

Beyond E-Waste:

Rethinking Circular Electronics Through Global South Perspectives

How repair, reuse, and material recovery can create more circular and equitable electronics systems

By Riddhima Karwa

CRADLE TO CRADLE ELECTRONICS INITIATIVE

CRADLE TO CRADLE NGO

1. Introduction

The Global South occupies multiple roles in the global electronics economy: as a source of raw materials, a growing consumer market, and a center for repair, reuse, refurbishment, and material recovery. Yet these roles are often considered separately, with circular-electronics discussions focusing largely on recycling, waste-management infrastructure, and formal circular-economy strategies. This can overlook the practices and knowledge that already help extend product lifetimes, recover value, and make electronics more accessible.

Repairing a smartphone rather than replacing it, reselling a used device, refurbishing electronics, or recovering materials can keep products and resources in use for longer. These activities are shaped by affordability, local livelihoods, and the availability of skills and infrastructure, as well as by formal policies. They can create economic and environmental value, but their potential is constrained by unsafe working conditions, limited processing capacity, and unequal access to higher-value activities.

The scale of the challenge is growing. In 2022, the world generated 62 million metric tons of e-waste, of which only 22,3% was documented as formally collected and recycled in an environmentally sound manner (ITU and UNITAR, 2024). However, circularity is not only about what happens to electronics once they become waste. It also depends on how long devices can be used, whether they can be repaired or refurbished, and what happens to their materials when they can no longer be used. Many of these possibilities are shaped by decisions made at the design stage, including the materials used, the availability of spare parts, and how easily a device can be opened and dismantled.

Using the smartphone as a starting point, this article explores perspectives from India, South Africa, and Mexico. It combines secondary research with practitioner insights from Susanne Karcher, Executive Director of the African Circular Economy Network, whose interview informs the discussion of South Africa, and Dylan Roman, Founder and CEO of Niu Niu, whose contribution to a panel discussion informs the discussion of Mexico. These insights are considered alongside research on India and relevant policy evidence. The article examines how local repair and recovery systems operate, what constrains them, and what these experiences suggest about more equitable circular-electronics policy—and how products should be designed for the conditions in which they are actually used.

The evidence draws on studies and data collected at different times and scales, alongside practitioner perspectives. The figures are therefore used to illustrate specific aspects of circular electronics rather than as directly comparable measures across countries. Formal collection statistics may not capture all repair, reuse, and informal recovery activity, while findings from individual facilities or surveys should be interpreted within their stated scope.

2. Smartphones, resources, and unequal circularity

A smartphone connects several stages of a global supply chain: mineral extraction, component production, assembly, consumption, repair, resale, and material recovery. These stages do not necessarily take place in the same country, and the economic value generated at each stage is not distributed evenly. Countries may supply raw materials, manufacture or assemble products, and provide large consumer markets without retaining an equivalent share of the value generated through advanced manufacturing, specialized processing, or control over technology.

The cobalt supply chain illustrates this imbalance. The Democratic Republic of the Congo (DRC) is a major source of mined cobalt, a mineral used in many lithium-ion smartphone batteries, while China plays a leading role in cobalt refining. UN Trade and Development reported that in 2022, the unit value of cobalt increased from USD 5.8 per kilogram to USD 16.2 per kilogram once processed locally in the DRC. The country exported processed cobalt worth approximately USD 6 billion, compared with USD 167 million in unprocessed cobalt ores (UNCTAD, 2024). These figures cover the wider cobalt supply chain, not smartphones alone, but illustrate how processing capacity can influence the value retained by a mineral-producing country. A similar question arises at the end of a device's use: where are its materials recovered, and who has the infrastructure and technical capacity to capture their value?

Differences in e-waste management illustrate another part of this imbalance. In 2022, Europe generated 17.6 kg of e-waste per person and documented the formal collection and recycling of 42.8% of it. Africa generated 2.5 kg per person, but documented formal collection and recycling amounted to just 0.7%. Asia generated 6.4 kg per person, with an 11.8% formal collection and recycling rate (ITU and UNITAR, 2024).

The economic story does not end when a device is discarded. A smartphone that is no longer needed by one owner may still serve another through resale, repair, or refurbishment. Research on Delhi's electronics economy documents how repairers and traders return used devices and components to productive use, creating value beyond formal waste-management systems (Corwin, 2018). Where continued use is safe and practical, preserving a device's function can retain more of its value than dismantling it for materials. When a device can no longer be used or repaired, safe material recovery becomes essential.

