Innovative circular economy approaches in e-waste management: a case study of telkomcel timor leste

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Article Info

ABSTRACT

This study evaluates the application of circular economy principles in managing e-waste at Telkomcel Timor Leste, a leading telecommunications company in the country. Timor Leste is facing increasing challenges in e-waste management due to the growing use of technological devices, which contributes to the rising volume of electronic waste. Inadequate management of e-waste poses significant environmental and health risks, including pollution and the leaching of harmful substances into the soil and water. The study uses a mixed-methods approach, including secondary data analysis and in-depth interviews with key stakeholders at Telkomcel, involving 4 respondents from various stakeholder related to waste management and sustainability. The analysis focuses on Telkomcel's strategies in implementing circular economy practices, such as device refurbishment, recycling programs, and internal policies. The findings reveal that while Telkomcel has taken significant steps toward adopting a circular economy model, challenges remain, including limited infrastructure, low public awareness, and insufficient recycling facilities. Notably, Telkomcel has initiated internal policies promoting e-waste collection, repair, and reuse of devices, yet the company faces barriers in scaling these efforts. The study highlights the importance of strengthening collaboration with third-party recycling partners, expanding the recycling infrastructure, and raising public awareness through education campaigns. This research is significant in the context of the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), as it emphasizes the need for sustainable e-waste management practices to mitigate environmental impact and contribute to long-term resource efficiency. The study concludes with recommendations for Telkomcel to enhance its sustainability efforts by improving infrastructure, increasing public education on e-waste recycling, and advocating for stronger government regulations. These efforts are expected to support sustainable development in Timor Leste while minimizing the environmental consequences of improper e-waste disposal.

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Introduction

The phenomenon of a global increase in electronic goods has occurred in the last 20 years. This is due to the increase in advantages ranging from the aspects of design, and function, to mobility, which causes the previous model of electronic goods to quickly become obsolete and replaced by the latest model. The need for electronic

goods continues to increase every year along with the rate of population growth. The use of electronic goods is influenced by the increasing economic growth of a country, population, and people's purchasing power (Chen et al., 2021; Mahaputra & Saputra, 2022). Rapid technological developments change people's lifestyles to keep up with the latest technology so that the age of electronic goods becomes shorter (Egard & Hansson, 2023; Pramono & Hanita, 2021). The reduction in the age range of electronic goods causes the growth of electronic waste to be faster (M. T. Islam et al., 2021; Rene et al., 2021).

Timor Leste, as a developing country, faces significant challenges in managing electronic waste (e-waste), particularly in its rapidly growing telecommunications sector. Telkomcel, a subsidiary of PT Telin and part of the Telkom Group, plays a crucial role in providing telecommunication services in the country. Since its establishment in 2012, Telkomcel has successfully expanded its network coverage to 92.46% of the population within its first year, exceeding government targets. However, the modernization of equipment and operational activities, such as infrastructure maintenance and problem-solving, have contributed to a significant increase in e-waste volumes. Internal data indicates that Telkomcel generates over 3 tons of e-waste annually, including devices such as laptops, routers, switches, fiber optic cables, and components from Base Transceiver Stations (BTS) like antennas, batteries, and generators.

The lack of e-waste processing infrastructure in Timor Leste represents a major challenge. Currently, most waste in the country is managed through landfills like Tibar, with only a small portion of non-electronic waste recycled by private companies. Unfortunately, there are no specialized facilities for e-waste management. As a result, much of the electronic waste is improperly discarded or burned, exacerbating environmental pollution and increasing public health risks due to hazardous substances such as lead and mercury (Abubakar et al., 2022; Ghulam & Abushammala, 2023; Rawat et al., 2020). Improper e-waste management also overlooks significant economic potential. Electronic waste contains valuable materials such as precious metals and plastics, which can be recycled and utilized within the framework of a circular economy (Sarkhoshkalat et al., 2024; Xavier et al., 2021). The principles of a circular economy, emphasizing waste reduction, resource recycling, and the creation of new economic value, are highly relevant in this context (Delchet-Cochet, 2020; Elroi et al., 2023). This approach can help reduce environmental impact while creating job opportunities and contributing to GDP growth, as observed in Indonesia, where e-waste contributes to GDP and national employment (Kalia et al., 2022; Kurniawan et al., 2022; Wikurendra, 2022).

