable as the primary source of academic research literature review and it has been adopted for similar purpose by studies such as June 2019 was adopted to avoid the error of hasty generalization because several relevant research can still be published in the year 2019. However, few relevant referred journal articles in the year 2019 were adopted and referenced as used in the traditional (manual) literature search and retrieval techniques. A comprehensive bibliographic search, extraction and indexing were carried out on WoS core collection using the search string “Greenhouse Gas Emissions*”, “Carbon Emissions” and “Carbon footprint”. The time span of the publications retrieved ranges from 1980 to June 2019 (29 years). The search results were refined only to include journal articles and articles written in English. Due to the thorough peer review process involved, journal articles are considered more trustworthy compared to other sources. Moreover, most authors usually republish their conference papers in scholarly journals, which is considered the “certified knowledge”. Accordingly, a total of 2945 journal articles were retrieved in June 2019 and the records were downloaded as text files containing the full record and cited references. The very first paper on carbon emissions has been published in 1981, which focused on developing a tool to measure carbon emissions of cooling towers. Subsequently, there have only been very few publications on the domain until 2010. Thereafter, there has been a significant increase in publications and 2018 recorded the highest number of publications (479). This review data search and retrieval approach identifies the trend in carbon emission

research using the traditional search of related articles to extract the relevant discussion over a period. This technique includes the search of the research topics, keywords from a search engine such as Ask.com, AOL, Bing, Google and Yahoo. This approach does not only provide the preliminary insight into the research area, but it also helps to verify the validity and reliability of the bibliometric approach used. It helps to create a foresight of what to expect in the scientometric analysis (qualitative and visualization) and consequently make significant relevant discussion.

3.3. Data Analysis Strategy

Scientometric analysis strategies adopted in this study include (1) tracking the history of carbon emission through literature search and extraction; (2) bibliometric search to identify the key researchers and institutions. The important subjects and journal categories, research keywords, representative references as well as relevant salient and emerging research themes; (3) science mapping through CiteSpace to visualize the results of the analysis; and (4) make a qualitative discussion to achieve the objective of the research. This strategy was adopted based on its validity by exploring several research studies which include Liang, et al. Jin, et al and Zhao

3.4. Scientometric Analysis

Several scientometric techniques have been identified by [40], such as author co-citation analysis, keyword co-occurrence analysis, and document co-citation analysis. Initially, networks were constructed through keyword co-occurrence analysis, direct citation analysis, co-authorship analysis, and citation burst analysis. This was followed by an analysis of useful information of the domain, which displays "the conceptual, intellectual, or social evolution of the research field, discovering patterns, trends, seasonality, and outliers". A scientometric analysis is a quantitative study of science and scientific communication in research or policy statement . Scientometric analysis as adopted in this study includes measuring the impact of communication links, referencing sets of articles, countries, journal, institution impact and scientific citations among others [65–67]. The analytical approach investigates a wide range of carbon emission subject areas for scientific

knowledge mapping. It identifies and captures knowledge area, structural patterns, trace the history and include prominent or salient relevant ideas for research decision. The scientometric analysis is adopted as a scientific process of analyzing research in this study because it uses mathematical formulae and visualization techniques in a systematic order as preferred by the researcher. Also, this scientific method has been adopted in several ways for capturing research knowledge such as bibliometric techniques content analysis literature review latent semantic analysis (LSA) and scientometric visualization with different software. CiteSpace is a Java software adapted to process article data obtained from Scopus database for scientific information and visualization, mining and analyzing data for scientific uses. It is used for several scientific knowledge networks and gathering information involving cited references, authors, co-occurring, bibliographic sources, keywords and many more. CiteSpace network analysis includes ‘nodes’ which show the result of significant collections of data such as keywords, authors, documents, institution, and region (countries) for making research inferences. The node size indicates the article or journal frequency, citation count or impact of the subject study. For example, the larger nodes reflect higher frequency or citation counts, and the combination of these nodes into groups is referred to as cluster(s), and it signifies an important domain or intensity of a specific thematic. While the links between two entities (authors, references) represent how frequently the two entities are cited together by other entities, the betweenness centrality result shows the impact of a node on another node. Similarly, the larger the centrality, the higher the impact of the entity on the other entities with the tendencies of becoming a key entity. The analysis conducted in this study includes significant cited articles, articles that attract research community attention, keywords with strong frequency surge to identify emerging topics and areas of further research in carbon emission research. The analysis involves six basic stages, namely the (1) Scopus bibliographic database search, (2) literature search indexing, (3) scientometric analysis, (4) the use of CiteSpace software, (5) the result and discussion in two subsections (trends of carbon emission related global research analysis and future research areas of carbon emission research), and (6) the conclusion. The first stage described how the data are accessed from the Scopus bibliographic database search. The second stage involves the sorting and indexes applied to retrieved articles from the first stage. While the third stage is the software (CiteSpace) which accept the RIS data format and process it for the required types of analysis in the study, the fourth stage is the analysis conducted using the CiteSpace software, and this is adopted for the result discussion and conclusion of this study.

