

INTERNATIONAL JOURNAL OF LEGAL STUDIES AND SOCIAL SCIENCES [IJLSSS]

ISSN: 2584-1513 (Online)

Volume 2 | Issue 3 [2024] | Page 272 - 282

© 2024 International Journal of Legal Studies and Social Sciences

Follow this and additional works at: <https://www.ijlsss.com/>

In case of any queries or suggestions, kindly contact editor@ijlsss.com

SOLAR TECHNOLOGY: ENVIRONMENTAL CHALLENGES TO EXTRACTION OF RAW MATERIALS AND WASTE DISPOSAL

- Devang. R¹

ABSTRACT

During the worldwide search for environmentally friendly energy sources, solar power technology is viewed as a bright spot because of its immense capacity to slow down global warming and lessen reliance on petroleum and coal for power. The overall sustainability of solar power technology is nevertheless severely constrained by the negative consequences of waste management and raw material extraction. This short attempt to give a summary of these difficulties is to highlight and take into account alternate ways to deal with them.

The procedure of extracting silicon, cadmium, along with tellurium-raw elements used in photovoltaic modules-may be harmful to the ecosystem as a whole. Deterioration of ecosystems and decreasing ecological diversity are frequently the results of mining activities, which also generate soil deterioration, contamination of waterways and destruction of habitats. Furthermore, the energy-consuming method for harvesting natural resources results in massive emission of carbon dioxide, which undermines the advantages of solar technology as a source of clean energy. Possibilities to think about include producing photovoltaic cells that are also simpler to break down and reuse, as well as promoting the development of alternative materials with a reduced ecological impact and better recycled procedures.

The present research aims to examine the vital importance of photovoltaic technology in light of the imminent need to shift rapidly to renewable energy sources in consideration of worldwide warming concerns and the goal of minimizing reliance on limited resources like fossil fuels. It has also been pointed out that the use of renewable energy sources misses environmental dangers since it contains exotic substances like tellurium and dangerous metals like cadmium and lead. It

¹ 2nd-year BBA LLB student at Symbiosis Law School, Hyderabad

is challenging to dispose of photovoltaic cells that include these materials as improper disposition might contaminate the environment as well as land. Furthermore, governments everywhere have established together a number of programs and laws to deal with the ecological issues associated with the extraction of essential components and the elimination of waste in solar energy systems. To sum up, whereas the development of solar energy has enormous potential to create a greener and more secure the future, its ecological viability depends on how well the mining of raw materials and waste management are handled. Through the implementation for an all- encompassing approach which considers environmentally friendly variables at every phase of the photovoltaic panel's life, researchers might maximize solar energy's possibilities without reducing its negative ecological impact,

Keywords: Solar Power Technology, Ecosystem, Photovoltaic cells, Ecological Viability

INTRODUCTION

The energy needs of mankind have always been evolving and increasing. Since the inception of human civilization, humankind has created tools and developed technology to make their life easier and win over the forces of nature. In this endeavor, the requirements for energy have only increased exponentially. Further with the advent of industrialization, and urbanization the demand for energy for domestic as well as commercial pulses has skyrocketed. However, the method of power generation has not evolved at the same pace. Although it is a known fact that the sun is the sole and the largest source of energy for earth, its importance and potential was realized once again in the mid 1970s when the world started experiencing global warming. Global warming is induced by its very own policy of unplanned and unregulated industrialization and urbanization which wreak havoc on the environment. During, 1970s suddenly the world observed extinction of species, depleting fossil fuels reserves, rising sea levels etc. an immediate threat to mankind was felt, which led to the shift towards a cleaner, sustainable and environment friendly energy source. Hence, the world pivoted to solar energy. Solar energy required specialized solar technology that could not only harness but channel and store huge gigawatts of solar energy that could be judiciously used for mankind. This technology is relatively newer, and comes with its own pros and cons. While the concept of harnessing clean and sustainable solar power is environment friendly, the technology used and the methods adopted, have not tested true to the litmus of eco-friendliness. Thus, this study aims to understand and critically analyze whether solar technology is

genuinely environment friendly or whether solar power generation is also a threat to the environment.

LITERATURE REVIEW

For the purpose of research and study of the research problem, various research articles and other documents have accessed and studied the following articles. For an introduction, the paper "Solar energy technology and its roles in sustainable development by Ali OM Maka and Jamal Albid"^[2] discusses the significance of solar energy in impacting the world's energy and the efforts to solve the problem of climate change. For this, it is explained how electricity is generated through solar technology.

It is largely structured on the impact on various aspects from economics to public health. Adding to it, "Solar Power on the Rise: The Technologies and Policies behind a Booming Energy Sector"^[3] explains how Solar powered electricity generation has been the talk of the globe in the past 2 decades but was not feasible then. This is due to the rarity of the materials required along with ever-rising complexity of the global supply and manufacturing chain, leading to high cost of production. The paper showcases how various government and multinational companies' investment and research have brought down the cost and increased the feasibility of solar panel installation.

