

MISSING SIGNAL



ELLEN MACARTHUR
FOUNDATION

Unlocking a Circular
Economy for Mobile
Phones in North America

EXECUTIVE SUMMARY

MOBILE PHONES ARE ONE OF THE MOST WIDELY DISTRIBUTED RESERVOIRS OF HIGH-VALUE MATERIALS IN THE ECONOMY TODAY

Mobile phones are woven into daily life in a way few other electronic devices are.¹ They mediate work, navigation, authentication, payment and social exchange, and for many people function as their primary computing interface. These uses impose particular design requirements—phones must be portable, secure and continuously functional—which have produced a class of devices extremely dense with plastics (40%), glass and ceramics (25%), and a remaining share made up of 63 other elements, including critical minerals such as cobalt, lithium and neodymium (Bruno, Sotera and Fiore 2022). Much of the recoverable economic value of a mobile phone comes from these critical minerals, while plastics and other materials are lower in commodity value and harder to recover at high quality. When phones are replaced or retired, many are used again. After that reuse, however, they often fall out of circulation. Drawing on modeling of mobile phone flows across North America, this research paper explores the potential of circularity for mobile phones with a focus on upstream opportunities for decision makers in the public and private sectors.

North America already has a circular economy foundation for mobile phones, but there remains significant room for improvement. Around 50–70% of phones leaving first use enter reuse, or “second lives,” through passdown, repair, refurbishment and resale, supported by commercial trade-in, buy-back and refurbishing programs. Subnational policy developments, such as right-to-repair legislation and circular procurement, are beginning to reinforce those pathways and help reduce the share of mobile phones (30–50%) that would prematurely become waste. However, as mobile phone consumption continues to rise, so too does the overall volume of phones exiting circulation. Under current conditions, an estimated 2 billion phones are projected to reach end of life by 2040 in the United States, alongside 410 million in Mexico and 180 million in Canada (RTI International 2025).

Gaps across design, collection and recovery continue to drive value loss across the region. Current business models continue to prioritize value from first sale and promote frequent replacement through upgrade cycles and financing arrangements, while many phones are designed in ways that shorten usable lifetimes. Phones often receive short-lived software support, their hardware is difficult to disassemble and some components are digitally locked, limiting their replacement to authorized parts and approved repair providers. Many consumers also store or discard used phones instead of returning them into the market because collection and resale remain inconvenient, and because concerns about data security reduce their trust in phone return programs. Even when phones are returned at the end of usable life, the region still lacks the processing and refining capacity, as well as the stable demand for recovered materials, to keep more value inside regional supply chains and reduce the environmental impacts of virgin material extraction.

Without efficient domestic reuse and material recovery pathways, North America will continue to absorb the impacts of a loss-heavy system. The critical minerals engineered into phones are core inputs for major regional industries such as electric vehicles, grid and power infrastructure, advanced electronics and defense—at a time when demand pressures and supply chain volatility are on the rise (International Energy Agency 2021). When phones that could be reused, repaired, refurbished, remanufactured or recycled are instead discarded or exported outside North America, the region loses mineral value, increasing the need for virgin extraction. Even if mining and refining expand, virgin material supply alone is unlikely to provide a secure and sustainable base of critical minerals at acceptable cost and risk. Virgin extraction also leads to harms such as habitat loss, water contamination and impacts that have often fallen disproportionately on marginalized communities, especially Indigenous peoples (World Resources Institute 2024; United Nations Institute for Training and Research 2025; Basel Convention Secretariat 2026). Designing phones with fossil-derived plastics and chemical additives, including flame retardants, also raises the risk of leakage and contamination when the phones are mishandled, and leads to the loss of devices and materials from circulation before their value can be retained.

Implementing a circular economy by 2040 could improve material security, reduce environmental degradation and recover an estimated US\$2.2 billion in critical minerals from end-of-life mobile phones.

This paper sets out recommendations (Section 4) for how governments and industry can realize that opportunity by transforming the way mobile phones are designed and brought to market, how they are collected and recirculated, and how materials are processed and reintegrated into supply. The recommendations focus on the following areas:

- **Design and business models:** Ensure phones are designed and supported for longevity, modularity, repair and non-destructive disassembly so that devices, parts and materials can remain circulating until reuse is no longer possible, then be recovered at their highest value.
- **Collection and movement:** Make it easy and economic for consumers to reuse and return phones, including older and non-functional ones, through targeted policies and investment in collection infrastructure and reverse logistics. Align definitions, grading and documentation so that phones and components can move through reuse and material recovery pathways with consistent standards and secure data handling.
- **Processing and demand:** Scale domestic primary and secondary processing so that materials recovered from phones no longer suitable for reuse can re-enter manufacturing supply chains, supported by sufficient demand and economies of scale to make recovery systems viable.

These changes could keep phones in use longer, expand repair and refurbishment markets and create new revenue opportunities beyond first sale through activities such as resale, leasing and maintenance. They could also turn the current high volume of underutilized and eventually discarded mobile phones into a reliable regional supply of durable, refurbished and remanufactured products and recovered materials, including critical minerals. By reducing reliance on volatile global supply chains and virgin extraction, these changes could strengthen regional resilience and reduce waste, pollution and greenhouse gas emissions. For consumers, they could increase the availability of durable new and used phones, make repair easier and cheaper, and improve access to affordable refurbished and remanufactured devices. As jurisdictions such as the European Union begin introducing ecodesign requirements for products entering their markets, including imports, these changes could also help North American industries stay competitive in global markets increasingly shaped by durability, repairability and material transparency requirements. Today, mobile phones are one of the most viable opportunities to apply circular economy strategies at scale.



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ABBREVIATIONS

CHARGE	Critical and High-value Advanced Resources from Green E-waste
DPP	digital product passport
EPEAT	Electronic Product Environmental Assessment Tool
EPRA	Electronic Products Recycling Association
EPR	Extended Producer Responsibility
ESPR	Ecodesign for Sustainable Products Regulation [EU]
EU	European Union
LGEC	<i>Ley General de Economía Circular</i> (General Act on Circular Economy)
OEM	original equipment manufacturer
R2	Responsible Recycling
R2R	right to repair
Semarnat	<i>Secretaría de Medio Ambiente y Recursos Naturales</i> (Ministry of Environment and Natural Resources)

ABSTRACT

This paper examines how mobile phones move through use, reuse, collection and processing systems across Canada, Mexico and the United States, and how product design, business models, collection systems, processing infrastructure and trade influence circular economy outcomes across North America. Although many phones already move through multiple use cycles, current systems continue to favor frequent replacement and low-value recovery pathways over longer product use and value-retention processes such as reuse, repair and refurbishment.

Combining material flow modeling by RTI International with key actor consultation, policy analysis and desk research, the paper compares policy and market conditions across the three countries, including repair systems, take-back models, processing capacity and emerging approaches to repairability, durability and material recovery. Figures, Sankey diagrams, tables and case studies that highlight “bright spots” are used throughout to illustrate how phones, components and materials move through regional systems and where value is retained, downgraded or lost.

PURPOSE AND APPROACH

Prepared by the Ellen MacArthur Foundation, this paper focuses on upstream opportunities for decision makers in the public and private sectors to implement a circular economy for mobile phones in North America. Although the narrative refers to “mobile phones” as a category, the quantitative model used in the study tracks smartphones. For the purposes of this analysis, smartphones are treated as the dominant subclass of mobile phones. Many of the study’s insights can be extrapolated to other categories of consumer electronics (International Telecommunication Union 2025).

