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Report on Development of Circular Economy Indicators in Electrical and Electronics Sector in India

October 2023

EU-INDIA JOINT STUDY

Toxics Link
for a toxics-free world

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Report on Development of Circular Economy Indicators in Electrical and Electronics Sector in India

October 2023

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Foreword

'*Circular Economy*' is the new 'Mantra' for future development and growth. Circular economy approach is imperative to fulfill the need of resources for the growing economy, like India. It minimizes the wastage at each life-cycle stage and promotes 4Rs (i.e. reuse, repair, recover, re-manufacture) and also ensures regeneration of products and materials.

India is the third largest consumer of raw materials produced globally. If current economic trends persist, then India's material consumption would reach nearly 15 billion tonnes by 2030 and above 25 billion tonnes by 2050. In order to fulfill the resources need, it is essential to follow circular economy approach rather than the current linear economy principle of take-make-dispose.

This study report prepared under European Union – Resource Efficiency Initiative (EU-REI), India on circular economy in E-waste provides an international scenario on global best practices to be adopted by Indian Manufacturer and Recyclers. Promotion of eco-design & Green products, scientific extraction and reuse of SRM & CRM in manufacturing value chain would be a forthcoming step in the country. This report ensures an India-centric approach to understand the preparedness of circular economy business models, identify gaps and opportunities, as also to formulate evidence-based policy recommendations.

I compliment EU-REI team for this comprehensive well-researched report on Global best practices in circular economy in E-waste.

Best Wishes,

(S. Krishnan)

Dated: 22.9.2023
Place: New Delhi

आज़ादी का अमृत महोत्सव

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INTRODUCTION

The contemporary epoch of capitalist production is characterised by the act of consumption. For the modern market economies, all of us are potential consumers; of goods, services, utilities, and what not. The indiscriminate act of production, consumption and disposal is, however, placing huge burden on the finite resources and raw materials of the world. Material footprint gives an indication of the pressures placed on the environment to support economic growth, to satisfy the material needs of people, and refers to the total amount of raw materials extracted to meet final consumption demands. The global material footprint rose from 43 billion metric tons in 1990 to 54 billion in 2000, and 92 billion in 2017—an increase of 70 percent since 2000, and 113 percent since 1990. It is projected to grow to 190 billion metric tons by 2060, without concrete steps and political will.[1]

Circular economy as a regenerative economic model, offers an alternative to the conventional model of production, consumption and disposal. The term was initially introduced in the study titled 'Sustainable Economic Development' by Pearce and Turner, highlight the interconnectedness of the economy and the environment.[2] It proposed a modification to the conventional economic paradigm, which is primarily focused on utilitarian benefit-cost analysis, to incorporate the idea of intergenerational utility. As the definition suggests, the aim of the circular economy framework is to decouple economic growth from resource consumption and environmental degradation. It emphasises the principles of designing out waste and pollution, keeping products and materials in use for as long as possible, and regenerating natural systems. Hence, recycling, reusing, and remanufacturing are central to the circular economy framework. The transition from a linear model of production, characterized by the "take-make-dispose" approach, to a circular economy model is crucial for sustainable development addressing global environmental challenges. It not only addresses environmental concerns but also offers economic opportunities and resilience.

Several regions of the world have made significant progress in adopting robust frameworks for a circular economy. The European Union (EU) has been at the forefront of this transition, implementing policies and initiatives to promote circularity. EU's Circular Economy Action Plan, launched in 2015 and revamped in 2020, sets out a comprehensive strategy to transform the EU economy into a more circular and sustainable one. It includes measures such as promoting sustainable product design, improving waste management and recycling systems, and supporting the development of secondary raw materials markets.[3] Even within EU, countries like the Netherlands have made even more significant progress in transitioning to a circular economy. The Dutch government has developed a comprehensive Circular Economy Programme, focusing on areas such as sustainable procurement, circular design, and waste reduction. Initiatives like the Circular Economy Innovation Program and Circular Economy Policy Plan promote collaboration among stakeholders and drive innovation.[4]

China is another notable example, with its commitment to transitioning to a circular economy outlined in its 13th Five-Year Plan. China has implemented various policies and regulations to promote circularity, including the establishment of a National Circular Economy Pilot Zone Program. This program focuses on resource conservation, waste reduction, and recycling, aiming to transform traditional industries into eco-friendly and sustainable ones.[5]

Japan has also made significant strides in advancing the circular economy agenda. The country's Circular Economy Promotion Law, enacted in 2000, provides a legal framework for promoting recycling, waste reduction, and resource conservation. Japan has implemented various initiatives, such as the 3R (Reduce, Reuse, Recycle) Policy, eco-town programs, and established legislation such as the Home Appliance Recycling Law. Japan also encourages resource-efficient technologies, promotes product life extension, and emphasizes recycling to promote circularity and sustainable waste management.[6]

For India, transitioning to a circular economy is of paramount importance. The country faces numerous environmental challenges, including scarcity of resource and critical raw materials, waste management issues, and pollution. Adopting a circular economy model can help India address these challenges while promoting sustainable economic growth. Lessons can be drawn from the global experience to inform India's approach. One key lesson is the importance of policy and regulatory frameworks. The EU's Circular Economy Action Plan and China's Circular Economy Pilot Zone Program demonstrate the significance of comprehensive policies that set clear goals and provide incentives for circularity. India can develop similar policy frameworks that prioritize sustainable product design, resource conservation, and waste management.

Another lesson that can be drawn from the worldwide experience is the need for collaboration among various stakeholders. Circular economy transition requires the involvement of businesses, governments, academia, and civil society. Japan's eco-town programs, which involve partnerships between local governments, businesses, and communities, showcase the power of collaboration in achieving circularity. India can encourage multi-stakeholder partnerships to drive the circular economy agenda. Furthermore, investing in research and development (R&D) and innovation is crucial. The development of new technologies, materials, and business models is key to unlocking the full potential of a circular economy. India can foster R&D and innovation ecosystems, providing support for startups, promoting collaboration between academia and industry, and incentivizing sustainable innovation.

The concept of a circular economy offers a promising pathway towards sustainable development. Regions such as the EU, China, and Japan have made substantial progress in adopting circular economy frameworks. India can learn from their experiences by developing robust policy frameworks, fostering collaboration among stakeholders, and investing in R&D and innovation. Transitioning to a circular economy can enable India to address its environmental challenges while fostering sustainable economic growth.

METHODOLOGY

The following research paper aims to develop circular economy indicators with the objective to create benchmarks for circular economy approaches in order to effectively monitor circular economy implementation and progress. The proposed methodology for developing Circularity Indicators begins with the comparative and critical evaluation of all existing frameworks of circular economy and its indicators for the EEE sector, around the world, and contrasting it with the contextualities of the Indian EEE sector. The major regions whose circularity strategies have been evaluated include; - Europe, China, and Japan. After the desk review and analysis of the circular economy frameworks and indicators of these regions, the exercise of developing nascent circular economy indicators for the Indian EEE sector was initiated by adopting a mixed-method research approach to conduct an exploratory study. The research was exploratory in nature as the topic of study is still emergent and there is limited existing knowledge on circular economy indicators for the EEE sector in a developing economy like India. As suggested, the aim of the study is to develop a multidimensional set of macro and micro-level circular economy indicators capable of measuring and monitoring the implementation and progress of circularity principles in the Indian EEE sector.

