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Circular economy approaches in e-waste management: From recovery to reuse.

Franziska Sayed*

Department of Environmental Sciences, Bavarian Technical Institute of Chemistry, Germany

***Correspondence to:** Franziska Sayed, Department of Environmental Sciences, Bavarian Technical Institute of Chemistry, Germany. E-mail: f.sayed@btic-env.de

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Introduction

The digital revolution has led to exponential growth in electronic devices—from smartphones and laptops to household appliances and industrial machinery. However, this boom has come with a steep environmental cost: electronic waste (e-waste). Globally, over 60 million metric tons of e-waste are generated each year, with less than 20% formally recycled. The rest ends up in landfills or informal sectors, leading to toxic pollution and loss of valuable materials. As concerns mount, circular economy approaches have emerged as a transformative framework for managing e-waste—shifting the focus from linear “take-make-dispose” models to systems based on recovery, reuse, remanufacturing, and resource efficiency [1].

E-waste is one of the fastest-growing waste streams in the world, driven by rapid technological advancement, planned obsolescence, and increasing consumer demand. It contains hazardous materials such as lead, mercury, and brominated flame retardants, which can leach into soil and water if not properly handled. At the same time, e-waste is rich in valuable and rare metals like gold, palladium, cobalt, and neodymium, offering a critical opportunity for material recovery and circularity [2].

The circular economy is a systemic approach aimed at eliminating waste and keeping products and materials in use for as long as possible. It relies on design innovation, restorative systems, and closed-loop supply chains. In the context of e-waste, circular economy practices seek to redesign electronics for durability, enable component reuse, and promote efficient material recovery, thereby reducing environmental harm and creating economic value from waste [3].

Material recovery is a core component of circular e-waste management. Modern recovery techniques include mechanical separation, pyrometallurgy, hydrometallurgy, and bioleaching. These processes extract precious metals and rare earth elements from discarded electronics. For example, circuit boards can be treated to recover gold and copper, while lithium-ion batteries are mined for cobalt and lithium. Innovations in urban mining—the extraction of metals from e-waste—are enhancing recovery yields and reducing reliance on virgin raw materials [4].

To close the loop in the product lifecycle, electronics must be designed for disassembly, repair, and upgradeability. Modular designs enable individual components to be replaced or reused without discarding the entire device. Companies like Fairphone and Framework are pioneering this model, offering repairable phones and laptops with easily replaceable parts. Such approaches extend product life, reduce waste, and empower consumers to participate in circular practices [5].

Conclusion

Circular economy approaches provide a holistic, forward-looking solution to the growing e-waste problem. By prioritizing resource recovery, product reuse, remanufacturing, and smart design, these strategies not only mitigate environmental harm but also unlock new economic opportunities. As digital technology continues to evolve, integrating circular principles into e-waste management is no longer optional—it is essential for building a more resilient, sustainable, and inclusive future.

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