1. **Reduce, Reuse, Recycle**
   Buying products with minimal packaging will help to reduce waste. By recycling half of your household waste, you can save 2,400 pounds of carbon dioxide annually.

2. **Use Less Heat and Air Conditioning**
   Adding insulation to your walls and installing weather stripping or caulking around doors and windows can lower your heating costs more than 25 percent, by reducing the amount of energy you need to heat and cool your home. Turn down the heat while you're sleeping at night or away during the day, and keep temperatures moderate at all times. Install a programmable thermostat because setting it just 2 degrees lower in winter and higher in summer could save about 2,000 pounds of carbon dioxide each year

3. **Replace Your Light Bulbs**
   Wherever practical, replace regular light bulbs with compact florescent light (CFL) bulbs. Replacing just one 60-watt incandescent light bulb with a CFL will save you $30 over the life of the bulb. CFLs also last 10 times longer than incandescent bulbs, use two-thirds less energy, and give off 70 percent less heat. If every Canadian family replaced one regular light bulb with a CFL, it would eliminate 90 billion pounds of greenhouse gases, the same as taking 7.5 million cars off the road.

4. **Drive Less and Drive Smart**
   Less driving means fewer emissions. Besides saving gasoline, walking and biking are great forms of exercise. Explore the York Region Transit system and check out options for carpooling to work or school.
   When you do drive, make sure your car is running efficiently. For example, keeping your tires properly inflated can improve your gas mileage by more than 3 percent. Every gallon of gas you save not only helps your budget, it also keeps 20 pounds of carbon dioxide out of the atmosphere.

5. **Buy Energy-Efficient Products**
   Home appliances now come in a range of energy-efficient models, and compact florescent bulbs are designed to provide more natural-looking light while using far less energy than standard light bulbs.

6. **Use Less Hot Water**
   Set your water heater at 120 degrees to save energy, and wrap it in an insulating blanket if it is more than 15 years old. Buy low-flow showerheads to save hot water and about 350 pounds of carbon dioxide yearly. Wash your clothes in warm or cold water to reduce your use of hot water and the energy required to produce it. That change alone can save at least 500 pounds of carbon dioxide annually in most households.

7. **Use the "Off" Switch**

Save electricity and reduce global warming by turning off lights when you leave a room, and using only as much light as you need. And remember to turn off your television, stereo and computer when you're not using them. It’s also a good idea to turn off the water when you’re not using it. While brushing your teeth, shampooing the dog or washing your car, turn off the water until you actually need it for rinsing.

8. **Plant a Tree**

If you have the means to plant a tree, start digging. Trees absorb carbon dioxide and give off oxygen. A single tree will absorb approximately one ton of carbon dioxide during its lifetime.

9. **Get a Report Card from Your Utility Company**

Many utility companies provide free home energy audits to help consumers identify areas in their homes that may not be energy efficient. In addition, many utility companies offer rebate programs to help pay for the cost of energy-efficient upgrades.

10. **Encourage Others to Conserve**
Share information about recycling and energy conservation with your friends, neighbours and co-workers, and take opportunities to encourage public officials to establish programs and policies that are good for the environment.

Energy

Renewables should make up at least 30% of total global electricity generation in 2020, up from 23.7% in 2015. They also propose that no new coal-fired power plants be built anywhere in the world after 2020 and all existing coal plants begin being retired.