The data collection strategy involved the identification and mapping of all relevant stakeholders in the EEE sector in India. It comprised two levels of engagement:

(1) In-depth interviews all stakeholders in the EEE sector using a semi-structured interview schedule, focused on formulating a novel set of CIs and rating their relevance to the Indian E&E sector (interview schedule has been attached in Annexure 1), then,

(2) the formulated circular economy indicators were drawn and validated by discussions with groups of stakeholders like manufacturers, recyclers (formal and informal) and policymakers.

Following the validation of the indicators, they have then been enlisted as recommendations proposed for adoption by Meity and all other relevant stakeholders.

CIRCULAR ECONOMY IN THE ELECTRICAL AND ELECTRONIC EQUIPMENT (EEE) SECTOR

The Circular Economy principles are especially relevant for resource and raw material intensive sectors like Electrical and Electronic Equipment (EEE) Sector. The rise in 'smart objects' has meant the addition of EEE functionality to a growing number of products, at a rate faster than ever before and the subsequent rise in waste electrical and electronic equipment (WEEE) which is one of the fastest-growing waste streams globally. The EEE sector is generating environmental challenges not just due to the rising rates of consumption but also to the rapid obsolescence of electronic devices. For example, the usage of EEEs like laptops, computers, notebooks, and mobile phones has grown exponentially in the last decade, with sales of EEEs at 14.5 million units worldwide (in 2018)[7], however, the average lifespan of a new computer has decreased from 4.5 years in 1992 to an estimated 2 years in 2005 and is further decreasing.[8] The disposal of end-of-life electronic products is also a concern due to its specific particularities. E-waste contains not just valuable materials and precious metals, but also toxic metals and polyhalogenated organics including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDES), etc. which can easily be released from e-waste, as numerous researchers have demonstrated, posing serious risks of harm to humans and the environment.[9] To address these issues related to the consumption of electronic devices, countries worldwide have been adopting circular economy principles in the EEE sector.

Circular economy in the EEE sector - Policies and Practices worldwide

In this overview, we will consider the insights about the circular economy policies and practices implemented in China, Europe, and Japan.

Circular Economy Policies	
China	Cleaner Production Promotion Law: In 2002, People's Republic of China implemented the Cleaner Production Promotion Law and entered a new era of cleaner production. The process of Environmental pollution control gradually shifted from end treatment to source prevention, thus greatly promoting the increase in resource utilisation rate and reduction in pollutant emissions in industrial sectors and laying the foundation for the development of circular economy.
	China's first circular economy pilot city and province: The State Environmental Protection Administration also launched the circular economy programme in 2002, and pilot stage of circular economy was initiated with Guiyang City and Liaoning Province selected as China's first circular economy pilot city and province, respectively. In 2005 the Chinese State Council indicated circular economy as the new development model and in 2005 and 2007 it launched the first and second sets of circular economy pilot projects in targeted provinces and cities, sectors, areas, and industrial parks.
	Circular Economy Promotion Law: In January, 2009 China implemented the Circular Economy Promotion Law, indicating the integration of the circular economy principles not just in economic development model but also into the legislation process. This coincided with the rapid increase in the number of pilot projects and scope of circular economy, which now covered 27 provinces and numerous industries, indicating a widespread trend in implementation.[10]
Europe	EU Directives on waste electrical and electronic equipment (WEEE): The European Parliament approved the WEEE directives in 2012, with the primary goal of promoting sustainable production and consumption. The directives aim to achieve this by: → Prioritizing the prevention of waste electrical and electronic equipment (WEEE) generation. → Promoting the efficient utilization of resources and the recovery of secondary raw materials through methods such as re-use, recycling, and other forms of recovery. → Enhancing the environmental performance of all stakeholders involved in the life cycle of electrical and electronic equipment (EEE) The directives mandated the collection, treatment, recycling, and proper disposal of EEE waste, while also promoting eco-design and setting recycling targets for member states.[11]
	New circular economy action plan: In March 2020, the European Commission implemented the new circular economy action plan (CEAP) with the following objectives: → Promote the mainstream adoption of sustainable products throughout the European Union (EU). → Empower consumers and public buyers to make informed choices that support sustainability. → Concentrate efforts on sectors that have a significant resource consumption and high potential for circularity, such as electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water, and nutrients. → Reduce waste generation and promote waste reduction strategies. → Ensure that the circular economy benefits people, regions, and cities, fostering inclusive and sustainable development. → Take a leadership role in global initiatives and collaborations related to the circular economy. By implementing these measures, the European Commission aims to drive the transition towards a circular economy both within the EU and on a global scale.[12]

	The Eco-design Directive: These were first implemented in 2009, later amended in 2012 and again in 2022. The objective of this Directive originally was to create a structure for establishing eco-design requirements for energy-related products within the Community. This framework aims to facilitate the unrestricted movement of such products within the internal market.[13] The latest eco-design directives (which is set to replace the earlier one) has expanded its scope and mandates diverse requirements covering various aspects such as: → Enhancing product durability, reusability, upgradability, and reparability → Addressing the presence of substances that hinder circularity → Promoting energy and resource efficiency → Encouraging the use of recycled content → Supporting remanufacturing and recycling practices → Assessing carbon and environmental footprints → Compelling information disclosure, including the implementation of a Digital Product Passport The introduction of the Digital Product Passport aims to provide comprehensive information about the environmental sustainability of products. This tool is envisioned to assist consumers and businesses in making informed decisions during product purchases, facilitate repairs and recycling, and enhance transparency regarding the environmental impact of products throughout their life cycles.[14]
Japan	Eco-points System: To incentivise consumers to purchase energy-efficient and environmentally friendly appliances, the Japanese government implemented an eco-points system. Following its success, the programme was expanded to include residential buildings in 2010, Eco points are awarded to people who buy eco-friendly, energy efficient appliances and who build green home or undertake energy-efficient remodelling. One eco-point is equivalent to 1 yen but it cannot be redeemed for cash; points can be exchanged for eco-friendly products or gift certificates.[15]
	The Small Home Appliance Recycling Law: In April 2013, the Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment (abbreviated as "the Small Home Appliance Recycling Law") came into force in Japan. The law aims to promote the recycling of small home appliances to achieve their proper disposal and effective use of resources. This new policy goes beyond the existing Home Appliance Recycling Law (enforced in 2001) which covered only four items, namely TVs, air conditioners, refrigerators/freezers and washing machines/dryers, and obliged manufacturers to recycle these items with consumers bearing the cost. In contrast, the new law covers a wide range of electric/electronic appliances excluding the above-mentioned four items and encourages voluntary participation, compared with the above-mentioned Home Appliance Recycling Law that imposes obligations on the concerned parties.[16]
	Circular Economy Vision 2020: Japan first introduced the Circular economy vision in 1999, with the aim to transform the economic system from one based on mass production, mass consumption and mass disposal, to a circular economic system where environmental and economic aspects are integrated. The vision proposed the full-scale adoption of the 3Rs (reduce, reuse, recycle), which included measures to control the generation of waste (Reduce) and to repeatedly use materials from products or parts which are still usable (Reuse) and strengthening the conventional recycling measures. The new Circular Economy Vision, 2020, builds on the two decades of implementation of 1999's circular economy visions, while also incorporating the changing realties of current times, which includes; the development of digital technologies and the growing demand from markets and society for environmental action.[17]