For an India-centric approach, the authors studied "Impacts of Solar Power in India: A review by Madhu Kumari and Dr. Prasoon Kumar Singh"^[4] where this paper restricts its research to the impact of solar energy in India. Various statistics with respect to the number of investments, electricity generation have been provided and how the renewable energy sector would be beneficial for the country in various aspects. Apart from advantages, the paper also provides the challenges on the environment and possible solutions for the same.

The paper "Sustainability of utility-scale solar energy critical ecological concepts"^[5] provided us with the knowledge that solar electricity generation, like other generating technology, uses resources in an exhaustive manner and hence requires huge amounts of land and water. Huge scale installation poses a potential threat to existing flora and fauna in the region along with the challenge of ground water due to exhaustive hydrological needs, though several alternatives and solutions have been presented for a more sustainable solar plant installation.

Derived from the above, the paper "The use of nanotechnology within the solar industry: a 18 sustainability perspective by Lauren A. Ferrigni"^[6] teaches the concept of nanotechnology used in solar panel production. The method has been appreciated for increasing the efficiency of the panel in electricity generation, but also has potential risk to the environment due to the use of nano-particles in the tech. Due to its nature of being a small sized product particle, the particles have the risk of getting into the biological elements, thus contributing to the toxicity levels.

STATEMENT OF PROBLEM

The ecological concerns surrounding renewable energy sources include waste management as well as mineral mining. The extraction method for elements like silicon, cadmium, and tellurium-materials used in photovoltaic panels-can lead to emitting greenhouse gasses, loss of ecosystems, and pollution of water. The passing of a photovoltaic cell disposal also raises questions about how to properly dispose of electrical debris and whether toxic chemicals will leak into the atmosphere. The building's structure for recycling solar panel assemblies is currently lacking, despite the fact that efficient recycling processes are essential to reducing these impacts. To tackle these obstacles, all-encompassing approaches that give priority towards environmentally friendly component procurement, effective recycling techniques, and the creation of a circular economy are necessary.

RESEARCH METHODOLOGY

Numerous sources have been used to compile secondary data. In order to reach a relevant conclusion regarding the topic and, if required, provide additional suggestions, data and information acquired from different secondary sources have been evaluated and processed. The majority of the information for this study was gathered from secondary sources, such as journal articles, books, research papers, documentaries and publications.

ANALYSIS

NEED AND GROWTH OF SOLAR TECHNOLOGY

The use of solar technology, refers to harnessing the everlasting and omnipresent Sun's heat in various forms to meet the energy needs of mankind. As it may be presumed by many that use of solar energy or technology is a rather new or contemporary technique, however it has been used

since ancient times. In ancient times in countries like Egypt, Athens and Greece, Solar cookers were used to cook food. Basic reflective materials such as metals and mirrors were arranged strategically to trap the sun's heat and bake food. Similarly, reflective materials were placed at rooftops of houses of elite class to heat water for warm baths. Not only that, a method of solar distillation was used in semi-arid or coastal areas where freshwater sources were not available, people built solar stills-simple devices consisting of a transparent cover over a basin of water to evaporate and collect clean water vapor condensation. Solar distillation provided a sustainable and energy-efficient solution for obtaining safe drinking water in areas where traditional water sources were searched or contaminated.

Thus, mankind has been using solar technology from the onset of civilization. However, its need was once again felt after the world witnessed the aftermath of the industrial revolution. The industrial revolution brought with itself the practices of using fossil fuels exhaustively. It started making and breaking economies, political ties, reasons for waging wars etc. the country which harnessed and burned as much fossil fuels could run faster in the race of industrialization. Unfortunately, those practices were not sustainable and the environmental effects of such practices were soon to be borne by all. In the later part of the 20th century, the world started witnessing effects of climate change, fresh water reserves drying up rapidly, frequent droughts, and most importantly the greenhouse effects.

Thus, the bringing of fossil fuels had significant environmental, public health, and socioeconomic benefits. Climate change mitigation effects, highlighting the importance of transitioning to cleaner, more sustainable energy sources such as renewable energy and energy efficiency measures. Hence the value for cleaner, affordable and inexhaustible energy resources was realized, which thus triggered the need for solar power generation and technology.

The following factors justify the need for solar technology -

Climate change- climate change mitigation is a pressing global concern, and solar technology presents a sustainable and environmentally friendly solution to reduce rely on fossil fuels, the main contributors to climate change. Solar panels harness solar energy to generate electricity without emitting greenhouse gasses, thereby aiding in the reduction of carbon emissions associated with energy production and helping to alleviate the impacts of climate change.