The research uses a mixed-methods approach combining key actor consultation, desk research and quantitative modeling by RTI International. Between April and September 2025, the research team consulted more than 90 relevant actors across 11 sectors in the three countries, including finance; government; industry association; logistics; manufacturing; recycling and information technology (IT); asset disposition; repair; research and civil society; retail; startup; and telecommunications. Through five round tables and 16 semi-structured interviews, it followed a process developed with federal representatives from the three countries. RTI’s CHARGE model was used to establish regional and country-level baselines and to inform the paper’s analysis and recommendations (Section 4). Appendix 2 provides the model methodology.

Scope: This study identifies the principal barriers to circular economy outcomes for mobile phones and the opportunity pathways most relevant to decision makers, with particular attention to upstream interventions. It is not a market-sizing exercise nor does it seek to quantify the full range of environmental or human health impacts. It should not be interpreted as an exhaustive assessment of all sectoral interventions.

Interpreting the modeling outputs: RTI’s Critical and High-value Advanced Resources from Green E-waste (CHARGE) model estimates how smartphones move through first use, reuse, collection and processing and ultimately into commodity markets, disposal or export. Sankey diagrams show the probabilistic flows of devices in tonnes rather than material recovery outcomes. They do not account for losses during processing, nor do they reflect how long devices remain in use or storage. For that reason, Sankey values will not exactly match the model’s material-based key performance indicators, which track the share of device material reaching domestic commodity markets and the share lost to disposal or export. Export is defined broadly as material sent to another country from recycling collection or secondary processing for any purpose (see Appendix 3 for definitions). Because downstream handling is not consistently traceable once exported, flows are treated as “export” rather than being attributed to specific outcomes such as reuse or recycling.



01

A CIRCULAR ECONOMY FOR MOBILE PHONES



01 A CIRCULAR ECONOMY FOR MOBILE PHONES

DESIGN, COLLECTION AND RECOVERY CAN WORK TOGETHER TO KEEP PHONES CIRCULATING AT THEIR HIGHEST VALUE

In a circular economy, mobile phones are designed to stay in use for as long as possible before material recovery becomes necessary (Figure 1). Phones are made durable, repairable and easy to disassemble. They have long-term software support and business models that reward repairing phones and buying reused, refurbished or remanufactured devices over purchasing newly manufactured ones. Once a phone changes hands or reaches the end of active use, convenient collection and resale systems help move it back into circulation through repair, refurbishment, remanufacturing and further use. Only when reuse is no longer viable do phones enter recovery systems, which are designed to separate and process components and materials at high value so they can re-enter manufacturing supply chains. In this kind of system, value-retention processes such as reuse, repair and refurbishment reduce the need for new extraction and manufacturing, while high-quality recovery reduces both material loss and reliance on virgin supply.

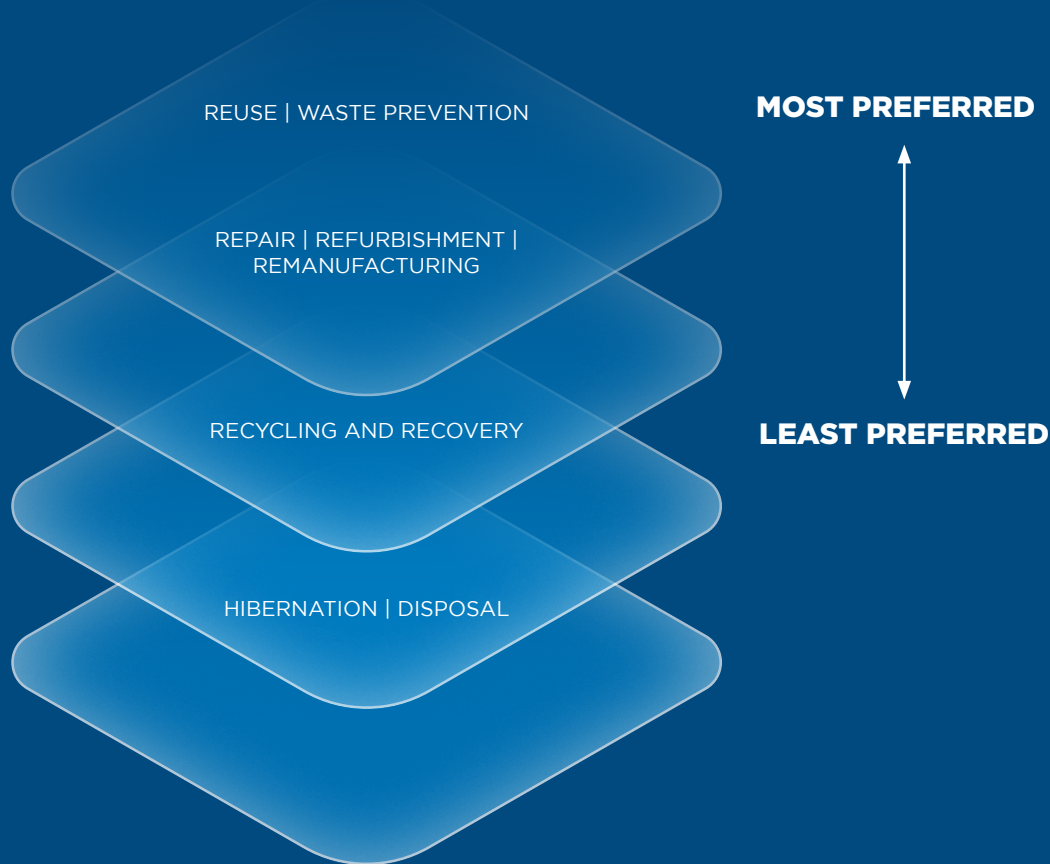
THE CIRCULAR ECONOMY

In this study, we define “circular economy” as a system in which materials never become waste and nature is regenerated. In a circular economy, products, parts and materials are kept in use at their highest value through processes such as repair, refurbishment and remanufacture, and, when use is no longer possible, through recycling and composting. The circular economy tackles climate change and other global challenges, such as biodiversity loss, waste and pollution, by decoupling economic activity from the consumption of finite resources.

The circular economy is based on three principles, driven by design:

- Eliminate waste and pollution
- Circulate products and materials at their highest value
- Regenerate nature

Underpinned by a transition to renewable energy and materials, the circular economy is a resilient system that benefits business, people and the environment (Ellen MacArthur Foundation n.d.).

FIGURE 1.**VALUE RETENTION HIERARCHY**

Note: Among circular economy strategies, reuse retains the greatest amount of embedded labor, energy and material value while requiring the least industrial processing.

Despite the growing foundations for circularity across the region, mobile phones in North America do not yet fully move through the system this way. Devices are often replaced before the end of their usable life, and barriers across the life cycle hinder reuse as well as the high-value recovery of materials. This causes large volumes of phones and embedded materials to fall out of circulation entirely. The world generated about 62 million tonnes of e-waste in 2022, according to the United Nations Institute for Training and Research (2025), and this number continues to rise each year. Canada, Mexico and the United States together generate around 9.5 million tonnes annually, spanning products as varied as televisions, laptops and mobile phones. By weight, mobile phones represent a small share of e-waste, but they contain a concentrated mix of recoverable materials. Demand for these materials is growing, and, under current conditions, this report (using the CHARGE model) estimates the value of recoverable critical minerals from end-of-use phones in North America could reach US\$2.2 billion by 2040.

