Anjali Taneja

Khushboo Garg

Center for Study of Science, Technology and Policy (CSTEP), Bengaluru, India.

Advancing Circular Economy in India: Sustainable Resource Efficiency and Policy Imperatives in Solar Photovoltaics and Telecommunication

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ABSTRACT

In an era of escalating environmental concerns and the pursuit of sustainable development, the circular economy emerges as a transformative solution. This paper examines India's Solar Photovoltaics and Telecommunication sectors, assessing their potential for circular economy practices, resource efficiency, and waste management. While solar photovoltaics contribute to a greener energy mix, the mounting concern of PV waste persists. Similarly, the telecommunications industry faces a surge in electronic waste due to rapid advancements. Mitigating these challenges necessitates robust policies, technological innovation, and collaboration. The paper identifies key policy and technology barriers and offers tailored recommendations. Synergistic strategies like energy exchange, dual land usage, and smart grid integration are proposed. This insight is crucial for policymakers, industry, and researchers committed to a more sustainable future in India.

Keywords

Solar photovoltaic panels; Telecommunication; Circular economy; Waste management; Recycling; Resource efficiency

INTRODUCTION

Amid global sustainability goals, the shift to a circular economy emerges as a transformative force, replacing linear models with resource-efficient, waste-reducing practices. This research paper focuses on India’s Solar Photovoltaics (PV) and Telecommunications sector, underscoring their scope and potential to transform to a circular economy (CE), thereby ensuring sustainable resource efficiency and effective waste management.

Both sectors are vital for India's growth but also major contributors to e-waste; the country generates about 3.2 million metric tonnes annually, with limited proper recycling [1]. In 2022, India expanded e-waste guidelines to cover telecom equipment and PV waste [2] [3], but policy gaps persist and inadequate recycling infrastructure raises environmental concerns.

This paper aims to address the challenges and policy gaps in handling e-waste effectively and presents a roadmap for India. Additionally, it proposes a recycling framework for the solar PV sector. It seeks to answer the following questions:

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1. What is the scale of waste generated in the solar PV and telecommunication segments? Why is the adoption of circular economy imperative in these sectors?
2. What are the existing gaps that hinder the seamless transformation of circular economy principles in the solar PV and telecommunication sectors?
3. How can the existing policies and practices be strengthened to enable sustainable resource efficiency and effective waste management in these sectors? What are the potential policy solutions for effective resource efficiency and waste management?

MATERIALS AND METHODS

The methodology involves an extensive literature review and in-depth data analyses, aiming to generate evidence-based insights for policy enrichment. The paper is organized as follows:

1. Following the introduction section that sets the background to our paper, the next section examines the solar PV and telecommunication sectors' growth, assessing their e-waste composition, and pinpointing policy gaps and waste management challenges.
2. The results and potential policy solutions form a roadmap for enhancing the integration and deployment of circular economy practices in the solar PV and telecommunication sectors.
3. Furthermore, the paper highlights cross-sector challenges and opportunities, emphasizing potential synergies, mutual benefits, innovation, and collaborative efforts to achieve a greener and more sustainable future.

Solar Photovoltaics in India: Overview

The remarkable growth of solar photovoltaics (PV) in India, exceeding yearly targets, is a key facet of the nation's pursuit of 500 GW renewable energy capacity by 2030, with solar contributing over 292 GW [4]. This shift towards solar energy is crucial in diversifying India's energy mix and reducing reliance on fossil fuels. However, the expansion also arises the concern about the PV waste's environmental impact.

With nearly 64 GW of PV installations as of March 2023 [5], projected to generate 4 million tonnes of waste by 2050 [6], urgent attention to proper management is needed. While India has initiated policies and regulations for PV waste management, ambiguity persists in policy maturity and recycling measures. Establishing a robust recycling framework and regulatory bodies is essential to ensure environmentally responsible PV waste management.

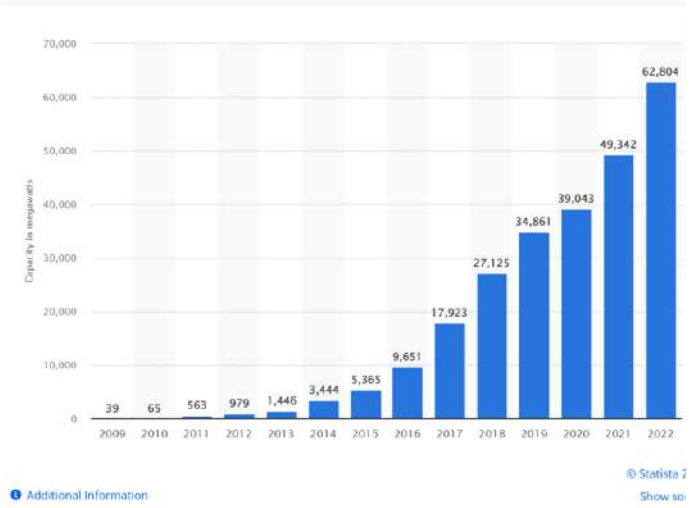

*Figure SEQ Figure * ARABIC 1 Growth of Solar Capacity over the years in India*
Source: Statista 2023