Exhausting resources - The depletion of finite fossil fuel resources is a critical issue, necessitating the transition to renewable energy sources like solar power. Solar energy offers an abundant and renewable energy supply that can help offset the diminishing availability and escalating costs of fossil fuels, emphasizing the urgency of adopting sustainable alternatives.

Energy insecurity - Enhancing energy security is another benefit of solar technology, as it diminishes reliance on imported fossil fuels, thereby reducing vulnerability to geopolitical tensions and price fluctuations. Solar energy, being widely available across various regions, enables countries to diversify their energy sources and enhance resilience against supply disruptions and price instabilities.

Cheap cost of production - The decreasing cost of solar technology in recent years has significantly enhanced its competitiveness with traditional energy sources. With continual price reductions and technological advancements improving efficiency, solar power is increasingly becoming a cost-effective energy solution for both residential and commercial applications. This affordability makes solar technology an appealing choice for consumers seeking long-term energy cost savings.

Energy insecurity Enhancing energy security is another benefit of solar technology

Eco friendly - Furthermore, solar technology not only aids in reducing greenhouse gas emissions but also contributes to environmental protection by minimizing air and water pollution associated with fossil fuel extraction and combustion. Solar energy production is clean and non-polluting, thereby helping to preserve ecosystems, biodiversity, and natural resources.

Job opportunities - The solar industry has emerged as a key driver of job creation and economic development, offering employment opportunities in manufacturing, installation, maintenance, and related sectors. The growing demand for solar technology presents significant prospects for job growth and economic advancement, particularly in regions with ample sunlight resources and supportive policy frameworks.

The inception of solar technology can be traced back to the mid-19th century when French physicist Alexandre-Edmond Becquerel discovered the photovoltaic effect, which laid the groundwork for the evolution of solar cells.¹ Initially, solar cells were inefficient and costly, primarily utilized for specialized applications like powering telecommunication satellites and remote off-grid installations.² However, advancements in materials science, engineering, and

manufacturing processes have resulted in substantial enhancements in solar cell efficiency, durability, and cost-effectiveness. The competition between the United States and the Soviet Union during the space race in the 1950s and 1960s accelerated progress in solar technology, leading to the deployment of solar panels on spacecraft and satellites for power generation. These early space missions showcased the potential of solar energy as a dependable and sustainable electricity source, generating interest and investments in terrestrial applications.

Throughout the latter part of the 20th century, research and development endeavors concentrated on enhancing the performance and scalability of solar cells, resulting in the introduction of new materials and manufacturing methods. Silicon-based solar cells emerged as the predominant technology, offering high efficiency and reliability at relatively low costs. The oil crises of the 1970s further intensified interest in solar energy to decrease reliance on fossil fuels and address energy security concerns. Governments worldwide began investing in solar research and development, supporting initiatives to enhance solar cell efficiency, lower production costs, and encourage solar deployment.

The 21st century has witnessed a significant surge in the advancement of solar technology, driven by a combination of technological innovation, cost reductions, and growing environmental consciousness. Breakthroughs in materials science, such as the innovation of thin-film solar technologies and perovskite solar cells, have broadened the array of solar cell choices and enhanced overall efficiency. Simultaneously, enhancements in manufacturing processes, automation, and economies of scale have led to substantial cost reductions in solar panel production, rendering solar energy increasingly competitive with traditional energy sources. Government policies and incentives have also played a pivotal role in propelling the expansion of solar technology. Numerous countries have implemented renewable energy objectives, feed-in tariffs, tax credits, and other financial incentives to promote investment in solar energy infrastructure and stimulate market demand. These policies have established a favorable regulatory landscape for solar development, attracting investments from both public and private sectors and fostering innovation throughout the solar value chain.

Environmental Risks of Solar Technology Utilization of Hazardous Material in production:- the analysis of composition of solar cells in recent years has raised several concerns about hazardous materials and their recycling/disposal. Even after 25 years, a significant majority of the solar cell technologies are using hazardous chemicals to achieve a higher rate of conversion to electricity.

The nature of the raw material generally determines the efficiency of conversion of the solar cells, panels and other products.

The most efficient solar cells derive from single crystalline solar cells, which require humongous worklond and toxic chemical usage. Many hazardous materials are part of the manufacturing process of silicon used in the cells.

MINING

The mining extraction of raw materials for silicon-based PV: thin-film (TF) PV (CdTe, CIGS, InGaAs, etc.) and solar cells can also pave the way to possible ecosystem, bodily health, and security³. On a parallel note, rising solar PV production technologies such as organic solar cells and perovskite solar cells are also connected with health and environmental hazards, where there is lack of knowledge.

Moreover, the cells require are minerals like Bauxite, which require deep level mining at various areas covered with dense forests, thus affecting the flora and fauna along with the indigenous tribes of the region. For example, people have protested against mining of such rare-earth metals in Australia and Guinea where the mining has threatened the local ecosystems.