In Timor Leste, the scope of existing environmental policies remains largely confined to general waste management, with minimal emphasis on the specific challenges posed by electronic waste (e-waste). Public participation in recycling activities also remains relatively low, primarily due to limited awareness and education regarding the importance of sustainable waste practices. Programs such as PacWastePlus, launched by the Secretariat of the Pacific Regional Environment Program (SPREP), have identified critical gaps in the country's waste management system. These include insufficient infrastructure for handling and processing e-waste, a lack of specialized recycling facilities, and inadequate investments in modern technologies to safely and efficiently manage hazardous electronic materials. Furthermore, the absence of clear regulations and enforcement mechanisms for e-waste disposal exacerbates the issue, leading to improper practices such as illegal dumping and burning, which contribute to environmental degradation and pose significant health risks to local communities.

Based on the description of the phenomenon, this study aims to identify specific challenges in e-waste management at Telkomcel and explore the potential of applying circular economy principles to improve the efficiency and sustainability of e-waste management. The expected benefits of this research, both theoretically and practically, are to add insight into science, especially in the field of management studies, and provide information related to the circular economy process in sustainable e-waste management. By aligning this research with the Sustainable Development Goals (SDGs), particularly SDG 12 Responsible Consumption and Production, and SDG 13 Climate Action, this study seeks to make a significant contribution to both national and international strategies for addressing the electronic waste problem.

Method

This research adopts a qualitative approach to explore and understand the meaning behind the actions, behaviors, and perceptions of the research subjects. According to (Anas & Ishaq, 2022; Lim, 2024; Patton, 2020), qualitative research seeks to holistically understand phenomena experienced by individuals in a natural context through descriptive narratives. Similarly, (Safarpour et al., 2020; Spearing et al., 2022; Xue et al., 2020) highlights that qualitative research involves collecting and analyzing data inductively to derive themes and interpretations, making it suitable for understanding complex social or humanitarian problems.

The qualitative method was chosen because it provides a deeper understanding of complex, context-specific phenomena that quantitative methods may not capture. This approach allowed the researchers to explore the lived experiences and perspectives of respondents, aligning with the study's objective to investigate the social, cultural, and systemic aspects of e-waste management.

Data Collection

Primary data was gathered through in-depth semi-structured interviews with selected respondents. Each interview lasted approximately 60–90 minutes, ensuring ample time to explore respondents' perspectives. Interviews were conducted face-to-face at locations convenient for the participants to encourage open communication. Secondary Data is supporting data was obtained from relevant documents, reports, and prior studies related to the topic. These sources provided contextual information to supplement and validate primary data.

The study was conducted in Timor Leste, focusing on areas significantly impacted by telecommunications infrastructure and e-waste challenges. Interviews were conducted in July 2024, with respondents located in Dili and surrounding regions office, the second in the Telkomcel warehouse in Aimutin and the third in the Telkomcel warehouse in Beduku. All participants were provided with detailed information about the study's objectives and procedures. Informed consent forms were obtained prior to data collection, ensuring that respondents understood their rights, including the right to withdraw at any time.

The study involved 4 respondents, selected using purposive sampling. Respondents were chosen based on their relevance to the research topic, ensuring a diverse range of perspectives. The respondents included professionals in the telecommunications sector, e-waste management practitioners, policymakers, and community representatives. Their roles and expertise provided valuable insights into the challenges and opportunities surrounding e-waste management. The criteria for selection included experience in e-waste handling or policy formulation, as well as their willingness to participate in the study.

An interview guide was developed, featuring open-ended questions aimed at eliciting detailed responses. The guide included sections on participants' experiences, perceptions of e-waste challenges, and recommendations for improvement. The instrument was pilot-tested with two respondents to ensure clarity and relevance.

Data Analisis

The data was analyzed using a thematic analysis approach as outlined by Braun and Clarke (Byrne, 2022; Dawadi, 2020). The process began with familiarization with the data, achieved through repeated readings of the interview transcripts to gain a comprehensive understanding. This was followed by manual coding to identify key themes and patterns emerging from the data. The codes were then grouped into broader categories to reflect recurring themes, ensuring alignment with the research objectives. To further enhance the rigor of the analysis, all transcripts were reviewed twice, and the coding was cross-checked by another researcher to maintain consistency. Additionally, NVivo software was employed to efficiently manage and organize the qualitative data throughout the analysis process.

To enhance the credibility of the findings, several validation techniques were employed. Triangulation was conducted by comparing data from interviews with secondary data to identify consistencies and discrepancies. Member checking was utilized by sharing preliminary findings with respondents to ensure accuracy and confirm that their views were accurately represented. Additionally, a peer review was carried out, where the analysis process was reviewed by an independent expert to minimize potential bias and ensure the robustness of the study.