The opportunity now is to build on North America's foundations for mobile phone circularity and turn it into a system that enables longer, multiple uses, prevents waste, retains value and reduces demand for virgin extraction. Extending the usable life of phones through reuse, repair, refurbishment and remanufacturing (upstream) preserves significantly more embedded value before material recovery (downstream) becomes necessary, and reduces the waste and pollution associated with frequent replacement and disposal. Section 2 examines where value can be retained across the three stages, or "streams," of the mobile phone life cycle:

- **Upstream**, where product design, software support, supply chain configuration and business model incentives shape phone longevity and eventual recoverability
- **Midstream**, where grading, collection, repair, refurbishment, remanufacturing and trust determine whether phones remain in circulation at high value or move into lower-value pathways
- **Downstream**, where end-of-use collection, processing capacity and market conditions affect whether recovered materials re-enter manufacturing supply chains or are lost through disposal, export or low-value recovery

02

LIFE-CYCLE DIAGNOSTICS

HOW MOBILE PHONES
MOVE THROUGH THE
NORTH AMERICAN SYSTEM

02

LIFE-CYCLE DIAGNOSTICS

HOW MOBILE PHONES MOVE THROUGH THE NORTH AMERICAN SYSTEM

OUR RESEARCH SUGGESTS THAT, AFTER FIRST USE, 50–70% OF PHONES MOVE INTO AT LEAST ONE ADDITIONAL USE CYCLE—OR REUSE—YET 30–50% ARE NOT RELIABLY RECAPTURED WHEN THAT REUSE ENDS (FIGURE 3)

Mobile phones are typically replaced every two to three years, though recent findings suggest lifetimes can extend to between four and five (RTI International 2025; Assurant 2026; Mohammadi and Habib 2026). The pressure on users to replace their phones is driven by several factors. Frequent model releases, marketing campaigns and upgrade incentives can create the perception that an existing phone is obsolete before its functional life ends. Simultaneously, that lifetime is physically shortened by limited software support and product designs that use non-durable materials or hard-to-replace parts.

THE RESULT IS LARGE STOCKS OF “HIBERNATING” DEVICES THAT CANNOT BE COLLECTED AND RECIRCULATED

After first use, consumers are left with few options beyond informal resale or limited formal trade-in and buy-back programs. This leads to many phones staying in households for years, where they are either passed down for reuse, or placed in post-use storage. In storage, the phone's battery condition, software support and resale value gradually decline. Users store phones away for various reasons, notably the lack of convenient return options and the concern that their data will not be fully wiped.

The result is large stocks of “hibernating” devices that cannot be collected and recirculated. Based on the probabilistic flows captured in the CHARGE model, hundreds of millions of phones may pass through these periods of hibernation, where their number of viable reuse cycles drops and the risk that they exit into disposal or export, rather than high-value domestic material recovery, increases.

FIGURE 2. THE MOBILE PHONE LIFE CYCLE IN NORTH AMERICA

UPSTREAM

BUSINESS MODEL & PRODUCT DESIGN



MATERIAL & COMPONENT SOURCING



MANUFACTURING & ASSEMBLY



LOGISTICS



DISTRIBUTION



SALE

MIDSTREAM

FIRST USE



REUSE (continued use • resale • passdown • enabled by repair, refurbishment and remanufacturing)



HIBERNATION/STORAGE



COLLECTION/RETURN

DOWNSTREAM

RECYCLING

RECOVERED MATERIALS

DISPOSAL

EXPORT

OUTSIDE NORTH AMERICAN SYSTEM

WIDER MATERIALS ECONOMY

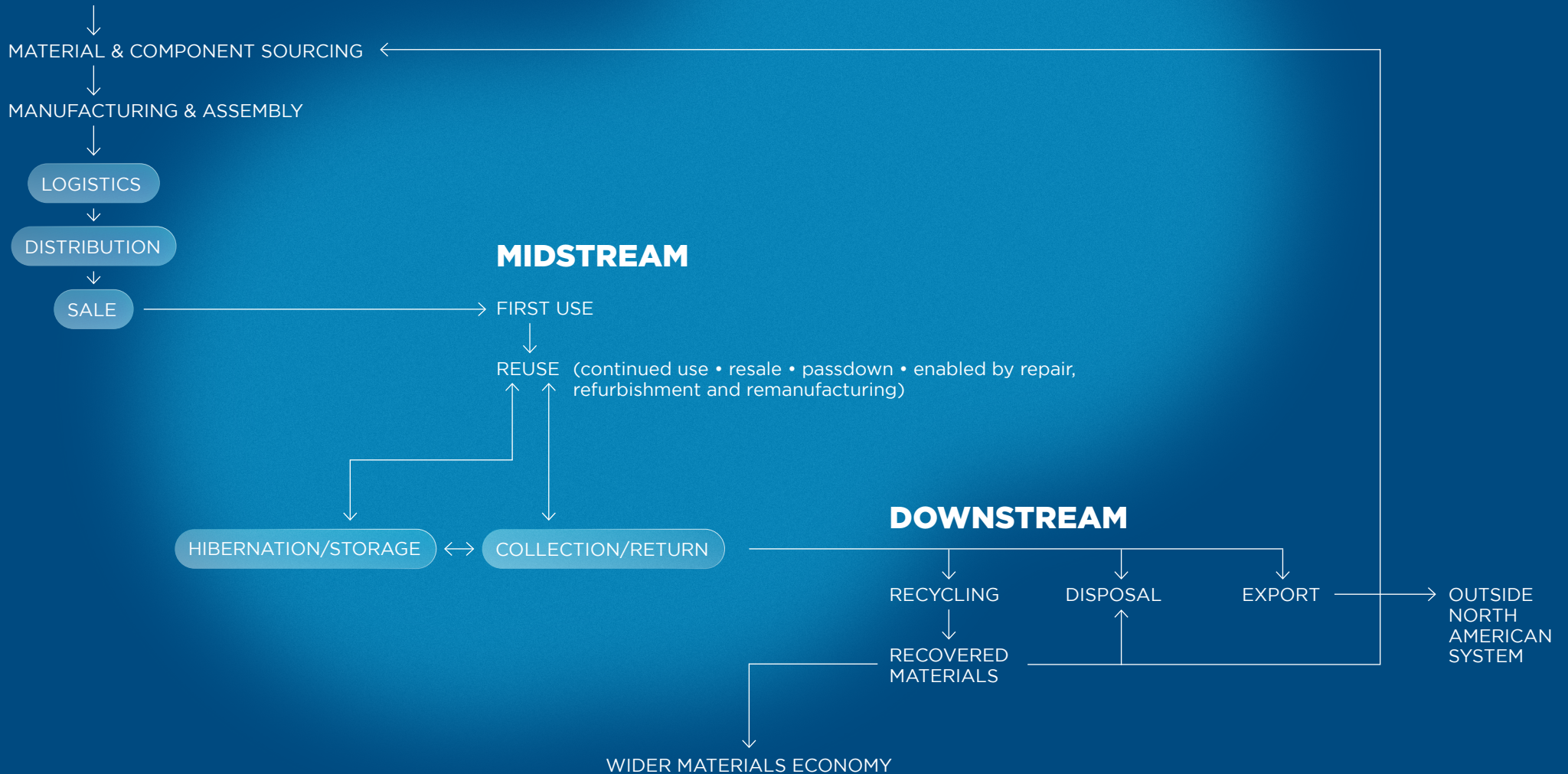
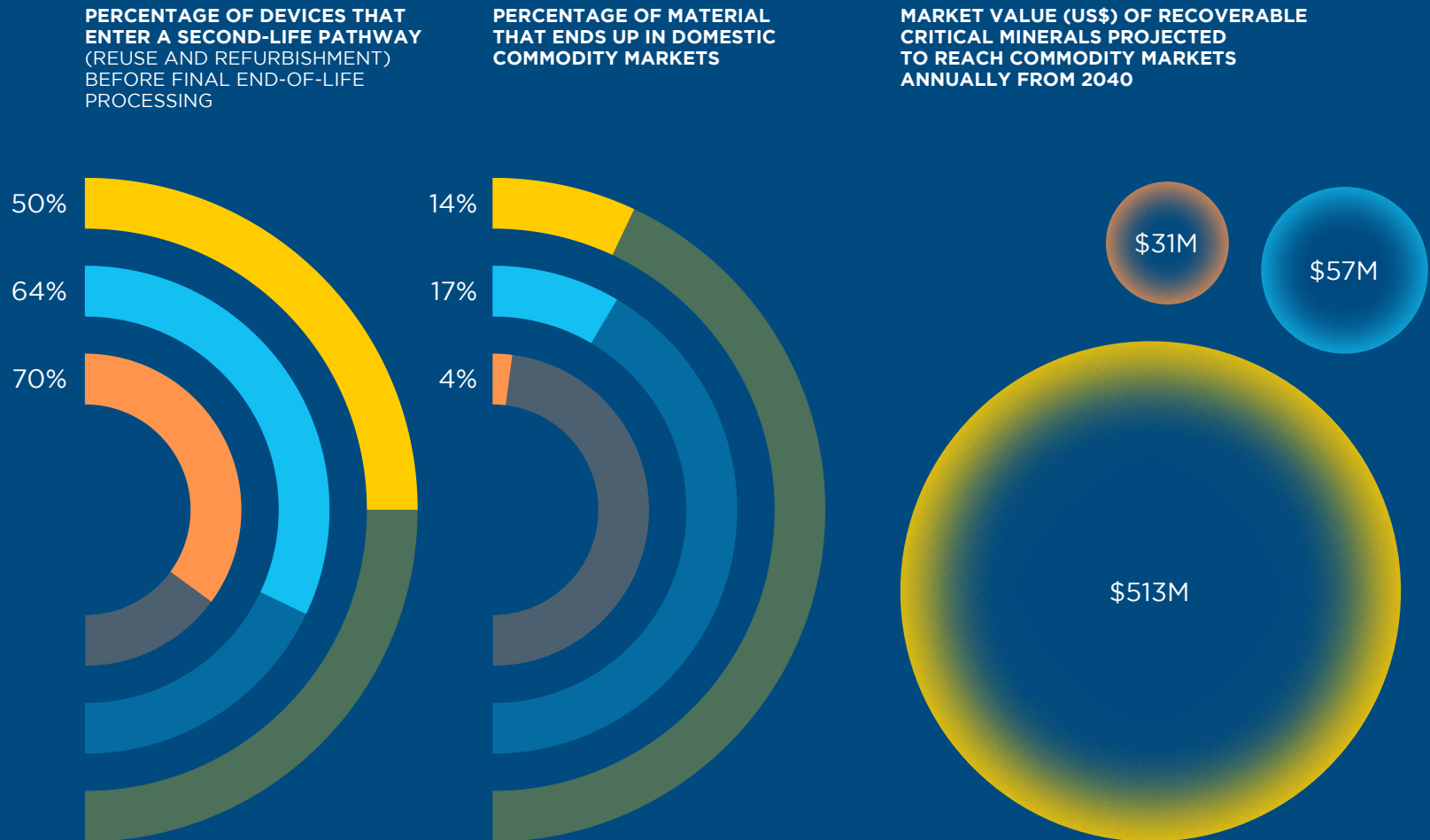