Regardless of the specific PV technology, PV can produce 89% more potential harmful air emissions per kilowatt-hour than conventional fossil fuels^[7]. The creation of PV cells contains chemical dangers due to the toxicity, corrosivity, flammability, and explosiveness of the materials used to create solar PV components.

IMPACT ON WATER RESOURCES

Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system.

CSP systems using wet-recirculating technology with cooling towers use between 600 and 650 gallons of water every megawatt-hour of electricity generated. CSP facilities using once-through cooling technology have higher water extraction rates but lower overall water usage (since water is not lost as steam). Dry-cooling technology can reduce water consumption at CSP facilities by up to 90%.

However, the trade-offs for these water reductions are increased prices and reduced efficiency. Furthermore, dry-cooling technology is substantially less effective when temperatures exceed 100 degrees Fahrenheit.

Due to large parts receiving direct sunlight all through the year, India also faces the problem of water scarcity. Many towns and cities depend on groundwater for their agricultural and industrial needs. Without considering this aspect of water utilization in dry areas, such construction would not be just water depleting, but may also render the project's feasibility a difficult level. Many of the regions in the United States that have the highest potential for solar energy also tend to be those with the driest climates, so careful consideration of these water trade-offs is essential.

WASTE GENERATION

India is expected to generate around 280 gigawatts of electricity through solar panels. The International Renewable Energy Agency has stated in its annual report that by 2050, India is expected to produce 4.5-7.55 million tonnes of solar waste, making it the 4th highest generator of solar waste at that time⁴. This quantity is approximately 1.4 times the current amount of e- waste generated in the country. The statistics regarding solar waste are acted to expedite globally as it is expected that the domestic and industrial users of the technology may replace their panels with ones being innovated with better efficiency and lesser cost of generation. Future reduction in cost of replacement shall be a contributor to such replacement. In simple words, if a solar panel is expected to last 25 years and around 40% users replace the panels with upgraded versions after 15 years, then 40% waste is generated 10 years before the projected time.

INITIATIVES AND POLICIES OF THE GOVERNMENT IN THIS CAUSE

As observed above, solar power generation and solar technology generates huge amounts of waste. According to a statistic, approximately 2.95 billion tons of solar panel waste consisting of the solar panels and the balance of the system will be accumulated from 2020 to 2047⁶. Hence solar technology poses a major threat towards solar waste management in India in near future. In response the government of India has recently enacted the E-Waste management rules (2022),

according to which, the photo-Voltic cells and batteries used in solar technology have also been covered under its ambit.

The policy thus, lays down the following-

These regulations are to be followed for solar photovoltaic modules, panels, or cells, in accordance with the stipulations outlined in this section.

Manufacturers and producers of these solar products are required to:

- (1) register on the designated portal,
- (ii) appropriately manage and store waste generated by solar photovoltaic modules, panels, or cells until the year 2034-2035 as per guidelines established by the Central Pollution Control Board.
- (iii) submit annual reports in the prescribed format on the portal by the end of the relevant year up to 2034-2035.
- (iv) ensure that waste is processed. excluding solar photovoltaic modules, panels adheres to the prevailing rules and guidelines,
- (v) maintain a distinct inventory of solar photovoltaic modules, panels, or cells on the portal, and
- (vi) adhere to the standard operating procedures and guidelines set forth by the Central Pollution Control Board. Additionally, recyclers of solar photovoltaic modules, panels, or cells are required to comply with the recovery of materials as specified by the Central Pollution Control Board.⁸

These rules are an initiative to regularize the generation and management of waste of solar technology, however these are very vague and incompetent to tackle with the current .

CONCLUSION

Solar Technology for the generation is the need of the hour in order to tackle climate change by being an alternative to the conventional methods. But the existing technology has certain requirements that can degrade the land, soil and the water resources. This means that though technology can reduce the impact of climate change, it can significantly contribute as a harmful pollutant. Due to its potential in electricity generation, governments and multinational companies are investing billions of dollars in such a transition. This transition can only be successful if the result of such installations actuates the purpose, sustainable and emission-less electricity generation. If we do not work on improvisation or alternatives to harmful nature of the materials used or the waste disposal, then such mode would be a burden on the ecosystem, thus losing the

purpose of such resourceful transition. The government has formulated certain policies and initiatives in this concern, but the solution lies in implementation and further research and development. The bright side of tackling this challenge is two-fold. Firstly, the challenge of waste management is not specific to solar cells and the scope has been over all types of waste especially e-waste. Solving the challenge would be, hence, beneficial for all the sectors. Moreover, waste disposal can be considered as a business opportunity as recycling would rejuvenate the raw materials required for further production of cells/panels and so would raise a billion-dollar sector further contributing to sustainable growth.