Results and Discussions

Description of Respondent Profile

Information on the research was obtained from four respondents, 2 key respondents, and 2 supporting respondents, including 2 respondents from Telkomcel Management 1 from the Government as a supporting respondent, and one from the Community as a supporting respondent.

Key Respondents

The key respondents in this research are both serving in management roles at Telkomcel Timor Leste. the position of Vice President (VP) of Mobile Network Operation (MNO). First respondent responsible for planning, infrastructure in Timor Leste as a telecommunications operator. Meanwhile, the second respondent responsible oversees financial policy implementation, budgeting, treasury, financial accounting, and reporting, ensuring the company's financial processes support sustainable business growth. Additionally, the second respondent manages the company's security, safety functions, and general support, while establishing and implementing strategies, policies, and procedures for supply management.

Support respondents

The supporting respondents in this study include representing government and community perspectives. A government agency under the Ministry of the Environment responsible for regulating and issuing policies and licenses for environmentally sustainable development and waste management in Timor Leste. On the other hand, community perspectives Telkomcel service user who resides in Comoro-Lorumata, Dili, providing insights from the community's viewpoint as a stakeholder in this research.

Telkomcel Electronic Waste Data

The results of field observations revealed that Telkomcel has three e-waste storage locations, namely the first in the storage cabinet of the Telkomcel Timor Plaza office, the second in the Telkomcel warehouse in Aimutin and the third in the Telkomcel warehouse in Beduku. Based on the observations, it can be concluded that the electronic waste currently present at Telkomcel is highly diverse, encompassing both B3 (hazardous) and non-B3 (non-hazardous) categories. The waste includes a variety of devices such as computers, laptops, printers, servers, cables, generators, batteries, radios, antennas, CPE (Customer Premises Equipment) routers, switches, methanol drums, and other telecommunications electronic components.

The condition of the waste varies significantly, ranging from items that are repairable to those that are completely damaged and unusable. Detailed information and data regarding this waste can be found at the Telkomcel deviation site in Timor Leste: (1) Storage Cabinets at Telkomcel Timor Plaza office. Electronic waste that is stored in the storage cabinet at the Telkomcel Timor Plaza office in the form of laptops, printers, and chargers is managed by the Telkomcel human capital unit, this electronic waste is stored for approximately 4-5 years; (2) Telkomcel Warehouse in Aimutin. The results of the identification that electronic waste in the Aimutin warehouse is electronic waste in the form of Router devices, Switches, IP cameras, Radios, Antennas, Power Supplies, and other telecommunications devices, this electronic waste is stored in the last 5-10 years with conditions that can still be repaired and some are in a damaged condition; (3) Telkomcel Beduku Warehouse. The results of the identification that electronic waste in the Aimutin warehouse is electronic waste in the form of batteries, radios, antennas, cables, CPE, generators, and other telecommunication devices, this electronic waste has been stored since the last 5-10 years with conditions that can still be repaired and some are in a damaged condition. From the results of observations for the three existing Telkomcel deviation locations, most of the equipment is still not well managed and has not been placed in a safe place.

Interview Results

The Right Environmental Approach pillar demonstrates Telkomcel's commitment to operating responsibly while minimizing environmental impacts. This commitment is reflected in the company's efforts to manage both B3 waste (hazardous electronic and chemical waste) and non-B3 waste (general waste like paper, plastic, and bottles) generated from its telecommunications operations and infrastructure. Telkomcel's B3 waste primarily consists of obsolete or damaged equipment, such as routers, servers, batteries, antennas, and fiber optic cables. Meanwhile, non-B3 waste originates from day-to-day office and operational activities. By implementing structured e-waste management processes, including proper collection, sorting, and disposal in collaboration with recycling partners, Telkomcel continues to uphold sustainable practices aligned with its environmental goals. This was conveyed by Telkomcel Management in his interview that:

"Telkomcel generates various types of B3 waste (electronic and chemical) related to its telecommunication operations and infrastructure such as network devices: Routers, switches, servers, modems, BTS (Base Transceiver Station) devices, Antennas. computer devices: Laptops, Monitors, Printers, Batteries, Fiber optic cables, LAN cables, Telkomcel also produces non-B3 waste such as Paper, plastic, bottles, and methanol drums in its operations."

The results of these interviews were supported by respondents from the government and the community:

"Electronic devices, packaging, and paper are waste solids generated from Telkomcel's operations." Government

"As far as I know, Telkomcel, Timor-Leste as a telecommunication company generates waste such as electronic devices such as routers, paper, plastic from office and operational activities." Community.