FIGURE 3.

THE PROBABILISTIC MOVEMENT OF MOBILE PHONES (IN TONNES) THROUGH CANADA, MEXICO AND THE UNITED STATES COMBINED GENERATED VIA RTI INTERNATIONAL'S CHARGE MODEL



Source: Data from RTI International (2025).

Note: Numbers derive from the Critical and High-value Advanced Resources from Green E-waste (CHARGE) model developed by RTI International, which traces smartphone flows through first use, reuse and refurbishment pathways, collection channels, recycling infrastructure, export flows and end-of-use outcomes, including entry into commodity markets or landfill. See Appendix 3 for definitions.

2A.**UPSTREAM****PRODUCT DESIGN AND BUSINESS MODELS SET THE CEILING ON VALUE RETENTION AND MATERIALS SECURITY****UPSTREAM DECISIONS ARE MADE LONG BEFORE MOBILE PHONES ENTER USE, YET DETERMINE MUCH OF WHAT BECOMES POSSIBLE LATER IN THE LIFE CYCLE**

How durable, repairable, transferable and eventually recoverable mobile phones become depends on what designs and business models are selected by manufacturers, carriers and platform providers. Product design also drives much of the cost and environmental footprint, making it the earliest leverage point for reducing both.

2A.1 BUSINESS MODELS AND CONTROL MECHANISMS

Most business model strategies today prioritize value from first sale, despite the growing number of revenue streams from repairs, extended warranties and subscriptions. Apple's services division, for example, generated US\$9 billion annually from AppleCare alone (Mickle, Koeze and Chen 2023). But rather than reducing reliance on frequent replacement, these revenue streams tend to complement or even reinforce device sales. Mainstream consumer phones designed and marketed around repairability and longevity remain uncommon in North America.

These characteristics are more common in rugged and enterprise devices—such as Samsung's Galaxy XCover line, featuring replaceable batteries and serviceable components (Samsung Electronics n.d.)—whose design is rewarded by enterprise and public-sector procurement requirements. Consumer-market examples also exist, such as Teracube 2e (replaceable battery; standard four-year warranty) in North America, but they are currently niche (Teracube n.d.). This is partly because they lack the distribution, carrier support and brand pull of dominant original equipment manufacturers (OEMs), and face region-specific obstacles such as service coverage.

Business models where providers retain ownership of the phone, such as leasing or Device-as-a-Service, could better align commercial incentives with durability and repair by enabling value to be recovered across multiple use cycles rather than through a single sale. They can also increase the share of devices that are returned and consistently directed into reuse and recovery pathways, provided trust and data concerns are addressed (Section 2b). This is already visible in the growth of professional refurbishment and resale markets, including Back Market (17 countries including the United States), Mobile Klinik (Canada) and Reuse (Mexico, Chile, Peru). Major manufacturers and telecoms carriers have also expanded trade-in and buy-back programs that collect millions of devices for formal testing and refurbishment, reflecting growing consumer demand for affordable, high-quality used phones and the value embedded in returned devices.



2A.II HARDWARE, SOFTWARE, AND REPAIR

Value retention also depends on the hardware–software interface.

On the hardware side, mobile phones today are engineered for thinness and energy efficiency as well as high manufacturing yield.² Batteries and displays are commonly bonded with adhesives, which means accessing them requires heat, solvents or force.³ At the board level, key components such as the system-on-chip and power management units are densely integrated to improve performance, creating a strict interdependence between parts. Accessing or replacing one often risks damaging others, which raises fault rates (Speight 2025) and makes board-level repair costly without specialized equipment and documentation. Information such as schematics, component histories and advanced diagnostics is often inaccessible to refurbishers, hindering their ability to perform assessments and complex repairs.

On the software side, manufacturer control over operating systems and firmware updates also affects how long a mobile phone stays in use. When a phone loses update support or its software compatibility degrades, it becomes harder to safely reuse; even a more durably designed phone will need replacing in such an instance. This form of obsolescence is becoming less common, as seen in recent flagship models from Google (Pixel 10 series) and Samsung (Galaxy S26 series) that now commit to periods of up to seven years, versus older models that typically received two to three. Other software-related barriers to repair and refurbishment include component authentication and parts pairing. For example, cameras, biometric sensors and batteries tend to be digitally linked to the original device. Replacing one of them with a component not recognized or authorized by the phone's software can lead to malfunction. These kinds of software controls increase repair costs, exclude independent refurbishers and remanufacturers and undermine trust in the reliability of repaired phones.

BRIGHT SPOT 1

RIGHT-TO-REPAIR AND ECODESIGN RULES ARE BEGINNING TO TRANSFORM MOBILE MARKETS

The right-to-repair movement is expanding across North America as civil society responds to rising repair costs and increasing restrictions on independent repair. Community repair initiatives such as Repair Cafés continue to grow, with Repair Café International (n.d.) reporting 4,000+ groups globally, including hundreds in the United States and a growing number in Canada.