These stages should therefore be understood as connected parts of one system, rather than separate activities. The question is not simply how much e-waste is recycled, but whether products remain useful for longer, whether materials are recovered safely when reuse is no longer possible, and whether the people and countries involved retain a fair share of the resulting value. India, South Africa, and Mexico illuminate different aspects of this challenge: consumer access and repair networks, the livelihoods and logistics that support repair and collection, and the capacity to recover and retain value from discarded materials.

3. Country perspectives: Existing practices and unrealized potential

3.1 India: Recognizing the value of repair and reuse

India's repair, resale, and refurbishment networks help keep smartphones in use and make devices more affordable. As the Delhi research cited above shows, repairers and traders recover value from used devices and components through repair, resale, and remanufacturing (Corwin, 2018). Circularity therefore does not begin only when a product enters a formal recycling system. It also depends on the people, skills, and markets that allow devices to remain useful.

The economic significance is visible in India's secondary smartphone market. Counterpoint Research data reported by Business Standard indicate that used and refurbished phones together accounted for more than 19% of smartphone sales in India in 2024. Premium smartphones were available at prices approximately 40% below their original prices, on average, within six months of use (Das Gupta, 2025). The secondary market can make devices accessible to buyers who might otherwise be priced out and create opportunities for businesses that test, repair, and resell used phones. Resale is distinct from repair, but both can extend a device's useful life and preserve its value.

Repair quality and accessibility also influence whether consumers choose to repair a device rather than replace it. A 2025 Counterpoint Research survey across 28 Indian cities found that around four in ten respondents needed repeat visits to complete a repair (Chawla & Paleja, 2025). This suggests that access to repair services alone is not enough: repairs must also be effective and reliable if they are to help extend product lifespans.

As the survey was commissioned by Xiaomi India and covered customers of service centers, its findings should be interpreted within that scope rather than as nationally representative estimates.

The existence of a repair market does not mean that repair is always accessible or that every device can be economically repaired. Access to spare parts, repair information, technical skills, and reasonably priced services can influence whether a device remains in use. Extending product life must also be accompanied by safe end-of-life management: devices that can no longer be repaired still require responsible collection and treatment, while unsafe dismantling or material extraction can expose workers and communities to hazardous substances.

India's experience highlights the importance of recognizing repair and reuse as part of circular-electronics policy, while ensuring that products reaching the end of their useful lives are handled safely. A system that measures success only through formal recycling risks overlooking the value retained before a device becomes waste.

3.2 South Africa: Supporting repairers and making collection viable

In South Africa, small repair businesses and informal operators contribute to extending product life but face barriers to obtaining tools, suitable workspaces, finance, and spare parts. In an interview conducted for this article, Susanne Karcher described repairers working in townships, including shops operating from shipping containers. Such businesses rely on practical knowledge, local customer relationships, and the ability to source parts and provide affordable services.

A 2026 study of 832 informal repairers and refurbishers across 11 South African cities and towns provides evidence of their economic role. Nearly 99% of respondents reported undertaking repairs, while 45.2% also refurbished electronic products. The study documented 486 additional income-generating opportunities associated with the businesses. These findings indicate that repair and refurbishment support livelihoods as well as extending product life. However, the researchers could not establish reliable earnings for all respondents and noted that expenses such as spare parts, rent, transport, and electricity reduced what operators retained (Schenck et al., 2026).

Karcher also highlighted how licensing requirements can place disproportionate burdens on small e-waste operators. As discussed in Section 4, regulation needs to account for the activities operators undertake and the risks they pose, while maintaining appropriate safeguards for workers and the environment.

The scale of the end-of-life challenge is also significant. The Global E-waste Monitor 2024 estimates that South Africa generated approximately 530,000 metric tons of e-waste in 2022. Across Southern Africa as a whole, around 23,000 metric tons were documented as formally collected; this is a regional figure, not South Africa's national collection rate (ITU and UNITAR, 2024).