In the implementation of the e-waste treatment process at Telkomcel, Timor-Leste itself is carried out through collection, dismantling, and separation of components, to recycling or final processing. As stated by the management of Telkomcel;

"The processing of e-waste at Telkomcel involves several crucial steps, from collection, dismantling, component separation, to recycling or final processing. In its operation, e-waste such as infrastructure devices from BTS are obsolete and damaged. Telkomcel has also implemented end-of-life management for its Telecommunication hardware such as Laptops, Servers, Routers, Radios, Antennas, Batteries, UPS, and Generators, including Customer premises equipment (CPE). Devices that are still usable will be stored as temporary replacements or emergency backups. These devices will be stored pending management's decision if they can no longer be used. In addition, Telkomcel actively screens and repairs e-waste for reuse."

In line with this, the government also has an opinion regarding the implementation of the e-waste treatment process at Telkomcel as follows:

"I don't really know the details of the waste treatment process at Telkomcel but I believe Telkomcel has a series of programs and sustainable efforts have been used consistently to manage electronic waste and other waste at Telkomcel."

As for the current e-waste management planning at Telkomcel, the Telkomcel management stated that:

"Telkomcel Timor-Leste does not yet have or use machines to manage its waste, both shredding machines and recycling machines are still done manually by sorting and dismantling by working with partners for recycling processes or repairing damaged devices so that they can be reused."

So that the steps taken by Telkomcel in handling electrical waste at Telkomcel are explained;

"(1) Establish SOPs for the collection, sorting, storage, and delivery of e-waste to recycling facilities. (2) Provide safe and standardized storage facilities for e-waste before it is transported to the recycling facility. (3) Cooperate with recycling service providers."

For the circular economy process in sustainable e-waste management, Telkomcel is carried out by applying economic principles. The following is a statement from Telkomcel's management in the interview:

"Telkomcel is committed to applying circular economy principles in e-waste management to reduce negative impacts on the environment and improve the efficiency of resource use and reuse, some of the steps taken are setting environmentally friendly product standards, structured collection programs, and cooperation with recycling partners.

Telkomcel's management also explained the recycling, reuse, and remanufacturing process carried out by Telkomcel as follows;

"The e-waste recycling process involves several steps such as Collection and sorting, Processing of e-waste is then sent to partners who have collaborated in facilitating recycling to process these materials, for reuse e-waste includes steps such as Inspection and Repair, Redistribution of repaired devices, some devices that still have market value can be resold (after obtaining shareholder approval). As well as Repurposing, Telkomcel changes the function of e-waste into a new, different product. For example, turning used batteries into power banks or methanol drums into trash cans."

Regarding the legality of e-waste management, Telkomcel does not yet have an official license to process e-waste directly. This was conveyed by the management of Telkomcel in the interview as follows:

"Telkomcel has no regulation or policy yet but Telkomcel has implemented circular economy principles in e-waste management and Telin Group has implemented Sustainability policy with ESG concept."

This was also conveyed by the government in the interview that;

"Although Telkomcel does not have an official license to process e-waste directly, the company is demonstrating a strong commitment to handling e-waste responsibly through its programs."

This means that Telkomcel strives to minimize waste and maximize resource reuse. As stated by Telkomcel management;

"Telkomcel is committed to applying circular economy principles in e-waste management with several strategies such as; "(1) Device life enhancement (Routine maintenance, to extend its lifespan and reduce the need for replacement). (2) Repair and Refurbishment (Repair and refurbish devices that still have the potential to be reused before they are disposed to landfill). (3) Device redistribution & donation (Donating working electronic devices to educational institutions, non-profit organizations, or communities in need). (4) Internal reuse (allocating working devices for internal use, such as for training or specific projects) & utilizing e-waste for internal lab process materials".

In interviews with Telkomcel management, it was found that the implementation of e-waste treatment at Telkomcel provides economic, environmental, and social benefits that can encourage sustainable development. The following is the statement:

"The implementation of e-waste treatment at Telkomcel has a significant positive impact on the circular economy. It brings economic, environmental, and social benefits that can drive sustainable development."

For the positive impact of the implementation of Electronic Waste Processing at Telkomcel, Telkomcel management stated that;

"The positive impact on the environment is the reduction of environmental pollution, preservation of natural resources, and increasing environmental awareness. For the positive impact on the company's economy, including cost savings, improving the company's image, and opening new business opportunities. As for the community, namely creating jobs, improving public health, and increasing public environmental awareness."