Alongside these initiatives, right-to-repair legislation is progressing. In the United States, multiple states have enacted or advanced measures expanding access to parts, tools and repair information (e.g., California, Colorado, Connecticut, Minnesota, New York, Oregon and Texas), while some have restricted parts pairing (e.g., Colorado and Oregon). In Canada, federal copyright reforms in 2024 clarified that technological protection measures could be bypassed for lawful repair. Québec's Bill 29 introduced consumer protection provisions relevant to planned obsolescence. Manitoba has been exploring similar legislation as of 2026. Mexico already has extensive informal repair and resale networks that keep devices in circulation. The General Act on Circular Economy (*Ley General de Economía Circular*—LGEC), enacted in 2026, establishes a legal basis that could strengthen the repair ecosystem through access to information, parts, tools and repair options.

Durable and repairable design requirements are also making headway outside North America. The European Union (EU) recently introduced broader ecodesign requirements for mobile phones, tablets and other products through the Ecodesign for Sustainable Products Regulation (ESPR) and related measures. These rules affect durability, reparability, battery performance, software support and access to spare parts and repair information for products on the EU market, including imports from North America. The EU Battery Regulation requiring greater battery replaceability from 2027 is also expected to reduce repair barriers. These measures are making durability and reparability expected attributes in global electronics markets.



BRIGHT SPOT 2

INDUSTRY-LED CERTIFICATION DRIVES CIRCULAR PROCUREMENT

EPEAT, now operated by the Global Electronics Council (n.d.), is a globally recognized ecolabel used to support the procurement of more sustainable electronic products, including mobile phones. Manufacturers can register products in EPEAT by declaring compliance with multiple sustainability criteria (instead of a single circularity score) including repairability, materials, energy use and end-of-life management.

In the United States, EPEAT is embedded in federal purchasing requirements for many categories of electronics. Canada and Mexico also encourage ecolabels and sometimes reference EPEAT in federal procurement. By linking certification to institutional purchasing, EPEAT creates incentives for manufacturers to align product design with sustainability and circularity criteria.

In 2025, an updated “EPEAT 2.0” framework expanded criteria relating to circularity, climate impacts, chemicals and supply chain sustainability issues, including per- and polyfluoroalkyl substances, living wages and water stewardship in manufacturing. Updated circularity criteria strengthen repairability requirements and expand plastics criteria to include disclosure and minimum thresholds for post-consumer reused, recycled and biobased plastics. EPEAT 2.0 also introduces a voluntary criterion encouraging disclosure and increased use of recycled critical minerals in electronic products.

Where repair access is legally mandatory, OEMs may only minimally comply. They can still prevent repair by restricting parts supply, providing incomplete documentation, limiting access to diagnostic tools or retaining software locks. For independent operators, these actions may not affect the technical feasibility of repair, but they do make it commercially impractical, and, in cases where anti-circumvention rules restrict bypassing software locks, unlawful. However, interview evidence suggests that while most OEMs initially resisted the expansion of repair regulations, many now offer authorized repair services and self-repair parts programs, though affordability and availability vary. Nevertheless, restrictions on board-level repair information, diagnostic tools and software continue to limit many independent repair and refurbishment shops.

Procurement and certifications can also affect the market expectations for hardware and software design. For example, voluntary eco-labels such as the Electronic Product Environmental Assessment Tool (EPEAT) (Bright Spot 2) and TCO Certified⁴ are referenced in green public procurement in Canada, the United States and internationally, incentivizing major buyers to increase performance on repairability, recyclability and material efficiency through practical tools and standards. Canada’s participation in the Circular and Fair ICT Pact (n.d.) reinforces this procurement pull, while Mexico’s LGEC provides a basis for procurement preferences linked to circularity criteria.

2A.III MATERIALS COMPOSITION

Mobile phones mostly comprise plastics (40%), glass and ceramics (25%) and metals (35%) (Bruno, Sotera and Fiore 2022). Much of their recoverable value comes from metals, including critical minerals, while plastics and other materials are generally lower in commodity value and harder to recover at high quality. The average mobile phone contains around 63 elements, many in trace quantities embedded in strictly miniaturized components (Figure 4). Using these concentrations, 1,000 kg of end-of-life mobile phones can contain up to 53 kg of copper, 141 g gold, 270 g silver, 10 g platinum, 18 g palladium and 3.3 kg rare earth elements (Gomez et al. 2023), together representing a contained commodity value of approximately US\$20,000 at current prices.⁵

Phones that are not designed for disassembly and repair, or lack modular components, are more likely to be recovered in ways that retain less of their embedded value. Their materials tend to be downgraded in recycling systems that more reliably recover high-volume materials such as aluminum and copper,⁶ or lost through disposal or export, increasing the likelihood of environmental harm. Mobile phones also contain plastics and resins with chemical additives that can improve performance, for instance by providing ultraviolet resistance or flame retardancy, but which complicate later separation and recovery (Section 2c.ii).

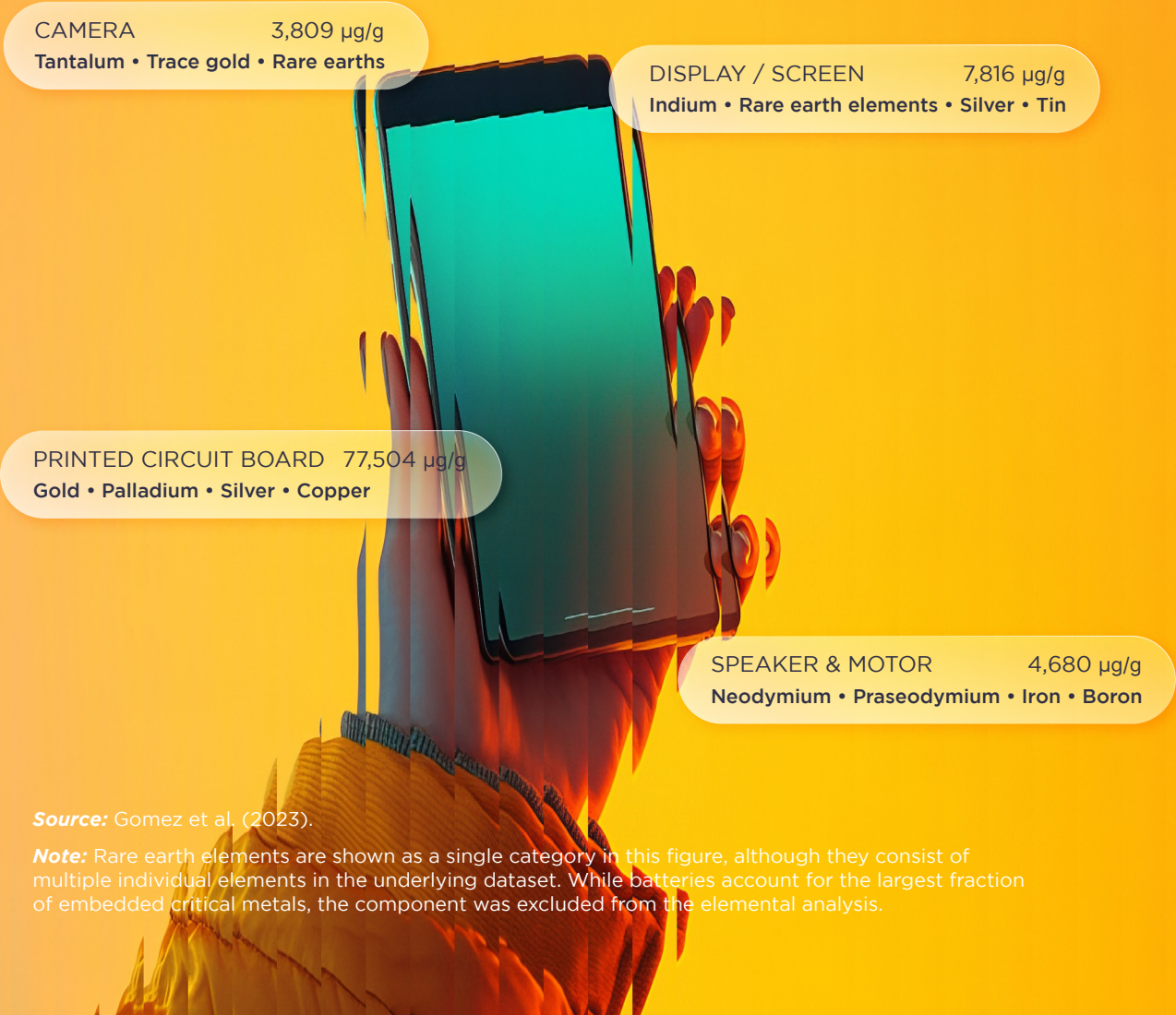
The materials that matter most economically and strategically—including gold and palladium in connectors and printed circuit boards, cobalt in lithium-ion batteries and rare earth elements in speakers and haptic motors—account for a large share of recoverable value. Many are sourced and refined through concentrated supply chains outside North America, exposing the region to disruption and supply shocks for industries that use these materials, such as renewable energy, advanced electronics and grid infrastructure. These risks may increase in the coming years as demand for several critical minerals is projected to rise and exceed supply (International Energy Agency 2025a).