Circular Economy Practices	
China	The circular economy practices in China can be grouped together at three levels; micro-level, meso-level, and macro-level. At the micro level, the producers and factories are required and encouraged to adopt cleaner production and eco-design practices. Cleaner production has emerged as an effective and widely implemented measure, particularly after the implementation of China's Cleaner Production Promotion Law in January 2003. Cleaner Production is a strategy that addresses pollution generation and promotes resource efficiency throughout the production process. Eco-design, which involves incorporating environmental considerations into the design of production processes and final products and encourages environmentally intensive manufacturing process, requiring industries to explore more integrated, efficient, and sustainable production methods through innovative design, is especially relevant in the case of the EEE sector. Eco-design for EEE entails proactively addressing environmental attributes during the product development stage to minimize negative environmental impacts throughout the product's life cycle. However, a survey conducted among 36 electrical and electronic manufacturers in China revealed limited evidence of eco-design practices, highlighting the need for its increased awareness and promotion.[18]
	The meso-level practices include development of eco-industrial parks, establishment of waste trading systems, and the creation of resource recovery parks. Eco-industrial parks adopt the concept of industrial symbiosis, where geographically clustered firms cooperatively manage resource flows. This approach allows for simultaneous improvements in environmental performance and a decrease in production costs. Firms within eco-industrial parks share infrastructure and services, as well as trade industrial by-products like heat, energy, wastewater, and manufacturing waste. This reduces dependency on external resources and minimizes environmental impact. Finally, in waste management, there is a focus on regulating and expanding the waste trade market and establishing resource recovery parks. These efforts aim to increase productivity and economic benefits in the resource recovery industry.
	At the macro level, cooperative networks between industries and industrial parks across different sectors (primary, secondary, and tertiary) emerges and become more complex and extensive. This involves redesigning and reorganizing a city's infrastructure and industrial layout according to regional characteristics, phasing out heavily polluting enterprises and supporting high-tech industries. On the consumption side, the perception is to proposal to the establishment of a renting system in cities based on the concept of a functional economy. This shift emphasizes the utilization of products rather than the buying and selling of products themselves. It creates new job opportunities, particularly in labour-intensive service centers, and reduces resource usage by minimizing the rapid movement of products from factories to customers and then to landfills. In waste management, promoting urban symbiosis is important. Urban symbiosis builds upon the principles of industrial symbiosis, focusing on the transfer of waste materials for both environmental and economic benefits. This involves various activities such as the use of environmentally friendly products and equipment, recycling of waste materials, utilization of green technologies and products, and the restoration and protection of natural ecosystems.[19]
Europe	In Europe, the electrical and electronics industry, which relies on critical and rare earth metals for its products, has gradually begun to adopt circular economy practices. Take-back facilities have been established in malls, retail outlets, and at industries to recover elements from products. This approach has reduced manufacturers' dependence on virgin raw materials, leading to a decrease in mining activities and a subsequent reduction in the carbon footprint of electrical products.[20]

	Europe is also leveraging development in artificial intelligence (AI) and algorithms to enable the assessment of material recovery potential at the end-of-life of electrical appliances. Other CE strategies employed in this industry include design for disassembly, which facilitates refurbishment and recycling. Some manufacturers have implemented incentivized recycling programs, offering consumers monetary benefits for returning products at the end of their useful life. Additionally, collaboration with other firms or manufacturers has been embraced to promote material and resource sharing, enhancing material reuse and recycling efforts.[21]
	The European Commission, in March 2023, has also adopted a new proposal for directives on common rules promoting the repair of goods, with a focus on addressing repair beyond the legal guarantee. The proposed rules for promoting repair encompass a combination of six preferred policy options to address the related issues, these are: → Prioritizing repair over replacement, when it is more cost-effective, within the framework of legal guarantees. → Establishing a national-level online platform that connects consumers with repairers and promotes the use of refurbished goods. → Imposing an obligation on repairers to provide consumers with a standardized quote for repair costs and conditions upon request (European Repair Information Form). → Obligating producers of goods to which reparability requirements under EU law applies to offer repair services beyond the legal guarantee period for a specified price. → Mandating producers to inform consumers about their obligations regarding repair services for their products. → Developing a voluntary European Standard for repair services, to facilitate and promote repair practices (European Standard for repair services). These policy options aim to make repairability a practical choice, encourage the repair industry, and provide consumers with more information and options for repairing products.[22]
Japan	Streamlined and Consumer-friendly Collection Process: The system for collecting old appliances for recycling is highly inclusive and user-friendly, making it easier for consumers to participate in recycling efforts. Retailers play a crucial role by offering collection services either in-store or during the delivery of new appliances. When it comes to old EEE equipment, consumers can request local authorities to collect it from their doorstep, or they have the option to return it to any post office for the manufacturer to retrieve. This collection system is well-established and widely utilized throughout Japan.
	Upfront Payment by Consumers: In the case of electronics, the costs associated with transportation and recovery are paid by consumers at the time of purchase. This means that customers do not face any disincentives when it comes to participating in the recycling process once a product reaches its end-of-life. Additionally, there are strict penalties in place for illegal dumping or improper disposal of electronic waste, ensuring compliance with recycling regulations.
	Shared Ownership of Recycling Infrastructure: Government legislation mandates that consortium of manufacturers operate disassembly plants, ensuring that they directly benefit from the recovery of materials and components. This ownership structure incentivizes companies to make long-term investments in recycling infrastructure. Moreover, since manufacturers own both the production and recovery facilities, they send product designers to disassembly factories to gain firsthand experience of the challenges involved in dismantling poorly designed products. Some companies even subject prototypes to the disassembly process to ensure that they are easily recoverable.[23]

What can be concluded from the above review is that China, Europe, and Japan have implemented various circular economy policies and practices in the EEE sector to address the environmental challenges associated with electronic waste. These initiatives include extended producer responsibility, eco-design, waste management, take-back programs, refurbishment, and material recovery. By embracing circular economy principles, these regions are striving to reduce waste, promote resource efficiency, and contribute to a more sustainable future.

Circular economy in the EEE sector - Potentials and Possibilities for India

India's Electrical and Electronic Equipment (EEE) sector is growing rapidly while contributing to the economic development of the country and improving the living standards of its citizens. Nonetheless, the growth of the sector is also bringing about significant challenges related to management of electronic waste and optimal utilisation of critical resources, which are scarce and depleting fast. As of 2019, India had already become the third largest e-waste generator in the world producing a total of 3.26 million tons of WEEE.[24]

Embracing circular economy principles opens up a plethora of potentials and possibilities for India to address these challenges and promote sustainable practices in the EEE sector. The transformation of businesses and enterprises towards Circular Economy Business Models (CEBMs) is also crucial for developing countries like India, because of its large population, significant share in global production and consumption, and the huge potential for future urban infrastructure development.[25] A recent study, undertaken by Accenture, suggested that India can unlock approximately half a trillion dollars of economic value by 2030 through adoption of Circular Economy Business Models.[26] According to the study, this can be accomplished through a range of approaches, including minimizing material and energy waste, optimizing the use of products and capital assets, prolonging the lifespan of products, and extracting value from waste streams.