This is in line with what was conveyed by one of the people who participated in this research as a supporting respondent:

"The implementation of e-waste processing at Telkomcel has several positive impacts on the community, including reduced pollution, resource conservation, job creation, improved public health, and increased awareness of the importance of e-waste recycling and proper disposal."

In managing electronic waste at Telkomcel, according to Telkomcel management, every year the company measures and assesses the costs incurred in waste management. The following is his statement:

"Regarding the costs incurred in waste, the company measures every year to find out how much costs are incurred for the next period."

The costs incurred annually for electronic waste management at Telkomcel are +- $ 30,000 (Thirty Thousand US Dollars) As stated by Telkomcel management;

"Telkomcel incurs costs of approximately $30,000 per year for B3 waste management. This cost covers the collection, transportation, treatment by partners and disposal of B3 waste generated from the company's operational activities to landfill."

As for revenue from electronic waste and other waste at Telkomcel, it is relatively small per year, this is because the recycled waste is more for internal use and Corporate Social Responsibility or CSR programs. The following is a statement in an interview with Telkomcel management;

"Telkomcel generates relatively little revenue for resale because the recycled electronic waste is only for internal use and Corporate Social Responsibility or CSR programs."

Meanwhile, according to the community in their interviews, the negative impacts of the implementation of Electronic Waste Processing at Telkomcel are;

"Telkomcel has several potential negative impacts on society, including Improper handling of e-waste, Transportation of e-waste from collection points to processing facilities may contribute to air pollution, Health risks for workers, Processing facilities cause odors, or air pollutants that may disturb residents and Potential illegal disposal of e-waste."

With these negative impacts, the community provides solutions to overcome these negative impacts through careful planning, implementation, and monitoring of e-waste processing programs. Here is the statement:

"These potential negative impacts can be mitigated through careful and correct planning, implementation, and monitoring of processing programs. For example, Telkomcel can work with leading e-waste processors to ensure that e-waste electronics are handled correctly, and they can invest in training and protective gear for their workers. They can also engage with local communities to address their concerns and minimize negative impacts."

E-waste management in telecommunications companies has interrelated barriers and supporters. The supporting factors conveyed by Telkomcel management respondents are:

" Supporting factors that can help in e-waste management include: More and more parties are beginning to understand the dangers of e-waste and the importance of proper management, The emergence of new technologies that can help in the treatment of e-waste more efficiently and effectively, The government is starting to give attention and support to e-waste management, such as by issuing regulations and providing good e-waste treatment facilities, More and more people are involved in e-waste management, such as by recycling unused electronic devices."

In line with this, the inhibiting factors for the implementation of E-Waste Processing at Telkomcel were conveyed by Telkomcel management as follows:

"Lack of education, Limited adequate e-waste processing infrastructure, such as collection points that are still mixed with new goods warehouses, processing is still managed by third parties, and the cost of e-waste management is relatively expensive, so it is a burden for companies, Telkomel does not yet have specific regulations and policies related to e-waste processing that are not comprehensive and not firm regarding e-waste management.

With the existence of these inhibiting factors, Telkomcel seeks to overcome these problems. The following is a statement from Telkomcel management as a respondent;

"Efforts to overcome these obstacles include providing electronic waste collection sites at both Telkomcel warehouses to make them more flexible and adequate, as well as working with vendors to recycle unused electronic devices, providing education to employees about electronic waste management, organizing trade-in programs to encourage people to recycle devices. Telkomcel as part of Telin Group has applied the principles of circular economy and implemented Sustainability policy with ESG concept."

From the efforts to overcome barriers and further develop the implementation of circular economy in Telkomcel as well as develop e-waste management in the future, the following statements from Telkomcel management are related to future plans;

> *"Increasing commitment from management to support circular economy initiatives by establishing supportive policies and allocating adequate resources, Educating employees on the importance of circular economy and how to apply it in their daily work, Investing in recycling Technology to upgrade internal facilities for e-waste processing with the latest technology that is more efficient and environmentally friendly, collaboration with recycling Companies, government and NGOs, Increased education and Awareness of employees and the community."*

Waste Management Practices

Telkomcel's approach to managing hazardous (B3) and non-hazardous waste highlights the company's commitment to sustainability in the telecommunications sector. Waste management, particularly of electronic waste (e-waste), is critical due to the growing volume of outdated and damaged electronic devices that result from rapid technological advancements in telecommunications. The handling of both B3 and non-B3 waste in this context reflects an organized and responsible approach to environmental stewardship.