Infrastructure

Countries should commit $300bn annually to help cities and states fully decarbonise buildings and infrastructure by 2050, with cities upgrading at least 3% of their building stock to zero- or near-zero emissions structures each year.

Transportation

Electric vehicles should make up at least 15% of new car sales globally, up from around 1% today. They also suggest a doubling of mass-transit utilisation in cities, a 20% increase in fuel efficiencies for heavy-duty vehicles and a 20% decrease in greenhouse-gas emissions from aviation per kilometre travelled.

Land

Enact policies that reduce deforestation and encourage more forest growth. They suggest cutting global deforestation to near zero by 2030 and focusing on agriculture practices that can sequester CO_2 in soils.

Industry

Heavy industries should plan to cut emissions in half by 2050.

Finance

Mobilise at least $1tn a year for climate mitigation and adaptation, mostly in the form of private investments, but with some government efforts to help set up “green bonds”.

Additionally, they suggest that a new focus on communication of climate science and mitigation solutions, stressing more accessible approaches than dense, oft-esoteric journal articles. One proposal is for scientific societies and associations to set up communication “boot camps” to help researchers make their science relevant to businesses and policymakers.

Finally, they suggest that optimism be encouraged and that there be more focus on the solutions rather than the problems. They suggest that the upcoming G20 meeting in Hamburg on 7-8 July should take up the goal of rapid transformation by 2020.

METHODS TO REDUCE CARBON EMISSION IN INDUSTRY SECTOR

The Industry sector produces goods and raw materials for everyday use, every single day. The greenhouse gasses that industrial production emits are split into two categories:

- **Direct emissions** are greenhouse gasses produced at the facility itself.
- **Indirect emissions** are associated with the facility's use of energy but happen off-site.

Carbon dioxide emissions can be caused by energy used at factories and other facilities to run machines, process raw materials, run computers, connect to the internet, heat and cool buildings, and more. Direct emissions can also be caused by leaks in the industrial process, chemical reactions during the manufacturing process, and the use of petroleum in production. Indirect emissions are caused by energy production off-site, such as the emissions created by the power plants from which facilities get their electricity.

In the United States, the industry sector accounts for approximately 22 percent of greenhouse gas emissions.

Emissions from the industry sector are significant contributors to increases in levels of CO_2 and other greenhouse gasses. However, there are many ways that businesses and factories can begin to reduce their emissions. Some are significant, requiring changing standards in production and facilities management.

Others are simple. Setting the thermostat just two degrees lower in winter and two degrees higher in summer, for example, could save thousands of pounds of carbon dioxide emissions each year per facility.

How to Reduce CO2 Emissions In the Industry Sector

No matter the size of your business, there are steps you can take to reduce carbon dioxide emissions and combat climate change.

1. **Measuring carbon footprint.** By assessing how much pollution an organization's actions generate, you can begin to see how minor policy changes can significantly reduce a company's overall carbon footprint.
   A carbon footprint can be measured by undertaking a greenhouse gas emissions assessment. Once the size of your carbon footprint is known, you can devise a strategy to reduce it through technological developments, better process and product management, changed Green Public or Private Procurement (GPP), carbon capture, consumption strategies, and others.
2. **Carbon capping.** Emissions trading, sometimes known as cap-and-trade policies, puts a limit on carbon dioxide emissions. A government entity sets a "cap" on the emissions that can be produced in its jurisdiction, and companies are given carbon allowances. These allowances can either be used or traded to other companies
3. **Reducing energy use.** The building industry now has multiple energy efficiency certifications. The standards help set measurable and achievable goals, reducing the amount of energy used from 12 percent all the way to 100 percent of typical building energy use. Some of the most common certifications include LEED Green Building certification, Energy Star, Net Zero Energy Building Certification, and High-Performance Building Program by ICLEI. The industry sector can ensure new buildings are energy efficient by earning any of these ratings.
4. **Rewarding green commuters:** Encouraging employees to switch to public transportation, carpooling, biking, telecommuting, and other environmentally-