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In India, nearly 93% of PV modules are made of crystalline silicone (c-Si), while the remaining 7% consists of cadmium telluride (CdTe) thin film modules [7]. The figure below shows the composition of these modules [8].
As these PV panels approach their end-of-life (EOL), only approximately 20% of PV waste is effectively recovered, with the remaining waste often being informally treated [7]. Mishandling solar PV waste can lead to soil and water contamination, inefficient recycling emissions, and resource depletion. Tackling these challenges requires a comprehensive approach, prioritizing recycling management and circular economy principles for a greener future.

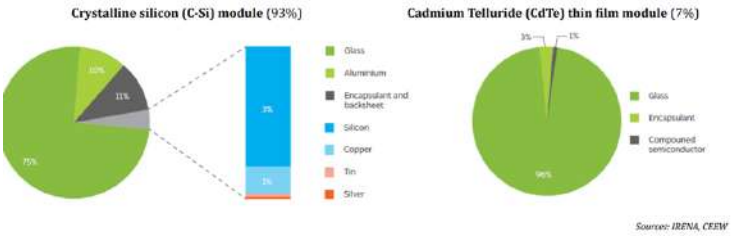

*Figure SEQ Figure * ARABIC 2 Composition of Solar PV panels*
Source: IRENA, CEEW

Recycling Framework

The proposed recycling framework [9] consists of the following three main components:

- 'Clusters' (addressed as Cs) are groups of PV plants that share common characteristics or are located near each other.
  The analysis of Cs serves as a valuable data exploration and mining tool, facilitating the division of a multivariate dataset into distinct and meaningful Cs or groups. In this study, groups or Cs of PV plants were identified on the basis of their proximity in terms of distance and the quantity of waste generated by each plant.
- 'Collection Centres' (addressed as CCs) are designated PV plants within each C that serve as collection points for EOL or failed panels from other PV plants within the C. These CCs store the panels temporarily before being transported for recycling. In this study, the CCs within each C were strategically located by considering the proximity to the PV plants and the overall transportation costs.
- 'Recycling Units' (addressed as RUs) are facilities established in an optimal industrial zone to recycle PV waste.

The stage-wise optimisation-modelling-driven recycling framework [9] is depicted in Figure 3.

Solar Power System For Telecommunications

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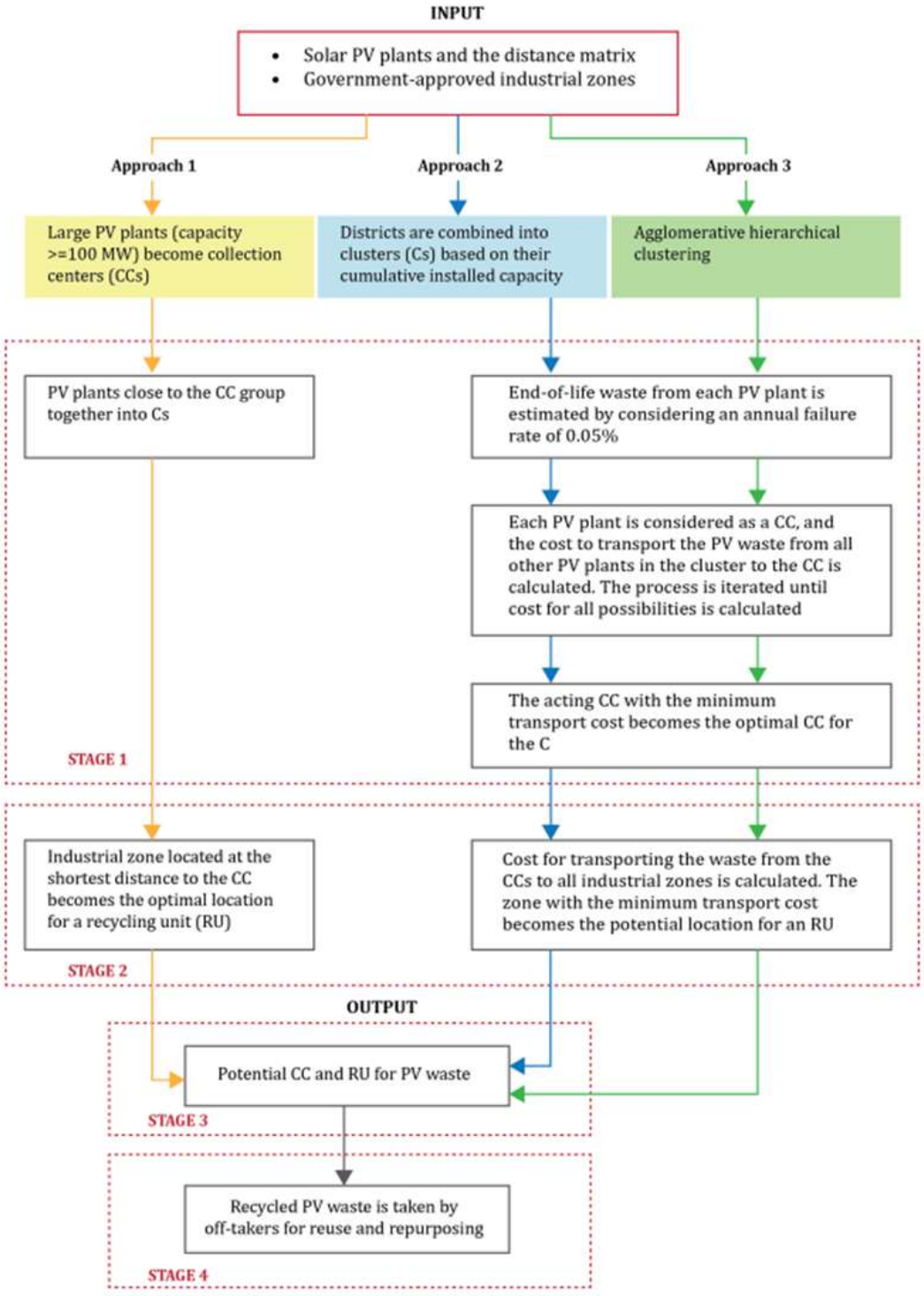