Even if mining and refining expand, virgin material supply alone is unlikely to provide a secure and sustainable base of critical minerals at acceptable cost and risk. Mining, smelting and refining also have significant environmental and health impacts, including particulate pollution and releases of metals and associated contaminants into soils and waterways that can persist long after operations change or close. Health effects such as respiratory illness, cardiovascular issues and developmental risks have disproportionately affected socioeconomically disadvantaged frontline communities, including Indigenous peoples, living near extraction and processing sites.⁷

Keeping phones in use longer through value-retention processes can reduce reliance on virgin extraction, manufacturing and their associated environmental impacts. Since around 80% of a mobile phone's embodied emissions occur before it reaches the user (Lövehagen et al. 2023), both reuse and secondary production can significantly reduce greenhouse gas, water and energy impacts relative to conventional mining supply chains (Machala et al. 2023), while strengthening supply resilience.



FIGURE 4. AVERAGE CONCENTRATIONS OF 63 METALS AND METALLOIDS IN END-OF-LIFE MOBILE PHONES (MICROGRAMS OF ELEMENT PER GRAM OF PHONE MATERIAL)



Source: Gomez et al. (2023).

Note: Rare earth elements are shown as a single category in this figure, although they consist of multiple individual elements in the underlying dataset. While batteries account for the largest fraction of embedded critical metals, the component was excluded from the elemental analysis.

Cu	Copper	53,260 µg/g
Al	Aluminium	7,892 µg/g
Ba	Barium	4,856 µg/g
Fe	Iron	4,435 µg/g
Ni	Nickel	4,103 µg/g
Ca	Calcium	4,088 µg/g
REEs	Rare earth elements*	3,380 µg/g
Sn	Tin	2,963 µg/g
B	Boron	1,467 µg/g
Zn	Zinc	1,109 µg/g
Mg	Magnesium	799 µg/g
Ti	Titanium	763 µg/g
U	Uranium	749 µg/g
Pb	Lead	559 µg/g
Na	Sodium	416 µg/g
Ag	Silver	270 µg/g
K	Potassium	151 µg/g
Sr	Strontium	149 µg/g
Au	Gold	141 µg/g
Mn	Manganese	121 µg/g
W	Tungsten	109 µg/g
Zr	Zirconium	108 µg/g
Cr	Chromium	103 µg/g
Ga	Gallium	76 µg/g
As	Arsenic	52 µg/g
Te	Tellurium	48 µg/g
In	Indium	44 µg/g
Co	Cobalt	42 µg/g
Ge	Germanium	31 µg/g
Sb	Antimony	28 µg/g
Ta	Tantalum	24 µg/g
Mo	Molybdenum	21 µg/g
Pd	Palladium	18 µg/g
Nb	Niobium	16 µg/g
Ir	Iridium	15 µg/g
Pt	Platinum	10 µg/g
Bi	Bismuth	8 µg/g
Li	Lithium	7 µg/g
Y	Yttrium	7 µg/g
V	Vanadium	3 µg/g
Cd	Cadmium	2 µg/g
Hf	Hafnium	2 µg/g
Re	Rhenium	2 µg/g
Be	Beryllium	1 µg/g
Sc	Scandium	1 µg/g

2B.**MIDSTREAM:**
COLLECTION AND TRUST INFRASTRUCTURE DECIDE
WHETHER PHONES KEEP CIRCULATING

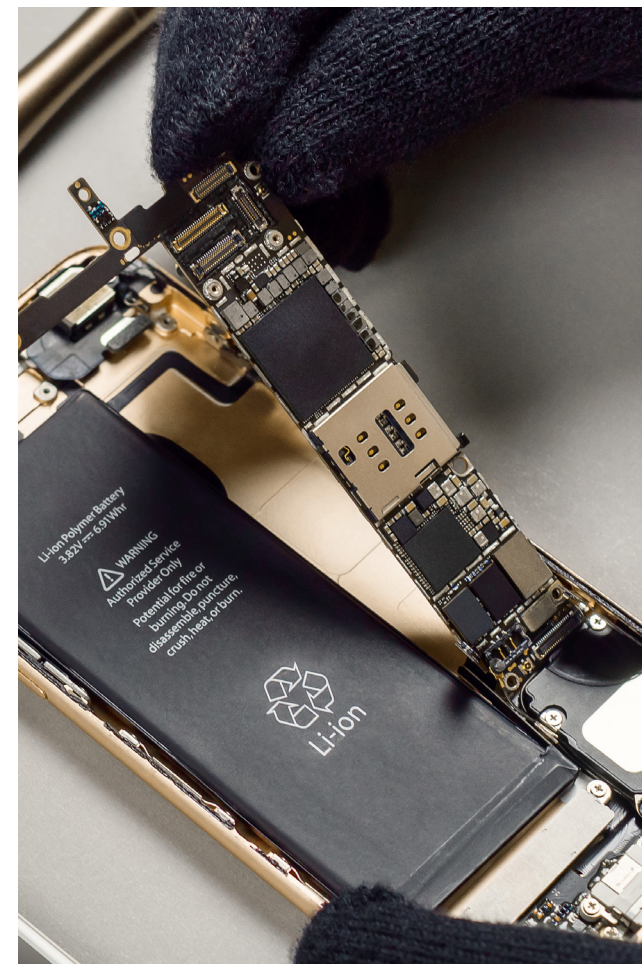
WHETHER MOBILE PHONES STAY IN USE PARTLY DEPENDS ON WHETHER USERS TRUST THE SYSTEMS COLLECTING THEM, PARTICULARLY IN THE HANDLING AND REMOVAL OF PERSONAL DATA

Once phones do leave users, they move through a mix of resale, repair, refurbishment, remanufacture and recovery pathways. Some of these pathways are controlled by manufacturers through “closed” routes that prioritize branded refurbishment and parts capture. Others are “open” routes that connect an ecosystem of collectors, refurbishers, remanufacturers and recyclers. The routing decisions affect whether phones remain viable for reuse, enter lower-value material recovery or leave regional supply chains altogether.