Another estimate provided by the Ellen Macarthur Foundation suggests that circular economy path to development could bring India annual benefits of ₹40 lakh crore (US$ 624 billion) in 2050 compared with the current development path – a benefit equivalent to 30% of India's current GDP.[27] In this light, the following overview examines and enlists the potential benefits and key possibilities for adopting circular economy principles in the EEE sector in India. They include;

- **Resource Conservation and Material Recovery:**

  Electrical and electronic equipment (EEE) possess a highly intricate material composition, encompassing a wide range of elements from the periodic table. EEE contains 69 elements, including valuable metals like platinum, gold, rhodium, silver, copper, iridium, ruthenium, and osmium. Additionally, EEE contains Critical Raw Materials (CRM) such as indium, cobalt, bismuth, palladium, antimony, and germanium. Alongside these, EEE also includes noncritical metals like iron and aluminum. Therefore, in the context of electrical and electronic products, resource sustainability is a significant issue as they often contain various rare earth metals.[28] Implementing circular economy principles in the EEE sector can enable resource conservation through efficient extractions of precious metals and better material recovery. Proper recycling and recovery processes will not only extract valuable materials from electronic waste, reducing the need for virgin resources but will also assist in conserving the environment along with improving social health protection.

- **Economic Opportunities and Job Creation:**

  The existing literature on Circular Economy primarily emphasizes the techno-managerial efforts of large corporations in addressing circular economy challenges, overlooking the significant resource flows that occur outside the formal economy, particularly in developing countries like India. These aspects present valuable opportunities to explore and understand the social and equity dimensions of CE, which have received less attention in current literature. Furthermore, studying and integrating India's informal economy can help businesses implement and replicate circular economy approaches and strategies on a larger scale from a technical systems perspective.[29] Such efforts using circular economy principles in the EEE sector will assist and contribute to job creation and local economic growth, leading to integration of recycling and refurbishment infrastructure which involve both formal and erstwhile informal participants, developing better reverse logistics networks, and promoting repair services etc.

- **Extended Product Lifespan:**

  Many developing countries, including India, face substantial climate action requirements while grappling with issues of resource efficiency, pollution generation, and low industrial productivity. Despite these challenges, Indian industries possess significant potential for driving circular economy transformation globally. According to a recent survey conducted by FICCI & Accenture in 2021 across India to gauge the views of business leaders on the CE landscape, its future, and the potential for decarbonization in the country, nearly 94% of the respondents believe that Circular Economy Business Models (CEBMs) can be integrated across various sectors within the next 3-5 years. Additionally, 77% of the surveyed business leaders are currently prioritizing CE strategies to achieve their organization's decarbonization objectives.[30] These circular economy strategies emphasise product durability and repairability, leading to an extended lifespan for electronic devices. Encouraging repair and maintenance services, along with consumer awareness campaigns. All these steps can help consumers maximize the use of their devices and reduce premature disposal, thereby promoting resource efficiency, reducing pollution, and increasing productivity.

- **Sustainable Consumption Patterns:**

  Circular economy principles promote sustainable consumption patterns by shifting towards product-as-a-service models. Implementing sharing and leasing schemes for electronic devices can enable consumers to access technology while reducing the overall demand for new products. Raising consumer awareness about the environmental impacts of electronic waste and the importance of adopting circular economy practices will also be essential in the transformation towards a more functional shared and service-based economy. Educational campaigns and initiatives can promote responsible consumption, sharing leasing models and schemes, e-waste recycling, and repair services among consumers.

- **Strengthening Waste Management Infrastructure:**

  The circular economy strategy envisions to transform the way industrial and consumer waste is managed by promoting the use of these wastes as substitutes for virgin materials. This approach seeks to eliminate inefficient and harmful waste disposal practices. Currently, numerous waste streams remain largely untapped and underutilized, presenting significant opportunities for resource recovery and utilization. Considering the quantum of e-waste generated reached a record-breaking 53.6 million metric tons in 2019 and only 17.4% of this e-waste was collected and recycled, it becomes obvious that inefficient handling of e-waste is leading to a substantial loss of recyclable material resources.[31] In a developing economy like India, a significant portion of resource recovery from e-waste happens in the informal sector, which faces challenges in occupational settings, including working under hazardous conditions without proper safety measures. The workers in the sector manually dismantle and process e-waste, exposing themselves to toxic substances like lead, mercury, cadmium, arsenic, and brominated flame retardants, which pose serious health risks. Another problem is the lack of awareness and knowledge about safe e-waste management practices among informal sector workers. Their current methods of managing e-waste involve crude techniques such as open burning, acid baths, and manual dismantling. This not only leads to improper handling, storage, and disposal of e-waste but also worsens environmental and health issues. Moreover, the rudimentary nature of these practices compromises the efficient recovery of resources, resulting in the loss of valuable materials. To make matters worse, there is also an issue of data blackout on flows of e-waste in the informal sector, making it extremely difficult to track the material flow.[32] To address this issue, it is crucial to develop effective waste management infrastructure and systems that specifically target e-waste, in order to combat improper practices such as hazardous landfill disposal, unscientific and inefficient material recovery or storing e-waste in homes.[33] Investing in waste management infrastructure, such as recycling facilities and collection networks, is crucial for efficient recovery and recycling. This will also require collaborating with the informal sector, which plays a significant role in e-waste management in India.

- **Fostering Innovation and Research:**

  Promoting and fostering extensive research and development in the realm of sustainable technologies is paramount for India. The goal should be to focus on pivotal areas like eco-design and recycling processes, which shall inevitably propel and ignite innovation within the EEE sector. Such development will pave the path towards embracing the Circular economy business model, a model whose significance cannot be understated for India's circular economy agenda. The crux lies in the harmonious convergence of academia, industry, and government, entwining their collective efforts in a symphony of collaboration. This will provide opportunities for knowledge exchange, sprouting the seeds for sustainable solutions to flourish. The key to unlocking the potential of sustainable advancements lies in fostering an ecosystem that nurtures and supports this virtuous cycle. By nurturing an environment that facilitates knowledge dissemination, where the finest minds intermingle and coalesce, the journey toward transformative and sustainable solutions can be expedited and enriched. The core principles of collaboration, innovation, and sustainability together form the backbone of India's quest for a circular economy in the EEE sector.

The adoption of circular economy principles in the EEE sector offers the possibility of unearthing untapped potential for India's growth and development. This potential can only be brought to surface if one recognises the unique specificities of the Indian EEE and WEEE economies, which includes; - a poor history of compliance with take-back and environmental legislation, - enormous presence of informal participants in the e-waste processing economy, - difficulty in identifying all manufacturers and - lack of design locally.[34] For a transition towards circularity to be made possible in the Indian EEE sector and for realising the potential gains from the same, all these peculiarities have to find their place in the circular economy strategies. Only such strategies can deliver resource conservation, economic opportunities, extended product lifespan, sustainable consumption patterns, strengthen waste management infrastructure, foster innovation, and promote consumer awareness.