Karcher highlighted the problem of selective recovery: when collectors remove only valuable components, the remaining device may have little resale value but still require safe treatment. One initiative therefore pays a premium for returning complete equipment, creating an incentive to bring the whole device to an appropriate facility for decontamination and processing. Linking producer-responsibility funding to evidence of proper treatment could further encourage safe recovery, rather than rewarding only the extraction of valuable parts.

This example illustrates how economic incentives can shape environmental outcomes. If collection systems reward only valuable components, the costs and risks associated with the remainder may be left with other operators or communities. Incentives for returning complete devices can help address that gap, provided the treatment requirements and funding arrangements are transparent and effective.

Collection costs create another barrier. Research on South Africa's e-waste sector identifies transport as a significant expense for recyclers, particularly where collection areas are extensive and downstream processing capacity is limited (Moyo et al., 2022). Karcher suggested using delivery vehicles to transport collected e-waste on journeys to or from rural shops, rather than organizing separate collection trips. This form of reverse logistics could make use of existing routes to reduce transport costs.

It illustrates how circular systems can be built around existing commercial activity, rather than assuming that dedicated infrastructure is always the most practical starting point.

South Africa's experience therefore points to two connected priorities: improving collection and safe treatment while recognizing the people and businesses already extending product life and moving devices through local economies. Formal systems are more likely to be effective when they work with these networks and address the practical costs of participation.

3.3 Mexico: Recovering materials and retaining value

Mexico highlights the gap between the value contained in discarded electronics and the value captured through recovery systems. Dylan Roman emphasized that supplying raw materials or assembling products does not necessarily allow a country to capture the greater economic returns associated with advanced manufacturing and processing. As with cobalt, the question at the end of a device's use is where recovered materials are processed and how much of their value remains in the country.

Research by Cordova-Pizarro et al. (2019), using estimates based on 2015 data, calculated that materials in discarded cellphone printed circuit boards represented an annual value of approximately USD 11.3–12.4 million in Mexico, while approximately USD 677,000 in material value was recovered through the formal channels examined. The facilities surveyed relied on manual or mechanical separation but lacked technologies for further processing recovered materials, and extracted circuit boards were exported for downstream processing. These are historical estimates, not current market values, and the difference should not be interpreted as recoverable profit. They nevertheless illustrate how limited domestic processing capacity can constrain the value retained from discarded electronics.

The study also examined reuse alongside material recovery. Approximately 42% of the used electronics handled by the surveyed facilities entered a second-hand market for reuse. This finding describes the facilities studied, not Mexico's national second-hand market or e-waste stream. The study further estimated that formal recycling captured 10.8% of the country's e-waste, based on the data available at the time. Together, these findings highlight two complementary priorities: keeping functional products and components in use for longer, and recovering materials safely when devices can no longer be used.

Capturing more value from discarded electronics requires more than increasing collection. It may also require investment in processing technologies, technical skills, reliable material flows, and viable markets for recovered materials. Yet building processing capacity is not, by itself, a guarantee of equitable outcomes. The distribution of value depends on who owns the facilities, who performs the work, what conditions they work under, and whether local businesses and workers can participate in higher-value activities.

Roman also raised concerns about downstream workers remaining invisible in formal supply chains and capturing little of the value they help create. Traceability tools, including digital product passports, may help document material flows, but documentation alone cannot guarantee fair compensation or safe working conditions.

Mexico's experience therefore connects domestic processing capacity with a broader question: how can countries retain more economic value from material recovery while ensuring that the people involved benefit from the system?

4. Designing circularity around people and local realities

The three country examples reveal complementary dimensions of circularity. India illustrates the importance of affordable, high-quality repair and secondary markets; South Africa shows how livelihoods, collection logistics, and regulatory design shape the effectiveness of repair and recovery systems; and Mexico highlights the role of processing capacity in retaining value from discarded materials. Together, they show why circularity cannot be assessed only by counting devices collected or tons recycled. It also depends on whether products remain useful, whether recovery is safe, and who can participate in and benefit from these activities.

The structure of local economies matters. Repair, refurbishment, and recovery may depend on small businesses and other operators working with limited capital, local customer relationships, and practical knowledge. These conditions differ from those of large, vertically integrated companies with dedicated compliance teams and access to substantial investment. Policies and technologies designed without considering differences in scale can unintentionally exclude smaller operators from formal circular systems.