Figure-3

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Policy Gaps and Challenges in Managing Solar PV Waste

Managing solar PV waste in India encounters policy and technology obstacles, impairing efficient recycling of end-of-life modules. These gaps pose serious environmental risks, demanding immediate attention. The following table summarises these challenges.

Policy Barriers	Technology Barriers
Existence of greater informal sector involvement in waste handling	Lack of suitable technologies or tools to track PV waste generation.
Lack of clear segregation of PV waste from e-waste and absence of penalties	Outdated recycling technologies and inefficient recycling processes.
Absence of a national monitoring and reporting mechanism	Limited awareness regarding viable avenues for business growth within the solar PV waste management sector.
Inadequate infrastructure facilities for collection and recycling of waste	Absence of adequate R&D programs to advance domestic PV panel manufacturing and enhance recycling and repurposing of PV waste.
Inadequate awareness and information dissemination on waste handling practices and mechanisms.	
Lack of clearly defined recycling benchmarks and targets	

Table 1 Policy and technology barriers for solar PV waste management in India

Implementing clear regulations, investing in advanced recycling technologies, promoting information exchange, and fostering R&D will be pivotal in achieving circular economy principles and resource efficiency in the solar PV sector

Telecommunication Sector in India: Overview

The Indian telecom industry's rapid growth has positioned it as a dynamic global market, driven by widespread mobile penetration and expanding internet connectivity. This digital progress, however, is counterbalanced by a mounting challenge —escalating electronic waste (e-waste) due to technological advancement and consumer demand [1].

E-waste from devices like smartphones, network equipment, and accessories contains valuable materials like plastics, metals, semiconductors, batteries and, certain precious elements like rare earth metals, germanium, and gallium [10]. And a significant portion of this waste is informally managed, employing hazardous practices like burning and acid baths, causing pollution and health hazards [11].

A circular economy approach, focusing on reduced waste and enhanced resource efficiency, offers a sustainable solution for this sector's challenges. Addressing the e-waste issue demands collaborative efforts from manufacturers, policymakers, consumers, and waste management systems, with a clear understanding of policy gaps and integration hurdles.

Policy Gaps and Challenges in Achieving CE in the Telecommunication Sector

In the journey towards a circular economy in the telecommunication industry, policy and technology barriers pose significant challenges. The table below highlights these barriers.

A strong policy framework and regulatory body are essential for information dissemination, recycling infrastructure enhancement, and efficient waste management. With evolving technologies, increased R&D is crucial for innovation and recycling efficiency.