CIRCULAR ECONOMY INDICATORS ~ ARCHETYPES OF MEASURING CIRCULARITY WORLDWIDE

As discussed in the prior sections, the transition towards a circular economy has gained significant attention worldwide, leading to the exploration of various key dimensions and indicators to measure progress in this area. In the EEE sector, circular economy indicators cover all domains over social, economic and environmental and predominantly deal with dimensions such as recycling recovery, reuse and remanufacturing, resource efficiency, product-life extension, eco-design or eco-innovation indicators, and waste management indicators, etc. Let us first document the archetypes of indicators developed in Europe, China and Japan. However, it should be noted that these indicators are generic and cover all sectors of the economy, rather than focusing just on the electrical and electronics sector.

EUROPE (based on Eurostat and European environment agency)[35]		
Theme	Indicator	Relevance
Production and consumption	Self-sufficiency of raw materials	To ensure sufficiency of CRM (which EU lacks) which are of high economic value, for a wide variety of industries.
Production and consumption	Green public procurement (as an indicator for financing aspects)	Mandating repairability, durability and recycling of products in public procurement.
Production and consumption	Waste generation	Reducing waste generation, by improved manufacturing, less packaging and customer awareness.
Production and consumption	Food waste	20 % of all food products are waste in EU, reducing it will reduce pressure on natural resources.
Waste management	Recycling rates	MSW is heterogeneous in composition, so, sound management is challenging, hence recycling rate of MSW provides a good indication of the quality of the overall waste management system.
Waste management	Specific waste streams	Percentage recycling targets for specific waste streams to avoid landfills

Secondary raw materials	Contribution of recycled materials to raw materials demand	Measure of the contribution of recycled material to overall demand, thereby leading to reduced consumption and waste generation.
Secondary raw materials	Trade of recyclable raw materials between EU members & Rest of World (RoW)	Benefits both reduction of net waste and increase in raw material security.
Competitiveness and innovation	Private investments, jobs and gross value added	Innovation and investments in Eco-design, SRM extraction, recycling process etc, give a good idea on the state of transition to CE.
Competitiveness and innovation	Patents related to recycling and SRM as a proxy for innovation	Large number of patents mean more innovation and investment.

CHINA (based on National Development and Reform Commission, China and paper by Geng et al., 2012)[36]

Theme / group	Indicator (at macro level)	Indicator (at meso level)	Relevance
Resource output rate	Output of main mineral resource	Output of main mineral resource	The Output of main mineral resource is equal to GDP/ total consumption of main mineral resource. The indicator helps in understanding the efficiency of mineral resource use, where a higher value means more efficient use of mineral resource. The main types of mineral resources include iron, copper, lead, zinc, tin, antinomy, tungsten, molybdenum, pyrite and phosphate ore, etc. At meso (industrial park) level the indicator measures the consumption of main mineral resource which is equal to main mineral resource production including imported mineral resource and excluding exported mineral resource.
	Output of energy	Output of energy	The Output of energy is equal to GDP/total consumption of energy. Indicators helps in understanding the efficiency of energy used where a where a higher value means more efficient use of energy. The energy source includes coal, oil, natural gas, nuclear power, wind power and hydro power. At meso (industrial park) level the indicator measures the energy output by the ratio of industrial production/ value of energy consumption.
		Output of land	Measured by value of Industrial production / total land area of industrial park, where a higher value donates more efficient use.
		Output of water resource	The output of water resources is measured by dividing the Industrial production value with the total amount of water withdrawal, where a higher value donates more efficient use.

Resource consumption rate	Energy consumption per unit GDP	Energy consumption per unit industrial production value	This indicator helps in understanding the efficiency of energy consumption. It measures the total energy consumed per 10,000 Yuan produced. The lower value means more efficient energy consumption. Similarly, at meso level it measures the Energy consumption per unit value of industrial production,
	Energy consumption per added industrial value		Denotes the average amount of energy consumed for producing one unit of industrial value. The lower value of this indicator means more efficient energy consumption.
	Energy consumption of per unit product in key industrial sectors	Energy consumption of per unit key product	Key industrial sectors include mining industry, manufacturing industry, water, electricity and gas production and supply industry. Main products include steel/iron, copper, aluminium, cement, fertilizer, paper etc. The Energy consumption of key industrial product is calculated by dividing the energy consumption of steel (copper, aluminium, cement, fertilizer, paper) with steel production (copper, aluminium, cement, fertilizer, paper). The lower value means more efficient energy consumption. At industrial park level it is calculated by dividing the energy consumed with the weight of production on key products.
	Water withdrawal per unit of GDP	Water consumption per unit industrial production value	Indicates the efficiency of water use and is calculated by dividing the total amount of water withdrawal with the GDP to get water withdrawal per unit of GDP. Water withdrawal includes all kinds of fresh water sources, such as surface water, groundwater, recycled wastewater, rainwater, desalinated seawater etc, but excludes the directly used seawater. The lower value means more efficient water consumption. At meso level Water withdrawal per unit industrial production value is equal to Water withdrawal amount/ industrial production value.
	Water withdrawal per added industrial value		Water withdrawal means water consumption. Water withdrawal here is the water consumed during the industrial processes, such as manufacturing process, cooling process, air conditioning and purification processes. Fresh water consumption value here does not include any recycled water. It is calculated by dividing the amount of industrial water withdrawal with AVI, the lower value means more efficient water consumption

	Water consumption of per unit product in key industrial sectors	Water consumption of per unit key product	Indicators helps to ascertain the water consumption efficiency in key industrial sectors. Water consumption of key industrial sector product is equal to total amount of fresh water consumption/total amount of steel production (copper, aluminium, cement, fertilizer, paper)
	Coefficient of irrigation water utilization		This is the ratio of actual amount of irrigation water consumption to total amount of irrigation water consumption. The higher value means more efficient water use in agricultural sector
Integrated resource utilization rate	Recycling rate of industrial solid waste	Recycling rate of industrial solid waste	This indicator represents the ratio of the amount of integrated utilized industrial solid waste to total amount of industrial solid waste. It is calculated by dividing the amount of industrial solid waste integrated utilization through recycling with the Industrial solid waste generation, and then multiplying that with 100%.
	Industrial water reuse ratio		Industrial water reuse includes both recycled water reuse and cascaded water reuse. Industrial water consumption includes water consumption for both industrial and living purposes. This indicator is measured as a percentage of repetitive water use in industry divided by the total water consumption of the industry.
	Recycling rate of reclaimed municipal wastewater		The indicator of the reuse of treated wastewater includes both treated domestic wastewater and industrial wastewater that is qualified with the national recycling water standard. The total treated wastewater is the actual amount of wastewater treated in the wastewater treatment plant, including physical, biological and chemical treatment. It is measured as a percentage by dividing the quantity of treated waste water which is reused with the quantity of total treated waste water and multiplying it with hundred.
	Safe treatment rate of domestic solid wastes		This indicator is a ratio of the total amount of safely treated domestic rubbish to total amount of domestic rubbish.
	Recycling rate of iron scrap		This indicator is a ratio of the amount of recycled wasted iron scraps to total amount of iron production.
	Recycling rate of non-ferrous metal		The indicator represents a ratio of the amount of recycled non-ferrous metal to total non-ferrous metal production