This has direct implications for regulation. As noted in Section 3.2, Karcher questioned licensing requirements that can place disproportionate burdens on small e-waste operators. Regulations should distinguish between the hazards of materials and the activities being performed: dismantling electronic equipment does not automatically present the same risks as handling concentrated hazardous substances. Requirements should reflect the actual activity and its risks, protect workers and the environment, and provide practical routes for smaller operators to comply.

A risk-proportionate approach is not an argument for weaker safeguards. It is an argument for matching requirements to the hazards and scale of the activity, while ensuring that workers receive appropriate protection and hazardous materials are handled safely. Where compliance is too costly or complex for small operators to achieve, policy should consider workable pathways to meeting standards, including training, shared facilities, technical support, and appropriately designed licensing arrangements.

Economic incentives matter as much as regulatory requirements. The South African example of rewarding complete-device returns shows how funding can encourage safer treatment of materials that might otherwise be abandoned after valuable components are removed. More broadly, producer-responsibility schemes need to support the safe management of products throughout the recovery process, rather than rewarding only the collection of valuable fractions. Transport arrangements that use existing delivery routes can also help reduce costs and make collection more viable in areas where dedicated logistics are expensive.

Technology and investment should follow the same principle. Mechanized processing and formal recovery facilities can improve safety and material recovery, but introducing them without considering existing repair networks and livelihoods risks excluding people already contributing to circularity. Investment should build local technical capacity and enable operators to improve their practices, rather than assume that replacing existing networks is always the best route to formalization. In countries where downstream processing is limited, partnerships can also support the development of local expertise and capacity, while ensuring that the benefits of new investment are not confined to a small number of businesses.

Circularity depends on decisions made long before a device reaches its first owner. Whether a smartphone can be opened without damage, repaired using available spare parts, refurbished reliably, or dismantled safely is shaped by its design. The Cradle to Cradle approach begins by considering how a product will be used and what will happen to its materials afterward. Applied to electronics, this means designing for the repair, reuse, refurbishment, and recovery practices that already sustain devices in markets such as India, South Africa, and Mexico. Accessible spare parts and repair information can help keep devices in use, while material selection and product construction can make dismantling safer and recovery more effective. These outcomes should be built into products from the outset, rather than left entirely to local operators and regulators to address later.

Design also determines the quality of material recovery. The materials selected and the way components are assembled influence whether recovered resources can return to production at a comparable level of quality or are instead downcycled into lower-grade applications. Manufacturers therefore hold important levers that local repairers, recovery businesses, and regulators cannot fully control: product design, material composition, spare-parts availability, access to repair information, and effective take-back arrangements. A more circular electronics system requires these upstream decisions to support the work undertaken downstream. Regulation and investment remain essential, but they cannot substitute for products designed for repair, reuse, and high-quality material recovery.

The repair, reuse, refurbishment, and recovery practices discussed in this article show why these decisions matter in practice. Strengthening existing local systems must therefore go hand in hand with designing electronics for circularity. This shifts the focus from managing electronic waste after it arises to creating products and systems that enable circularity from the outset.

5. Conclusion: Circularity begins with designing for how people use things

India, South Africa, and Mexico demonstrate that circular electronics depends on how products are designed, whether they can be repaired or resold, how materials are recovered, and who benefits from these activities. Their experiences highlight the value of local repair and reuse networks, the practical and economic conditions that enable collection, and the role of domestic processing capacity in retaining value.

The Global South's experiences offer lessons for global circularity – not because resource constraints should be celebrated, but because they reveal how products can remain useful through local skills, markets, and livelihoods. For policymakers and manufacturers in the Global North, the practices described in this article represent existing infrastructure for repair, reuse, and collection. Building on it is likely to be faster and less costly than replacing it, and assuming that formalization or mechanization is always the starting point risks losing the value it already creates.

A more equitable circular-electronics economy would design devices for the conditions in which they are actually used, keep them useful for longer, recover materials safely and at high quality when reuse is no longer possible, and distribute the resulting value more fairly. Achieving this requires not only better technologies and infrastructure, but also product design, regulations, and economic incentives that reflect local realities and enable the people who already contribute to circularity to participate in its future.