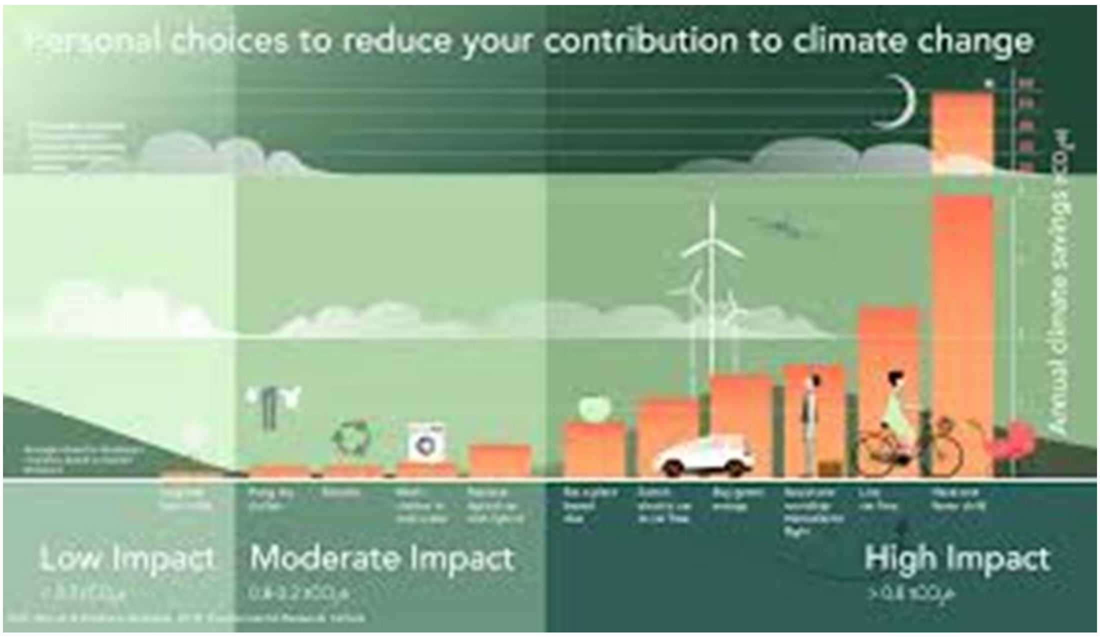
friendly commutes can add up and have tremendous effects. Employers can offer commuter benefits that address limited or expensive parking, reduce traffic congestion, improve employee recruiting and retention, and minimize the environmental impacts associated with drive-alone commuting.

5. **Reducing fossil fuel dependence.** Burning coal to produce energy creates carbon dioxide emissions and contributes to irreversible climate change. Businesses that make a conscious effort to switch to sustainable energy sources, such as wind or solar power, can help to reduce their daily CO_2 emissions.
6. **Voluntary offsets.** If a company can't afford to undertake new energy-efficient building initiatives or put solar panels on buildings, there are alternatives. Balancing your carbon footprints through alternative projects, such as solar or wind energy or reforestation, is known as carbon offsetting. Carbon offsets can be purchased from many third-party suppliers who then engage in these activities on behalf of the business.

Learning to Adapt to Climate Change

Climate change is already being felt around the world. Hundreds of municipalities have centered their climate change efforts on mitigation work and have successfully reduced their greenhouse gas emissions and lessened their climate impacts.

However, with the increasing effects of climate change becoming apparent, towns and cities are developing responses that protect their citizens and their economies from the changes that are already underway. In addition to reducing their own emissions, businesses can support and protect their local communities by participating in these programs.



4.DISCUSSION

Solar energy production by a PV module is numerically equal to the product of cell area, cell efficiency, light intensity and sunshine hours. In India, the intensity of solar energy varies from 4 to 7 kWh/m^2/day, considering the 10-h duration of sunshine in a day and always more than the threshold level of 1.50 kWh/day. West Bengal being located in the eastern part of the country receives a considerable intensity of solar radiation. On the other hand, the cell area and its efficiency depend on the type, number and characteristics of the cells used, which are important factors in determining the amount of solar energy produced. Generally, PV modules are formed by the combination of 36, 60 or 72 numbers of cells with dimensions of 150 × 150 or 156 × 156 mm. All the above facts, in turn, result in the difference in the overall efficiency of the PV module. Evidently, power generation by a particular module also differs significantly from others. The rate of solar energy production by the PV module as mentioned in the present study is 0.59