Telkomcel has implemented a structured process for managing its e-waste. According to literature on sustainable waste management, an effective system for e-waste disposal involves the following key phases: (1) The first stage involves the gathering of obsolete or damaged electronic devices. A well-organized collection system ensures that e-waste is collected in a timely manner, preventing the accumulation of devices that could cause environmental harm if left unmanaged; (2) Once collected, e-waste is dismantled into its components. This phase allows for the identification of materials that can be reused, recycled, or disposed of in an environmentally safe manner. Sorting allows valuable materials (such as copper, gold, and plastic) to be recovered, while hazardous materials are separated for safe disposal. A study by (Dutta et al., 2023; A. Islam et al., 2020, 2021) highlights that dismantling is crucial for recovering precious metals and other valuable components from e-waste, contributing to resource conservation; (3) Materials that are not harmful to the environment are sent to recycling facilities. Devices that are still functional or repairable are inspected, repaired, and stored for reuse. This practice reflects a circular economy model, where products are reused, refurbished, or recycled, rather than disposed of after their initial use. The concept of a circular economy, as described by (Adekomaya & Majozi, 2022; Korra, 2022; Okogwu et al., 2023), promotes the extended lifecycle of products, which reduces waste and conserves natural resources.

Circular Economy and Sustainability Efforts

Telkomcel integrates circular economy principles into its waste management strategies, which not only reflect its commitment to sustainability but also demonstrate its proactive approach to reducing electronic waste and contributing to environmental well-being. By enhancing device lifespans through routine maintenance, Telkomcel ensures that valuable resources are utilized to their full potential before they become obsolete. This effort aligns with the concept of *extend product life cycles*, a core principle of the circular economy, which seeks to maintain the value of products, materials, and resources in the economy for as long as possible (Blomsma & Tennant, 2020; Milios, 2021). Repairing and refurbishing devices for reuse further supports this approach, as it reduces the need for new products, lowers electronic waste, and minimizes environmental impact by keeping electronics out of landfills.

Moreover, Telkomcel's initiative to donate functional devices to educational institutions and non-profit organizations enhances the social aspect of sustainability, promoting *shared value* in line with (Di Vaio et al., 2020; Laukkanen & Tura, 2020) researches, which emphasizes the creation of economic value in a way that also creates value for society. Allocating repaired devices for internal training or projects is another example of internalizing the circular economy, as it maximizes the utility of devices across multiple areas of the business, improving the overall efficiency of operations. The repurposing of components, such as converting batteries into power banks, is an innovative practice that minimizes waste and demonstrates creativity in resource utilization, embodying the *eco-design* principles discussed by (Arora et al., 2023; Kandpal et al., 2024), which focus on designing products for longevity and resource efficiency.

Despite not holding an official e-waste management license, Telkomcel's efforts align with the Telin Group's ESG (Environmental, Social, and Governance) policies, which highlight the importance of sustainability in business operations. By adhering to these principles, Telkomcel is not only contributing to the broader sustainability agenda but is also reinforcing its corporate social responsibility (CSR) initiatives by promoting environmental and social well-being. This integration of circular economy practices is essential for fostering long-term sustainability and aligns with the broader transition towards a more sustainable, resource-efficient economy.
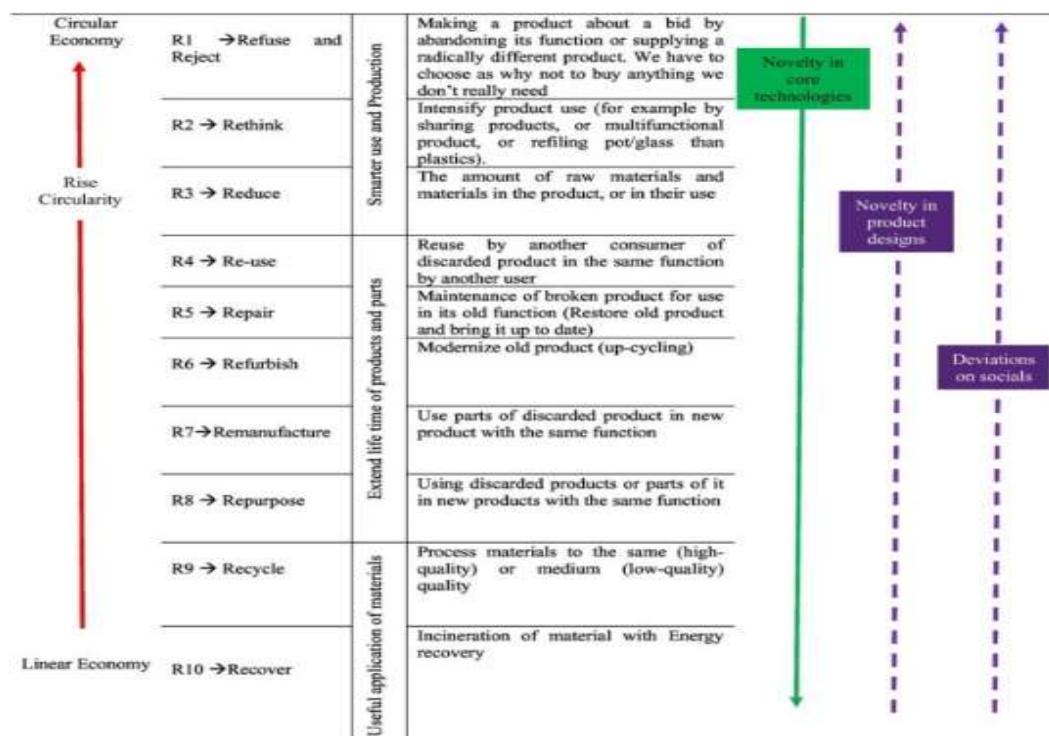
Figure 1 <The 10R Concept in the Implementation of Solid Waste Management Based on Circular Economy>