References

Chawla, A., & Paleja, A. (2025, September 15). Survey: 4 in 10 India smartphone consumers require repeat visits for repairs. *Counterpoint Research.* counterpointresearch.com/en/insights/survey-4-in-10-india-smartphone-consumers-require-repeat-visits%20for-repairs

Cordova-Pizarro, D., Aguilar-Barajas, I., Romero, D., & Rodriguez, C. A. (2019). Circular economy in the electronic products sector: Material flow analysis and economic impact of cellphone e-waste in Mexico. *Sustainability*, 11(5), Article 1361. doi.org/10.3390/su11051361

Corwin, J. (2018). "Nothing is useless in nature": Delhi's repair economies and value-creation in an electronics "waste" sector. *Environment and Planning A: Economy and Space, 50*(1), 14–30. doi.org/10.1177/0308518X17739006

Das Gupta, S. (2025, April 21). 1 in 5 smartphones sold in India is refurbished: Counterpoint Research. *Business Standard*. www.business-standard.com/industry/news/1-in-5-smartphones-sold-in-india-is-refurbished-counterpoint-research-125042101379_1.html

International Telecommunication Union, & United Nations Institute for Training and Research. (2024). *The global e-waste monitor 2024*. ewastemonitor.info/the-global-e-waste-monitor-2024/

Karcher, S. (2026, October 16). Personal interview.

Moyo, T., Sadan, Z., Lötter, A., & Petersen, J. (2022). Barriers to recycling e-waste within a changing legal environment in South Africa. *South African Journal of Science, 118*(Special issue: Waste as a Resource), Article 12564. doi.org/10.17159/sajs.2022/12564

Roman, D. (2026, September 8). Contribution to the panel discussion "International perspectives on circular economy," Cradle to Cradle Electronics Initiative, IFA Berlin.

Schenck, C., Loots, O., Fletcher, L., Petersen, J., Niyobuhungiro, R., & Grobler, L. (2026). Informal repairers and refurbishers of electrical and electronic products in the South African township economy. *South African Geographical Journal, 108*(1). doi.org/10.1080/03736245.2025.2601094

UN Trade and Development. (2024, April 26). *Critical minerals boom: Global energy shift brings opportunities and risks for developing countries.* unctad.org/news/critical-minerals-boom-global-energy-shift-brings-opportunities-and-risks-developing-countries



Riddhima Karwa is an Indian environmental education consultant. She co-founded the *Do-No Trash* initiative, co-created Uttarakhand's "Nature Vidya" portal at the Nature Science Initiative, and led the *Wipro* Earthian sustainability program for schools. Holding a Master's in Environmental Studies, she has been working as a freelance sustainability educator since 2026 while consulting for environmental group *Adharshila* in Madhya Pradesh. From August to October 2026, she completed a CCP Fellowship with Cradle to Cradle NGO in Berlin and contributed her insights in the context of the Engagement Global project to the Cradle to Cradle Electronics Initiative in the form of this publication.

CRADLE TO CRADLE NGO

Cradle to Cradle NGO is an independent nonprofit founded in 2012 that brings the Cradle to Cradle approach into practice – through education, policy engagement, and transformation projects such as the C2C LAB and Labor Tempelhof. Its large network spans business and municipalities, science, politics and civil society, and each year convenes the C2C Congress, the world's largest platform for the C2C community.

CRADLE TO CRADLE ELECTRONICS INITIATIVE

The Cradle to Cradle Electronics Initiative (C2CEI) was launched by the nonprofit organizations **Cradle to Cradle NGO, Bertelsmann Stiftung** and **Röchling Stiftung.** It is designed to run over three years with the goal of making Cradle to Cradle the design standard for electronic consumer goods. Under its roof, numerous companies, researchers and civil society run hands-on pilot projects and studies that turn circularity from principle into practice.

Cradle to Cradle – Wiege zur Wiege e.V.
Landsberger Allee 99c
10407 Berlin

Phone +49 (0)30 4677 4780
info@c2c.ngo

Donation account
GLS Bank IBAN: DE74 4306 0967 2036 5496 00
BIC: GENODEM1GLS

Cradle to Cradle NGO – Wiege zur Wiege e.V. is recognized as a non-profit organization and particularly eligible for support.

This publication is nutrient:
It is printed using the C2C process. C2C printed products are specifically designed for the biological cycle.

CERTIFIED cradle to cradle SILVER

Highest eco-effectiveness: Cradle to Cradle® certified printed products