	Recycling rate of waste paper		The indicator represents a ratio of the amount of recycled paper to the total paper production
	Recycling rate of plastic		The indicator represents a ratio of the quantum of recycled plastics to the total plastic production
	Recycling rate of rubber		The indicator represents a ratio of the amount of recycled rubber to the total rubber production
Waste disposal and pollutant emission	Total amount of industrial solid waste for final disposal	Total amount of industrial solid waste for final disposal	This indicator is a measure of the total amount of industrial solid waste, left after all processes of reuse, recycling and recovery which will go for final disposal.
	Total amount of industrial wastewater discharge	Total amount of industrial wastewater discharge	This indicator denotes the total amount of discharged industrial wastewater
	Total amount of SO^2 emission		A measure of the total amount of SO^2 emission
	Total amount of Chemical oxygen demand discharge		A measure of the total amount of chemical oxygen demand (COD)

JAPAN (based on Circular Economy Vision 2020, Ministry of Economy, Trade and Industry, Japan and EU-JAPAN Center for Industrial Cooperation paper)[37]

Theme	Indicator	Relevance
Resource	Material productivity	This indicator measures the economic value generated (GDP) per unit of materials consumed, in terms of domestic material consumption.
	Material footprint per capita	The material footprint a measure of the global allocation of used raw material extracted to meet the final demand of an economy, thus including materials used in the production of imported products. It is expressed in tonnes per capita.
Waste	Industrial waste generation	Measures reduction in Industrial waste generation, denotes improvements in manufacturing, packaging and customer awareness.
	Municipal waste generation	Measures reduction in municipal waste generation, denotes improvements in consumption patterns and customer awareness.
	Recycling rate of municipal waste	Indicator is calculated by dividing the recycled municipal waste with the total municipal waste and provides a good indication of the quality of the overall waste management system

	Compositing rate of municipal waste	Indicator provides a good measure to the quality of waste management infrastructure and consumer awareness.
	Rate of municipal waste incinerated of treated waste	
	Municipal waste incinerated with energy recovery	
	Rate of municipal waste incinerated with energy recovery	
Energy **Emissions** **Innovation**	Energy productivity	The indicator results from the division of GDP by the gross inland consumption of energy for a given calendar year. It measures the productivity of energy consumption.
	Share of renewable energy in total primary energy supply	Indicator is calculated by dividing the share of renewable energy with the total primary energy supplied and provides a good indication about the sustainability of energy infrastructure.
	GHG emissions intensity of energy consumption	
	GHG emissions per capita	CO^2 equivalent
	Overall score on Global Innovation Index	

Specifically, for the EEE sector, thematic and diverse sets of indicators do find presence in literature, especially at the micro-level. The following section discusses the various themes of circular economy indicators which are relevant to the EEE sector.

- Circular Economy Indicators for Recycling Recovery: Circular economy indicators for recycling recovery focus on measuring the effectiveness and efficiency of recycling processes, including collection, sorting, and reprocessing of waste materials. These indicators assess the amount of material that is successfully recycled, the recycling rates, and the quality of the recycled materials. Examples of such indicators are recycling rates, material recovery rates, and the percentage of recycled content in products.
- Reuse Indicators: Reuse indicators focus on tracking the extent to which products and materials are reused instead of being discarded or recycled. These indicators measure the number of reuse cycles a product undergoes, the volume of reused products or materials, and the reduction in waste generation resulting from reuse activities.
- Remanufacturing Indicators: Remanufacturing indicators assess the extent to which products or components are remanufactured instead of being disposed of. These indicators measure the percentage of remanufactured products in the market, the economic value generated from remanufacturing activities, and the reduction in energy and resource consumption achieved through remanufacturing.
- Resource Efficiency Indicators: Resource efficiency indicators focus on measuring the efficient use of resources in production and consumption processes. These indicators track the ratio of output to input materials, energy consumption per unit of output, and the overall reduction in resource consumption achieved through improved efficiency.

- Product-life Extension Indicators: Product-life extension indicators measure the extension of a product's lifespan through measures such as repair, refurbishment, or upgrading. These indicators assess the number of products that are repaired or refurbished, the average lifespan extension achieved, and the reduction in environmental impacts resulting from increased product durability.
- Eco-design or Disassembly Indicators: Eco-design or disassembly indicators focus on the design of products to facilitate their disassembly and the recovery of valuable materials. These indicators measure the ease of disassembly, the percentage of materials that can be recovered during disassembly, and the adoption of eco-design principles in product development.
- Waste Management Indicators: Waste management indicators assess the effectiveness of waste management practices in the circular economy context. These indicators track the amount of waste generated, the percentage of waste that is landfilled or incinerated, and the adoption of advanced waste treatment technologies such as anaerobic digestion or composting.[38]

The Table below provides a brief description of the major themes of indicators that are pertinent to the electrical and electronics sector.

Theme	Description
Resource Recovery	Indicators to measure the quantum of material recovered from used products which directly impacts the consumption of virgin material.
Reuse	Indicators to measure the potential for reuse of a product.
Remanufacturing	Indicators to measure the extent to which refurbishment, reconditioning and repurposing activities support circularity.
Resource efficiency	Indicators to measure the extent to which the consumption of resources can be reduced and mitigated.
Product-life extension	Indicators to measure the extent to which material or product's usable life can be extended.
Disassembly	Indicators to measure the extent to which the ease of disassembly facilitates the conduct of circular strategies (recycling, remanufacturing, etc.).
Recycling	Indicators to measure the recycled content or the recyclability of a product, or the extent to which recycling activities support circularity. Indicators measuring recycling also commonly address waste management, remanufacturing and reuse.
Waste management	Indicators to measure the extent to which waste generation can be reduced and mitigated.
End-of-life management	Indicators developed to support decision making at product's end-of-life by providing a comparison of different strategies.

Source: Pollard et al., (2022)[39]

CIRCULARITY INDICATORS FOR THE EEE SECTOR IN INDIA – RATIONALE AND RELEVANCE

Existing frameworks of circular economy indicators have been developed and implemented by various institutions, corporations, associations, and nations to measure progress towards a circular economy. Notable frameworks include those established by the European Union (EU), China, and Japan. In evaluating their suitability for the Indian scenario, it is important to consider the specific characteristics and challenges of the Indian economy, particularly in the electrical and electronic equipment (EEE) sector. Let us first articulate briefly, the major characteristics of the circular economy indicators developed in the above-mentioned three regions.

- **European Union (EU):** The EU has paid a lot of attention to its circular economy initiatives in the recent past and has developed a comprehensive framework of circular economy indicators. The EU framework includes indicators for material use, waste generation, recycling rates, resource efficiency, and circular business models. It also considers social aspects such as job creation and innovation.[40]

- **China:** China has also formulated circular economy indicators to drive sustainable development. These indicators focus on resource productivity, energy consumption, emission reduction, waste recycling rates, and circular production and consumption patterns. China's framework emphasizes the need for eco-design, clean production, and extended producer responsibility.[41]

- **Japan:** Japan has a well-established framework for measuring circular economy performance. It includes indicators for resource productivity, recycling rates, waste reduction, material flow analysis, and the adoption of eco-design and remanufacturing practices. Japan's framework also emphasizes the importance of collaboration among stakeholders and the integration of circular economy principles in policy and planning.[42]

While these existing frameworks provide valuable insights, there is a need to consider contextual specificities while formulating a relevant set of circular economy indicators for the Indian EEE sector. The following section lists the major themes that emerged from the review of existing literature and analysis of inputs from major stakeholders around which circular economy indicators could be developed:

- **E-waste Management:** Given India's significant electronic waste generation, indicators related to e-waste management are crucial. These may include e-waste collection rates, recycling efficiency, and the adoption of proper disposal practices to minimize environmental and health impacts.