$kWh/m^2/day$ (Table 1). Again CC earned is proportional to the power output and is directly deductible from the cost of electricity produced. As such CC is important in estimating return on capital cost and also estimating the cost of electricity production. CC in this study has been calculated as 0.33 tonnes of CO_2 which if traded amounts to USD 9.0 (Rs 450) per MWh power production

One important objective of the study was to show by numerical analysis that solar energy is involved with direct generation of CO_2, apart from many indirect involvement and consequently contribute to CFP, but definitely less than the thermal power unit . It is, however, mention worthy that the silicon wafer, which is the starting material for solar energy generation, is produced from silica by carbon reduction with the generation of equivalent amount of CO_2. It is, however, true that the use of equivalent amount of carbon to completely reduce silica to silicon is actually not feasible; instead, the excess amount of carbon must be added to ensure the complete reduction of silica, and consequently, this excess quantity of carbon may in some way produce some additional amount of CO_2 than the calculated value during the process. Moreover, quartzite may also contain some impurities of various metal oxides which along with silica might get reduced leading to more CO_2 evolution in the atmosphere. On considering all the above facts, the total amount of direct CO_2 generation would be more than what has been shown here. In this study, it has been found that the direct CO_2 generation contributes to 25% of the total CFP generation by the type of cells used in West Bengal, but if we consider the above possibilities then the contribution to CFP generation will also increase.

My research focused on a deeper understanding of energy generation and carbon emissions in California and how residential implementation of solar systems can help mitigate those emissions. Currently, there is little known about how renewable energy, especially solar panels, adopted by residential homes can contribute to carbon emissions mitigation in California. Through this research, I have assessed what the situation in 2020 will be like if different percentages of homes install solar and determined the percentage of homes in California that should install solar to significantly reduce carbon emissions. This research determines if the adoption of solar technology is a feasible and practical strategy to help California reach its AB 32 goals.

Current Scenario

The fact that only 0.9% of all California homes have currently installed solar implies that the implementation of solar for the majority of California homes still has some barriers. An important factor to consider is the high cost of solar systems, which can cost an average of $30,000. The cost of a solar system is much greater (about 80%) than the value of electricity that it can produce (Dastrup et al. 2012). In order to overcome this barrier to implementation, the government will likely need to invest more into the research and development of solar technology to make panels cheaper to produce, consequently lowering costs for consumers. Research and development investments can also lead to the production of more efficient solar panels, which can reduce the payback time for their installation (by means of lower electricity bills), and provide consumers more of an incentive to install solar. By overcoming the financial barrier, a higher percentage of consumers are likely to adopt solar; in fact, a much higher percentage than 0.9% of California homes need to install solar systems to result in a significant reduction in carbon emissions.

Limitations & Future Directions

The biggest limitation to my study was the amount of assumptions I had to make due to lack of available data, as well as assumptions that were necessary for my results to hold true. I had to assume that all residential solar systems in California are the same size and provide for the electricity needs of the entire household. While this is a valid assumption, my results would have been more accurate if I had specific data regarding solar system sizes and energy consumption in homes that install solar. More research is necessary regarding the sizes of already-installed solar systems. My findings suggest that more research needs to be done regarding the financial and housing characteristics of households that have installed solar; this can help the government decide where to focus its policies to promote solar. Also, other energy sectors should be researched in order to develop a more accurate scenario of California's energy emissions. My research did not consider energy generation for commercial purposes; further research could add to knowledge regarding the current energy scenario in California and policies could be suggested to promote renewable energy implementation in the commercial sector. Electricity companies and the government should also invest in other sources of renewable energy, as solar energy currently has high costs and faces barriers to implementation. It would be effective to look at other sources, such as wind or biofuels, and their carbon mitigation potential.