2B.1 COLLECTION AND MOVEMENT

After first use, phones may enter formal collection and take-back pathways while still suitable for reuse, or they may move into hibernation and, later, end-of-use handling. Storing or delaying the disposition of a device rather than returning phones in a timely manner, via formal or informal pathways, reduces the chance of reuse before recovery (Google LLC 2021).^{8,9}

Formal pathways include producer-funded collection networks, carrier trade-ins, retailer take-back programs and kiosks (Bright Spots 3 and 4). Informal pathways include peer-to-peer resale, small repair shops and unregulated collection. These pathways differ not only in scale but in the information accompanying the device: whether its condition has been graded, its data wiping verified and its chain of custody documented. Inconsistencies in those checks force downstream actors to price in risk and divert devices into lower-value handling routes, reducing the share that can move into verified reuse.





BRIGHT SPOT 3

TAKE-BACK SYSTEMS IN NORTH AMERICA SHOW DIFFERENT PATHWAYS FOR SCALING MOBILE PHONE COLLECTION

ecoATM shows how automated buy-back infrastructure can increase formal collection — Amid a fragmented policy landscape, ecoATM has built a network of over 7,000 automated kiosks across the United States and expanded into Canada (Recycling Today 2026). The kiosks use automated diagnostics and machine vision to assess device condition and generate immediate cash offers, allowing consumers to sell used phones in everyday retail settings within minutes. EcoATM (2020) reports having collected more than 50 million devices and paying out more than US\$1.56 billion to consumers since launching in 2009. Around 75% of collected devices are refurbished or resold by ecoATM, and the remainder are sent for material recycling.

Coppel-Reuse shows how existing retail infrastructure can support domestic resale and refurbishment — One of Mexico's largest electronics and appliances retailers, Coppel, partnered with the Chilean platform Reuse to offer customers digital credit for mobile phone purchases in exchange for used devices. Returned phones are collected through retail channels, then refurbished and resold domestically (Reuse México n.d.). By embedding trade-in at the point of sale and using existing retail and logistics infrastructure, the program captures phones that might otherwise have been stored or entered informal disposal, while increasing sales.

Carrier-led trade-in programs create predictable collection and refurbishment flows — Major mobile network operators in the United States operate large-scale trade-in programs that move devices through standardized data wiping, testing and grading before directing them into certified refurbishment, resale or material recovery channels. Trade-in credits, ranging from tens to several hundred dollars, drive consumer participation. Carrier control over device flows creates a predictable supply for refurbishers and processors. Large-scale take-back is supported by refurbishment and processing facilities concentrated in logistics hubs such as Dallas-Fort Worth, Texas, where OEMs and service providers including Samsung, Foxconn and Apkudo operate. Many processing partners operate under recognized standards such as R2 and e-Stewards certification, strengthening environmental control and downstream accountability.



BRIGHT SPOT 4

CANADA'S NATIONWIDE COLLECTION NETWORK COULD BECOME REUSE-FIRST INFRASTRUCTURE

Since 2007, the Electronic Products Recycling Association (EPRA) (n.d.) has coordinated the collection and recycling of electronics and batteries across nine Canadian provinces through a network of more than 3,150 public drop-off sites, giving most Canadians access to a collection point within a short travel distance. Through this extensive formal network for end-of-life electronics, EPRA's infrastructure has diverted over 1.3 million tonnes of e-waste from landfill and illegal export.

Provinces set the rules and targets under their own EPR programs, while producers finance collection and processing through environmental handling fees. EPRA then coordinates private-sector recyclers, processors, logistics providers and retail collection partners such as Best Buy (2022) and Staples (n.d.). The EPR programs it operates are currently assessed based on how much material they collect and recycle, which incentivizes recycling over other higher-value strategies such as reuse and refurbishment. However, EPRA also supports reuse and refurbishment through approved organizations. Its guidance in Quebec, for instance, states that functional electronics should be prioritized for reuse before material recovery (EPRA 2026).

Going forward, provinces could use EPRA's extensive collection network to incentivize reuse before recycling by changing their targets to higher-value strategies, instead of requiring entirely new infrastructure.

2B.II DIAGNOSTICS, GRADING AND TRUST FORMATION

Whether phones enter value-retention processes or are recycled or landfilled depends less on physical condition than on the consumer's trust that their data will be successfully wiped from their old device and that used devices are in good condition. Trust infrastructure—that is the standards, records and verification practices that allow midstream actors (e.g., IT asset disposition operators, refurbishers, processors) to validate device status, allocate liability and demonstrate controls such as secure data wiping—influences consumers' willingness to release phones and buyers' confidence in used devices (Bright Spot 5).

That trust infrastructure is uneven across North America. Grading systems are neither legally binding nor are they consistently usable across operators. US efforts, such as the Wireless Device Grading Scale of the Cellular Telecommunications Industry Association, provide a shared vocabulary for cosmetic and functional condition, but adoption is voluntary. The Cellular Telecommunications Industry Association's 2024 alignment with the Sustainable Electronics Recycling International's R2 marked a step toward interoperability in the US market.¹⁰ The lack of shared standards pushes the costs of item valuation and assessment onto firms and users, raising transaction costs and deterring investment in higher-value pathways.



Information and liability gaps compound the trust problem. Interview evidence suggests that OEMs and enterprises may choose destruction over third-party resale or refurbishment because they fear repairs will be misattributed to product failure, alongside accounting and tax considerations. A similar risk aversion shapes data-handling decisions. Where secure erasure tools are available, devices may still be destroyed or bulk-recycled if erasure cannot be demonstrated in an auditable way. At this stage, decisions are driven by defensibility more than feasibility.

Automated diagnostics, standardized testing and auditable process controls, especially for data wiping and grading, can reduce uncertainty and support reliable movement into reuse, repair and refurbishment. Apkudo—a platform for testing, grading and recirculating used electronics—reports processing over 16 million devices annually (Apkudo 2025), primarily through deployments with US carriers and logistics operators (Bright Spot 3).

Absent clearer standards and auditable records, midstream actors rationally default to destruction, recycling or export, rather than pathways that retain the highest value.

BRIGHT SPOT 5

REPAIRABILITY SCORES ARE MAKING DURABILITY VISIBLE TO CONSUMERS

France introduced a repairability index in 2021 (*Indice de réparabilité n.d.*), requiring retailers to display a repair score for electrical and electronic products (calculated by manufacturers) at the point of sale. The index evaluates documentation, disassembly-reassembly, spare parts availability and pricing, and other product-specific criteria.¹¹ An assessment by *Halte l'Obsolescence Programmée* (2022) found that three quarters of consumers considered the index useful when making purchase decisions, and a French government study found a positive association between higher repairability scores and sales of more repairable products (*Direction interministérielle de la transformation publique* 2023).

In 2025, France replaced the repairability index with a broader durability index incorporating both repairability and reliability (Ministère de la Transition écologique 2024). The shift reflects growing efforts to direct consumer demand toward products that remain functional for longer and are less likely to become prematurely obsolete.

The approach has influenced wider EU and international discourse. From June 2025, new EU energy labeling and ecodesign requirements for smartphones and tablets began requiring products placed on the EU market to display repairability information (European Commission n.d.). These requirements apply to imported and domestically manufactured products, including to North American products sold into the EU market. Other major policy developments affecting electronics circularity beyond North America are summarized in Appendix 1.

Interest in similar approaches is also increasing in North America. In Canada, organizations such as Équiterre (2024, 2026) have explored durability scoring as a consumer transparency tool; their research suggests durability information can influence consumer purchasing decisions. Several US states have proposed or explored repairability scoring approaches (Appendix 1). Though Mexico has not yet introduced comparable repairability scoring systems, the LGEC's emphasis on repairability and consumer information could provide a foundation for similar approaches in the future.