- **Informal Sector Integration:** India has a large informal sector involved in e-waste recycling. Indicators that consider the formalization and regulation of this sector, worker safety standards, and the reduction of informal e-waste recycling practices would be relevant.

- **Resource Efficiency:** India's EEE sector faces resource scarcity. Indicators measuring the efficient use of raw materials, energy consumption, and the adoption of eco-design principles can drive resource efficiency and promote circularity.
- **Extended Producer Responsibility (EPR):** EPR is gaining traction in India. Indicators assessing the implementation and effectiveness of EPR programs, producer responsibility compliance, and the promotion of sustainable product design should also be included.
- **Social and Economic Impacts:** India's circular economy efforts should consider indicators that capture the social and economic benefits, such as job creation, skill development, and the promotion of inclusive growth in the EEE sector.
- **Public Procurement:** The public procurement policy can also be used to encourage transition towards circularity. Indicator measuring the amount of public procurement of products which contain certain threshold of recycled material or with extended life-cycles can also be adopted.

Hence, by synthesizing elements from existing frameworks and considering India's specific context, a relevant set of circular economy indicators for the Indian EEE sector should include themes related to e-waste management, informal sector integration, resource efficiency, extended producer responsibility, and social and economic impacts.

CONCLUSION AND RECOMMENDATIONS ~ CLASSIFYING CIRCULAR ECONOMY INDICATORS

Proposing circular economy indicators for EEE sector at the macro and micro-levels in India requires a comprehensive appraisal of India's local scenario and the major frameworks of circularity developed worldwide. Here a tentative classification of indicators within the efficiency, economic, environment & sustainability, and social dimensions have been presented:

Macro Level Indicators: These indicators would provide an overview of the uptake of circular economy principles at the national level.

Resource Efficiency Indicators

1. **Self-sufficiency of raw materials:** In order to promote self-sufficiency of raw materials in the EEE industries, dependency on imports needs to be reduced. This can be made possible by encouraging substitution of material in product design with domestically available substitutes and through resource recovery. A measure for self-sufficiency of raw materials would be the quantum of decrease in the import of main material resources. The Centre for Monitoring Indian Economy, a leading thinktank providing business information, maintains periodic data about the imports of main materials to India. This can easily become the data source for the indicators where the percentage decrease (or increase) in imports would be the unit to measure performance on this indicator.

2. **Recovery rates of Secondary Raw Materials:** This indicator is about evaluating recovery rates (secondary raw materials) of ferrous metals and non-ferrous metals through efficient recycling systems. A benchmark for such evaluation is already being created by the Central Pollution Control Board (CPCB) and recyclers, who are mandated to register on the new E-waste management system portal[43] (under the E-waste management rules, 2022), will have to ensure that they comply with the benchmarks of secondary raw material recovery, as notified by the CPCB. Such a measure would also help the pollution control body to develop a repository of SRM recovered from different categories of e-waste. The unit for measuring performance on this indicator would be the percentage of SRM recovered per unit of recycled e-waste.

3. **Tracking Critical Raw Materials:** The tracking of such raw materials, which are critical within the Indian context can be made possible by adopting a 'digital product passport', in line with the European Union. Such a passport would not only inform about the different sources and supply channels of critical material but also help identify vulnerabilities and develop strategies for sustainable sourcing within the Indian context. The long-term focus of such tracking should be to reduce dependence on imports for Critical Raw Materials (CRM) and promote domestic extraction, recycling, and substitution. The unit for measuring performance on this indicator would be the percentage decrease in imports of CRM.

Economic Indicators

1. **Value-added from circular economy practices:** Sectors like repair, remanufacturing and second-hand products market are likely to witness expansion in terms of revenue generation and employment, through the adoption of CE practices by the EEE sector. This expansion can be ascertained through the contribution that these services make to total EEE market. Furthermore, the Government of India's Ministry of Consumer affairs has recently has set up a committee to come up with a Right to Repair framework.[44] The proposed framework identifies several categories of EEE products like Mobiles, Tablets, Wireless headphones and Earbuds, laptops, Universal Charging ports/cables, Batteries, Servers and Data Storage Hardware & Software and Printers to be included under right to repair. The framework intends to make it mandatory for manufacturers to to provide customers with product details so that they can either repair them by themselves or by third parties, rather than solely relying on the original manufacturers. Additionally, the framework seeks to harmonize the trade between the Original Equipment Manufacturers (OEMs), third-party buyers and sellers, which would not only leads to creation of new jobs but also help consolidate the total addition of values through the repair services. This framework would thus provide a robust data source to measure the total addition made to the GDP from expanded repair and refurbishment services.

   The unit to measure this indicator would be the amount of revenue generated (by the repair and refurbishment sector) as a percentage of GDP and total employment.

2. **Investment in circular economy infrastructure and technologies:** Investment in infrastructure meant to encourage circular economy adoption, like Materials Recovery Facilities (MRFs), Resource recovery parks, etc. and better adoption of recycling technologies also provide a good indication about the transition towards circular economy business models. The CPCB through its registration process (and now much more through its new portal) maintains a repository of all recycling infrastructure and technologies available in the country along with their optimum capacity.[45] This could become the data source and baseline to ascertain the additional investments made to the recycling and recovery infrastructure and technologies upon transition to circular economy practices.

3. **Contribution of circular economy practices to GDP growth and job creation:** The significant contribution of CE practices to GDP growth and job creation can be evaluated by combining the total value addition through repair and refurbishment and second-hand products with the total investment made in recycling/recovery infrastructure and technologies. It can be expressed as a percentage of GDP and total employment.

Environment and Sustainability Indicators

1. **Greenhouse gas emissions:** The transition to circular economy should also lead to reduction in greenhouse gas emissions and energy consumption by the EEE sector. Such a reduction can be estimated through regular audits of production and recycling operations, which the CPCB plans to undertake through the empanelment of around three hundred auditors. The audit report would then become the source of data for this indicator and the unit for measuring performance would be kilogram of emission of SO^2 and CO^2 per unit production.

2. **Material productivity and energy efficiency:** Economic output per unit of material and energy input is also a good indicator to decipher resource efficiency and circularity. It can tell us about the contribution made to GDP per unit of material input and energy consumption. The auditing reports of CPCB's impanelled auditors will also provide a dataset to evaluate the output contribution per unit of material and energy input. The unit of measurement would be a ratio between a unit of material/energy and material output.

3. **Decrease in waste generation and landfill disposal:** The rate at which discarded WEEE reaches the landfills provides a good indication about the overall health and efficacy of the recycling and recovery ecosystem. While reducing the quantum of e-waste being send to landfills the focus has to be on the hazardous material contents of such waste. The CPCB new E-waste management system portal, by providing all data on total material recovery, would also be able to

also provide a mechanism to estimate the rate of landfilling by discarded e-waste fractions. The transition to Circular Economy principles would require a contraction or decrease in the current rate of landfilling. The unit for measuring the same would be the percentage decrease in landfilling rates.