Broader Implications

My research shows that there is a great need for the government to make solar technology more accessible in order to reduce greenhouse gas emissions from the residential energy sector. Another implication of this research is that focusing on energy generation is not the only solution; other sources of greenhouse gas emissions must be targeted as well if California aspires to reach its AB 32 goals If emissions mitigation policies focus on the transportation sector, as well as electricity then a considerable portion of the state's greenhouse gas emissions can be targeted for reduction. This research shows that residential solar systems have the potential to significantly reduce carbon emissions; however, California has still not reached that potential due to barriers to implementation. With further research on different sources of renewable energy and with easier access to solar technology, California can overcome a significant portion of its greenhouse gas emissions derived from the energy sector, and hopefully meet AB 32 goals. With a goal to provide 33% of its energy and utilities companies already generating 19.8% of its energy through renewables, California is at the forefront of carbon emissions mitigation (CPUC 2007). By achieving AB 32, California can set an example for other states to contribute to a dramatic reduction in greenhouse gas emissions and help reduce climate change.

5.RESULTS

Results from the assessment are presented in this section. We report carbon footprint calculations for two alternative material sourcing scenarios: sustainably sourced and non-sustainably sourced wood and bamboo. Also primary energy calculations are presented.

Carbon Footprints Differ According to Chosen Materials

The results are shown with two different functional units: m^2 of living area and estimated service life. In addition, two alternative scenarios are presented: base scenario without calculating the climate benefits of sustainably sourced wood and comparative scenario showing the positive impacts of sustainable forestry (SF).

Findings clearly show the dominant impact of coverings in nearly all shelters. A majority of the shelters had coverings made of steel or plastic, which both cause remarkable CO_2e emissions when compared to her assessed materials.

The most environmentally friendly shelter seems to be the Indonesian model Shelter no. 1. Its structures are mainly made from bamboo, which is renewable material. Although the GHG emissions of the used bamboo are based on adaptive simulations from other studies, as explained earlier, it can be assumed with reasonable certainty that the emissions are very low.

Also, timber-based shelters from Peru (Shelter no. 4 and 5) seem to perform well in GHG comparison. This is due to the low global warming potential of wood material. In their case, a majority of emissions come from concrete foundations. When considering the climate benefits of sequestered atmospheric carbon of sustainably sourced wood material, these shelters perform even better.

It has to be noted that although uncertainties can distort the results, the trend is likely to be even stronger if possible replacements of coverings during the lifespan of the shelter would have been included in the study. It is likely that, especially in cyclone-prone areas, parts of the coverings would need to be replaced during the estimated service lives of the shelters.

A similar amplifying effect might also be caused, if the carbon storage capacity would have been taken into account. While trees and bamboos grow, they absorb CO_2 from the atmosphere. This biogenic carbon is stored in construction materials until it will be released back into the atmosphere in energy recovery (incineration) or natural decay. This inherent material property of wood and bamboo helps to mitigate climate change—assuming that it does not lead to deforestation due to illegal or un-sustainable forestry practices.

It is interesting to observe the impact of assuming sustainable forestry in the GWP of wooden frames. For example, the total GWP of the primary structures of Shelters 2, 4, and 5 turns negative.