Supporting SDGs 12 and 13

Telkomcel's commitment to circular economy practices aligns well with the United Nations Sustainable Development Goals (SDGs), specifically SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Through its efforts to enhance device lifespans, repair, refurbish, and repurpose electronic components, Telkomcel actively contributes to SDG 12, which aims to promote sustainable consumption and production patterns. By extending the life cycle of devices and reducing e-waste, Telkomcel minimizes the demand for new products, consequently reducing the resources consumed in manufacturing new electronics. This approach addresses the growing concern of electronic waste and resource depletion, aligning with the targets under SDG 12, which advocate for the reduction of waste generation through prevention, reduction, recycling, and reuse by 2030.
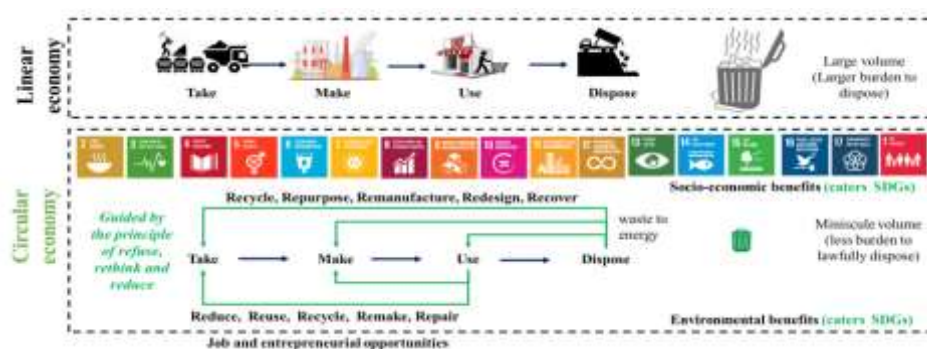

Figure 2 <Differences between linear and circular economy showing how to achieve the SDGs>

Furthermore, Telkomcel's initiative to repair and repurpose electronic devices and components, such as converting batteries into power banks, also ties into SDG 13, which focuses on taking urgent action to combat climate change and its impacts. The company's efforts to reduce the environmental impact of its operations by minimizing the disposal of e-waste into landfills and the associated emissions is a direct contribution to addressing climate change. The circular economy principles embedded in Telkomcel's waste management strategies help reduce the carbon footprint of its operations by decreasing the need for new raw materials, thereby lowering energy consumption and greenhouse gas emissions linked to production processes. These practices also foster the reduction of harmful pollutants released into the environment from improperly discarded electronic waste, aligning with climate action objectives set out in SDG 13. Telkomcel's commitment to these SDGs

reinforces the company's role in shaping a more sustainable and climate-conscious future while addressing both environmental and social sustainability in its operations.