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Policy Barriers	Technology Barriers
Excessive involvement of the informal sector.	Lack of suitable technologies to track and manage telecom waste generation.
Lack of clear segregation between e-waste and telecom waste handling guidelines and regulations.	Outdated recycling technologies and ineffective processes.
Absence of a national monitoring and reporting agency to regulate waste quantity and recycling efforts.	Absence of profitable business opportunities for recycling and repurposing telecom waste.
Lack of suitable infrastructure for cost-effective collection and recycling of telecom waste.	Insufficient Research & Development (R&D) programs to support domestic manufacturing and recycling.
Inadequate information dissemination about recycling rates, Extended Producer Responsibility (EPR) guidelines, and sustainable practices.	

Table 2 Policy and technology barriers for telecom waste management in India

Suggestions for Enhancing Resource Efficiency in Telecommunication

- Provide Policy Incentives: Establish and apply robust policy incentives, encompassing tax advantages, grants, and subsidies, to foster the expansion of an eco-friendly and circular telecom ecosystem.
- Capacity Building and Awareness: Introduce awareness initiatives to educate consumers about responsible consumption and effective end-of-life handling.
- Promote R&D Collaborations: Catalyze research-business partnerships with funding and incentives to accelerate innovative recycling methods, reducing electronic waste and conserving resources.
- Start Pilot Interventions: Launch pilot projects throughout the telecom value chain to showcase circular business models, addressing unprofitable opportunities and fostering wider adoption.
- Promote Resource Efficiency Solutions: Promote resource-efficient technologies in telecom, including e-SIM, cloud storage, AI, IoT, and Blockchain, to minimise waste and enhance sustainability [12].
- Material Recycling and Product Improvement: Prioritize stable supply mechanisms, global resource development, recycling initiatives, and design improvements to counter rare metal scarcity [11].
- Create E-Waste Tracking Systems: Advocate for comprehensive electronic waste tracking systems across the lifecycle of electronic devices to ensure holistic management, addressing informal sector involvement and monitoring gaps.

Synergies: Collaboration and Resource Sharing between Sectors

This section explores collaborative opportunities between the solar PV and telecom sectors, unveiling innovative synergies. By leveraging sector strengths and fostering initiatives, these industries can advance toward a resilient and sustainable future.

- Energy Exchange: Integrating solar PV systems with telecom towers, particularly in off-grid or remote locations, offers mutual benefits. Excess solar energy generated can be fed into the grid or stored for powering nearby towers, fostering energy efficiency and lowering carbon footprints.

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Figure Potential collaboration between Solar PV and Telecommunication sectors
Source: authors' ideation

- Natural Resource Efficiency: Solar PV installations often demand substantial land, whereas telecom towers occupy underutilized spaces. Integrating solar panels on towers or using tower sites for solar installations [14] optimizes land use and reduces resource competition.
- Smart Grid Integration: Collaborating on smart grid technologies can optimize energy management. Telecom's data analytics and real-time monitoring expertise can enhance smart grid integration, boosting solar PV system efficiency and reliability.
- R&D, Innovation and Collaborations: Collaborative R&D can drive innovation in energy storage, batteries, and smart grids. Shared expertise accelerates technological progress and cultivates an innovation-driven culture.

Conclusion

The solar PV and telecommunication sectors in India have the potential to drive circular economy and sustainable resource practices. Therefore, addressing e-waste challenges and policy gaps is crucial for a greener future. Effective recycling, domestic manufacturing promotion, and collaborative R&D can lead to sustainable resource management. Moreover, synergies between sectors offer energy optimization and environmental conservation. Proactive policies and collaboration will advance circularity, guiding India toward a sustainable future. By embracing circular principles, these sectors can steer India toward a greener, environmentally conscious future.

ABOUT THE AUTHOR:

DR. ANJALI TANEJA

GROUP HEAD OF SUSTAINABILITY AND SENIOR POLICY SPECIALIST,
CENTER FOR STUDY OF SCIENCE, TECHNOLOGY AND POLICY (CSTEP)

Dr Anjali Taneja is an Economist and a seasoned Sustainability Expert. She has been involved in sustainability initiatives over the last 15 plus different the multilateral institutions like UNDP, Government of India, Ashoka University and the national industry chambers of India like FICCI and CII. At CSTEP she heads the Sustainability vertical with circular economy at the core of her research and policy enrichment. She leads evidence-based research and policy initiatives in different sustainability fields including, solar photovoltaic waste management, circular economy in telecommunication, rural regeneration, and artificial intelligence for climate change, to name a few.

MS. KHUSHBOO GARG

Senior Analyst - Sustainability
Center for Study of Science, Technology and Policy (CSTEP)

Khushboo Garg is a young, analytical, and observant professional, actively contributing in the field of circular economy since 2022. At CSTEP she works as a Senior Analyst in the Sustainability vertical and has been assisting in various initiatives surrounding circular economy and sustainability. She also volunteers with the Germany-based NGO 'The Considerate Consumer,' writing impactful articles to inspire sustainable choices.