6.CONCLUSIONS AND FINDINGS

Carbon emission research has received increasing global attention due to rapid global climate change. Thus, academics, international organizations, and government agencies have paid special consideration to identifying the carbon emission sources and thereby implementing various carbon mitigation strategies. The initial research on carbon emissions was conducted in 1981 and the domain has evolved significantly over the past two decades. This study provides a scientometric analysis of carbon emission research using 2561 bibliographic records extracted from the WoS core collection database. Several scientometric analysis, such as co-authorship, author co-citation, document co-citation, and journal co-citation analysis were utilized to identify and explore the trends in carbon emission research. Research publication trend analysis revealed a steady increase in carbon emission research publications. Accordingly, the year 2018 was identified as the most productive year of publications, with a record of all-time high 443 publications. It is expected that the year 2019 will record an even higher number of publications as more and more researchers are now focusing on this important issue. As for the most productive authors on carbon emission research, several Chinese authors topped the list. While Yong Geng and Yi-Ming Wei were recognized as the most prolific authors in the domain, H. Scott Mathews was recognized as the only non-Chinese author among the top ten authors in the domain. The Peoples Republic of China, the USA, and England emerged as the most productive countries on carbon emission research. In terms of betweenness centrality, the USA topped the list, which indicated that the USA have had better research collaborations and links compared to other countries. On the contrary, betweenness centrality of China was low despite being the top publishing country. In addition, several Chinese institutions topped the list of the most productive institutions, which was led by the Chinese Academy of Sciences, Tsinghua University and the University of Chinese Academy of Sciences. In terms of centrality, the University of Cambridge, University of Leeds and University of Colorado held the top positions. It is evident that despite the high number of publications, China is not recording good research connections with other countries on this domain. It was clear that the majority of the carbon emission research studies were conducted in developed countries. As a result of this, scientometric analysis returned most of the results related to carbon emissions based on the developed countries. However, the lack of studies on developing countries has resulted in bringing more attention to global researchers towards addressing this issue in developing countries. Several core journals have published the most significant research studies on carbon emissions such as Energy Policy and Journal of Cleaner Production. These journals also received high citation frequencies as well as citation bursts making them the most prolific journals on carbon emission research. In terms of document co-citation analysis results, the publications by Eggleston HS and Weidema BP received the highest number of co-citations. Moreover, Solomon S and Finkbeiner M recorded significant citation bursts on carbon emission research. Most significantly, several citation bursts were recorded between 2010 and 2014, which indicate that more and more authors are focusing on carbon emission research since 2010. Additionally, IPCC and Wiedmann T topped the list of most cited authors in the domain. According to the results observed through the scientometric analysis, it is evident that the carbon emission research domain has attracted the attention of global researchers. A significant increase in research publications over the past two years is a strong indication of the growth in the carbon emission research domain. Carbon capturing, predicting future carbon emissions through trend analysis, evaluating carbon performance, identifying carbon mitigation opportunities and ultimately achieving zero carbon emission goals are some of the most popular research areas in the carbon emission research domain. The scientometric analysis revealed the trends of carbon emission research over the past three decades which was the objective of this research. There are certain limitations of this review which should be taken into consideration by the readers. Firstly, this paper was based only on the literature data obtained from the WoS core collection which might not cover all the available literature on the domain. Although many authors have used the WoS database, the comprehensive nature of this database cannot be assured. Moreover, data were only obtained from the journal articles which might not capture all the literature available on carbon emissions. It should also be noted that since the data obtained from the WoS core collection were filtered using the title, studies which might not reflect the carbon emission related work in the title were not included. However, this scientometric analysis provides a reflection of the global carbon emission research for researchers, government institutions and practitioners. It offers an in-depth understanding and a valuable insight into the most significant authors, institutions, countries in the carbon emission research domain as well as the trends of publications. The findings of this study can be used to obtain the necessary support and guidance to formulate carbon emission control policies

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The carbon footprint has started becoming synonymous to a comprehensive GHG account, over the life cycle stages of any product or activity. The carbon footprint study is the basis of low-carbon research. The carbon footprint has been commercialized and is being utilized by organizations to count themselves and their products' carbon and adopt measures to cut down emissions, to meet the green consumer expectations of consumers or governmental request, and provides enormous opportunities to encourage enterprises to improve production efficiency and reduce resource consumption and waste, and promote the development of innovation and technology, to help open new business opportunities, and promote corporate social responsibility and achieve sustainable development.

However, as carbon footprint reports are increasing in response to business and legal requirements, most of the calculations are following the GHG protocol and PAS worldwide. Since it has been extended to cover the natural system as well, it becomes essential to deal with the unavoidable emissions. The type of GHG, system settings, quantification and carbon footprint, selection of date and treatment of specific emissions are the most important part of the study of the carbon footprint and assessment standards, especially for organizations and products. Guidelines had been made on these issues from existing assessment standards, but it still needs further improvement. Because carbon emission has been commercialized, and has been found to influence businesses, legal guidelines are necessary to guide and monitor these calculations, so that enterprise' and their products' carbon footprint analysis will be included in the decision-making stage. Meanwhile, as the strong measures and tools for the global problem of climate warm, research of carbon footprint and assessment standards need to be carried out within the global scope, to solve problems such as carbon leakage and border-tax adjustment

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