The Factors Support and Hinder Effective E-Waste Management
The factors that both support and hinder effective e-waste management in telecommunication companies play a significant role in the adoption of circular economy practices. These factors are supporting as follows: (1) Public awareness of the environmental and health risks associated with improper e-waste disposal is gradually increasing. This awareness is driven by various awareness campaigns, environmental organizations, and media coverage about the harmful impact of toxic substances like lead, mercury, and cadmium found in e-waste on soil, water, and air quality; (2) Advances in e-waste treatment technologies have enabled more efficient and cost-effective ways to handle electronic waste. Innovations such as automated sorting systems, safer methods of extracting valuable materials like gold and copper from electronic devices, and chemical-free recycling processes have made it easier to recycle e-waste; (3) Governments across the globe are beginning to recognize the importance of e-waste management and are enacting regulations that enforce the proper treatment of e-waste. For example, the European Union's Waste Electrical and Electronic Equipment (WEEE) Directive mandates the recycling and safe disposal of electronic waste; (4) The growing involvement of individuals in e-waste management activities, such as recycling unused electronic devices, demonstrates a shift towards responsible consumer behavior. Community-based recycling programs and initiatives, such as take-back schemes organized by electronics retailers, encourage consumers to dispose of their e-waste responsibly.

These factors are inhibiting as follows: (1) Many people, including employees of telecommunication companies, still lack awareness about how to properly handle and dispose of e-waste. Without a proper understanding of the environmental impact and the available recycling options, e-waste might end up in landfills or be improperly disposed of. To overcome this challenge, companies can implement employee training programs and raise awareness among the public through informational campaigns; (2) A skilled workforce is essential to properly manage e-waste, but there is a shortage of trained professionals who understand the complexities of recycling and disposing of e-waste. This is due to the lack of specialized educational programs and training opportunities for e-waste management. One potential solution is for companies to invest in the training of their employees or collaborate with educational institutions to offer courses on waste management and environmental sustainability; (3) A major hindrance to effective e-waste management is the lack of infrastructure to support collection, processing, and recycling activities. Many regions, especially in developing countries, lack sufficient e-waste collection centers or advanced recycling facilities, making it difficult to handle electronic waste. To address this, public-private partnerships can be encouraged to establish collection points in convenient locations, such as shopping malls or electronics stores. Governments and telecommunication companies can also invest in building specialized recycling plants that use cutting-edge technologies to process e-waste efficiently and safely; (4) E-waste management requires significant financial investment, particularly for setting up collection systems, processing facilities, and conducting environmental impact assessments. For small to medium enterprises (SMEs), these costs can be a major burden. To mitigate this issue, companies can explore cost-sharing mechanisms, such as creating collaborative recycling networks with other businesses, especially within the same industry. Additionally, governments can offer financial support through grants or tax breaks for companies that invest in sustainable practices. Companies can also focus on long-term savings by implementing circular economy principles, such as extending product lifespans and minimizing waste generation; (5) In many countries, regulations surrounding e-waste management are still fragmented and lack clarity, leading to confusion among companies about their responsibilities and legal obligations. The lack of a unified framework makes it difficult for businesses to develop effective e-waste management strategies. To resolve this, companies should actively participate in dialogues with regulatory bodies to shape clearer, more comprehensive regulations. Businesses can also adopt international standards for e-waste management, such as the ISO 14001 environmental management system, to guide their efforts and ensure compliance with existing and future regulations.

While there are significant supporting factors that can drive e-waste management practices in telecommunication companies, several inhibiting factors must be addressed. By investing in education, infrastructure, and technology, and collaborating with governments, businesses, and consumers, telecommunication companies can overcome these challenges and contribute to a more sustainable and circular economy.

Conclusions

The conclusion of this research highlights the key findings related to the implementation of circular economy principles in Telkomcel's sustainable e-waste management practices. Telkomcel has effectively applied the principles of reduction, reuse, recycling, repair, and repurposing in its approach to managing e-waste, with several significant practices contributing to sustainability. These include the collection, sorting, and recycling of

e-waste, as well as the refurbishment and repurposing of functional devices for internal use or donation to educational institutions.

However, the research also identified specific challenges in Telkomcel's e-waste management efforts. A major obstacle is the limited public awareness about the dangers of e-waste and the need for proper disposal, which hinders wider community participation in recycling programs. Furthermore, the company faces challenges in securing the necessary infrastructure for collection and processing, such as the absence of advanced recycling facilities. While technological advancements are helping to improve e-waste treatment processes, the high costs of implementing such technologies and the shortage of trained human resources remain significant barriers. Additionally, the lack of comprehensive and enforceable government regulations further complicates the implementation of effective e-waste management strategies.

In conclusion, while Telkomcel's circular economy approach to e-waste management demonstrates a solid commitment to sustainability, there are clear areas for improvement, especially in terms of education, infrastructure, and regulatory frameworks. The company's practices are effective but require stronger public awareness, improved technological solutions, and clearer government regulations to overcome existing barriers and maximize their positive environmental impact.

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