4. **Expansion of renewable energy sources:** The promotion of clean and sustainable energy sources will also advance the adoption of circular economy processes, and hence quantifying the contribution of green energy as a fraction of total energy production will provide a good indication of the popular uptake of circularity principles. The Ministry of Power in India maintains all the details about the different energy sources currently being used by different sectors of the industry[46] and thus would prove to be a good source to estimate the expansion in renewable energy sources as a percentage of total energy consumption.

Social Indicators

1. **Occupational Safety and Social Wellbeing:** The ambit of occupational safety and social wellbeing can be improved with the adoption of circular economy strategy by the EEE sector. To ascertain the same it is required to study the different indicators under the Sustainable Development Goal 8 of promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Some of the indicators under this goal which provide information about occupational safety and health include;
   - Indicator 8.3.1: Proportion of informal employment in total employment, by sector and sex.[47]
   - Indicator 8.5.1: Average hourly earnings of employees, by sex, age, occupation and persons with disabilities.[48]
   - Indicator 8.7.1: Proportion and number of children aged 5-17 years engaged in child labour, by sex and age.[49]
   - Indicator 8.8.1: Fatal and non-fatal occupational injuries per 100,000 workers, by sex and migrant status.[50]
2. **Development of skills through capacity-building programs for circular economy practices:** The Ministry of Corporate affairs maintains a database[51] of all the Corporate Social Responsibility (CSR) funds spend by different organisation to fulfil their obligation under the Companies Act. This database provides sector wise data about the expenditure of CSR funds. The enterprises under the EEE sector may use a portion of their CSR budget to assist the development of vocational skill and build capacity of the informal workers involved in urban mining and recovery from e-waste. The transition to circularity in EEE sector should ensure an increase in the corpus of funds allocated by producers for development of skills among informal workers. The unit of measurement would be the percentage increase in CSR fund allocation by EEE enterprises for vocational skill development among informal workers and such data could easily be accessed through the data base of the Corporate Affairs Ministry.

Micro Level Indicators: These indicators would provide an overview about the adoption of circular economy principles at the level of organisation.

Resource Efficiency Indicators

1. **Resource efficiency within the organisation:** Measurements such as consumption of water, energy and main raw materials for producing one unit of output is a good way to ascertain resource efficiency. The organisation adopting CE strategy should calculate output contribution against per unit of material and energy input and try and bring down this ratio over medium and long run.

2. **Adoption of circular business models:** Circular economy business models (CEBMs) focus on aspects such as sharing platforms, rental services, and collaborative consumption. Number of EEE enterprises incorporating such aspects in their operations would provide a good measure about the popular uptake of circular economy strategy.

Economic Indicators

1. **Value added to products:** The CEBMs add value to the products by provisioning for extended warranty, repair facility and modular design, leading to creation of auxiliary channels of revenue generation and employment. An organisation can ascertain the quantum of such value addition by calculating the percentage of revenue earned through value added services (like extended warranty, repairs and availability of spares) compared to the total revenue generation.

2. **Adoption of take-back and recycling programs:** The compliance of EPR targets by producers/manufacturers helps promote product stewardship. It can be calculated as the percentage of compliance with overall EPR target of an organisation.

3. **Integration of circular procurement practices in organizations:** Organisation should prioritise such material and products which have longer lifecycles and offer better recyclability potential. Greater the number of such products (developed using CEBM) an organisation offers, the more in sync it is with the circular economy principles.

Environment and Sustainability Indicators

1. **Implementation of eco-design principles:** In order to enhance product durability, recyclability with easier disassembly, and use of environmentally friendly materials, organisations need to develop and adopt eco-design frameworks. At the organisational level, number of products developed using eco-design principles and their percentage share in organisational revenue provide a good measure about the status and stage of transition towards a circular economy business model.

2. **Establishment of circular economy clusters and networks:** To facilitate knowledge-sharing and collaboration and industrial symbiosis which also enhances resource recovery, incorporates SRM in successive production cycles and encourages high value recycling, building circular economy clusters and networks within each sector (especially the EEE sector) is important. The growth in number of such networks and clusters is an important indictor at the organisational and sectoral level.

Social Indicators

1. **Occupational safety and health:** The adoption of circular economy processes, especially by organisation which engage with informal sector workers for material recovery, would lead to gradual improvements in working conditions (as the demand for SRM goes up and they become a part of the expanding formal recycling systems). This would also reduce the social cost borne by the local communities where crude methods of recovery are implemented by informal enterprises. A measure for the same would be to enumerate new safe and decent jobs created by the such organisations involved in recycling.

2. **Awareness about products/services created using CEBM:** Consumer awareness about the benefits of circularity would also go a long way in strengthening demand for such products and services. Consumer awareness can be raised by organisation led advertising and reach-out campaigns. Number of such campaigns being undertaken by different organisation within the sector would provide a quantifiable index about the level of awareness.

3. **Implementation of skills and capacity-building programs using CSR funds:** Upskilling of informal sector workers by conducting training campaigns to impart vocational would be crucial to ensure mobility of the informal workers involved in e-waste recycling. The total increase in CSR funding for such circular economy practices (like upskilling) by an organisation would provide a discernible estimate of the same.

It should be noted that the proposed indicators are tentative and may require further refinement based on the availability of data from various government and non-government sources. These indicators also build on the recommendation provided by three research reports on - Critical Raw Materials (CRM) & Secondary Raw Materials (SRM), - Best available technologies to promote recycling and recovery of SRM from WEEE, - Eco-design guidelines for EEE sector, and - Measures to support and facilitate the upgradation of the informal workers in the value chain, submitted earlier. It is believed that the adoption of these circular economy indicator will not only help promotion of sustainable practices on the EEE sector but also smoothen India's transition towards a circular economy future.

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Annexure 1

Circular Economy Indicators

Developing CE indicators to evaluate the performance, productivity, and waste discharge

* Required

1. What kind of circular economy indicators can be applicable for Producers and Recyclers in India and what could be the possible timeframe? *

For producers/manufacturers

2. Resource efficiency Indicators: Ways in which the consumption of resources can be reduced and mitigated, and the use of secondary raw material accelerated? (answer in a few words)

3. Product life extension: How can we influence the design of products to be durable for a longer use period or multiple use periods considering that much of the design happens outside India? Can the huge Indian market be used as leverage for the same? (answer in a few words)

4. Remanufacturing Indicators: Are there ways to measure the extent to which refurbishment, reconditioning and repurposing activities, which support circularity, are being undertaken by producers? (answer in a few words)

For Recyclers/PROs

5. Recovery rates: To ensure the traceability of material resources, it would be helpful to have a material-wise record of recovered material, (quantity and percentages) against the total waste dismantled. Are you willing to adopt such a procedure (if not in place already)?

6. Landfilling rates: Lower rates of landfilling, or lower amount of waste send to TSDF indicate more efficient recycling, keep this in mind, can we measure the amount of waste (as a percentage of total e-waste dismantled) that is finally sent to the landfills, after all, recovery and recycling? What measure can help reduce the rates of landfilling?

   Better recycling technology / more advanced machines

   Better design of products/modularity

   Any other measure

7. Resource consumption rates: Do think it is feasible to measure the wastewater generated and energy (electricity used) in recovering per unit main material resource during the recycling process? Do you have any estimates of the same? How do you ensure that the wastewater used in recycling needs to be treated before discharges

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