2C.**DOWNSTREAM**

END-OF-USE COLLECTION, PROCESSING AND REFINING DETERMINE WHETHER MATERIALS RETURN TO SUPPLY OR BECOME LOST

DOWNSTREAM STAGES ARE AFFECTED BY COLLECTION RATES, POLICY AND MARKET INCENTIVES THAT FAVOR END-OF-LIFE PATHWAYS OVER VALUE RETENTION, AND PROCESSING BOTTLENECKS THAT CONTINUE TO PUSH MATERIAL ABROAD

2C.I END-OF-USE COLLECTION GAPS LIMIT MATERIAL RECOVERY

Across North America, RTI estimates that only 10–30% of devices enter formal collection, while 14–23% are lost to landfill, incineration and export, depending on the country (RTI International 2025). The remainder either circulate informally or are unaccounted for. Collection relies on a mix of subnational (Section 3) and market-based programs, alongside periodic pilots and campaigns that have uneven regional coverage. Many programs also continue to measure performance through collection weight and recycling volumes, which can disadvantage reuse and refurbishment pathways.

Low capture is a primary mechanism of material leakage. When end-of-use phones fail to enter formal collection, downstream processors cannot secure consistent feedstock, and even advanced material recovery capacity is left undersupplied. The consequent losses push demand back upstream onto virgin extraction, reinforcing its costs and impacts.

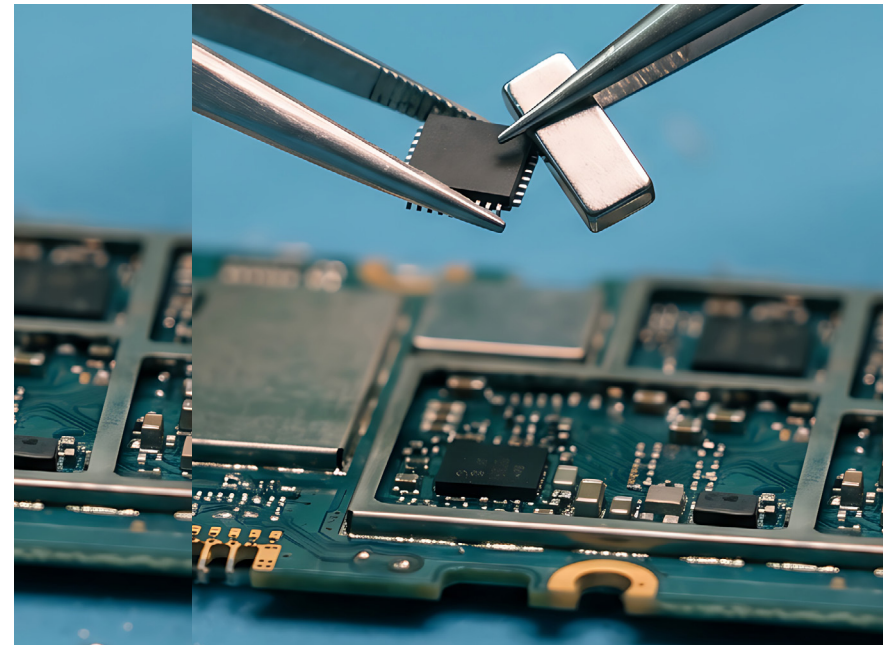


2.C.II STANDARDS, PROCESSING BOTTLENECKS AND EXPORT DEPENDENCE

Downstream handling is also affected by certification schemes such as Responsible Recycling (R2) and e-Stewards, which set requirements for worker safety, data security and environmentally responsible management. Though essential, these standards do not resolve the limited regional capacity for secondary processing and refining, which are capital-intensive and depend on a steady supply of sorted streams (e.g., printed circuit board fractions and batteries separated from phones), rather than mixed or contaminated loads.

Mobile phones may enter primary processing—which includes triage, dismantling, shredding and mechanical separation—but far fewer facilities provide the secondary processing needed to recover the metals from complex components like printed circuit boards.¹² North America's capacity to recover high-value materials from printed circuit boards at a large scale is low and currently concentrated in Quebec, Canada (Quebec, Ministère de la Culture et des Communications n.d.).

Facilities such as Glencore's Horne Smelter in Quebec process complex electronic scrap,¹³ including printed-circuit-board-bearing fractions. Newer investments such as Aurubis' facility in Richmond County, Georgia can also produce intermediate outputs, such as blister copper, that require further refining. Mexico's processing is more concentrated in collection and primary processing activities, with limited domestic routes for high-value metallurgical recovery. Across the region, specialized end-processing capacity is scarce, so many recovered phone fractions are exported for final smelting and refining (Aurubis AG 2025). Even where phones are collected and processed, recovered outputs might not meet the quality and volume requirements to re-enter manufacturing supply chains. As a result, an estimated 4–17% of recovered material reaches domestic commodity markets, while 83–96% is lost to disposal or export. Much of the value embedded in e-waste is therefore not realized through formal recovery, and secondary materials are often traded at a discount compared with virgin equivalents, weakening investment incentives for the processing capacity needed for more consistent secondary outputs.



AN ESTIMATED 4–17% OF RECOVERED MATERIAL REACHES DOMESTIC COMMODITY MARKETS, WHILE 83–96% IS LOST TO DISPOSAL OR EXPORT

Mobile phones also contain specialized additives, including brominated flame retardants, that can contaminate polymer recycling streams and reduce the value and safe usability of recycled outputs. When mismanaged, including through accidental fires or open burning, these materials can lead to toxic releases (Resource Recycling 2025). Downstream processors also inherit upstream design limitations that reduce the separability of parts and materials, leading to lower-value recovery. Under these conditions, export—often to Asia—and other low-value outcomes continue as the default (Associated Press 2025).

03

**MOBILE PHONES MOVE
THROUGH SHARED NORTH
AMERICAN MARKETS,**

**BUT ARE GOVERNED BY
THREE DISTINCT POLICY
ARCHITECTURES**

03

MOBILE PHONES MOVE THROUGH SHARED NORTH AMERICAN MARKETS, BUT ARE GOVERNED BY THREE DISTINCT POLICY ARCHITECTURES

TABLE 1.

CURRENT POLICY MECHANISMS IN NORTH AMERICA SHAPING CIRCULAR ECONOMY OUTCOMES FOR MOBILE PHONES

INTERNATIONAL POLICIES

POLICY MECHANISM	GENERAL DESCRIPTION	CANADA	MEXICO	UNITED STATES
Canada–Mexico–United States Agreement (which replaced North American Free Trade Agreement)	A regional trade framework enabling the movement of goods and secondary materials between Canada, Mexico and the United States.	Party	Party	Party
Basel Convention	The international treaty controlling transboundary movements of e-waste. It does not apply to mobile phones that are traded for repair, reuse or refurbishment.	Party	Party	Non-party
Stockholm Convention	Focuses on eliminating persistent organic pollutants, including certain flame retardants found in plastics used in mobile phones.	Party	Party	Non-party

NATIONAL AND SUBNATIONAL POLICIES

POLICY MECHANISM	GENERAL DESCRIPTION	CANADA	MEXICO	UNITED STATES	CIRCULAR ECONOMY IMPLICATIONS
Extended Producer Responsibility (EPR)	Programs require manufacturers to finance/manage end of life for electronics.	Provincial EPR is in place for mobile phones in all provinces, completed when Saskatchewan added cell phones to the list of covered products in 2025. Yukon became the first territory to have an EPR program in 2024. The programs are operated by industry-led producer responsibility organizations. Coverage, metrics and funding vary by province.	LGEC mandates a federal EPR system based on shared responsibility, to be implemented through the Ministry of Environment and Natural Resources (<i>Secretaría de Medio Ambiente y Recursos Naturales</i> —Semarnat) sector/product agreements (electronics scope pending).	State-level EPR in place in 24 states plus DC. Covered products, collection metrics and funding vary significantly by state. Some laws cover electronics generally, some cover embedded batteries including mobile phones, and some are specific to mobile phones.	Builds collection and material recovery infrastructure, but incentives remain tied to tonnage recycled rather than reuse, refurbishment or value retained.
Digital right to repair (R2R)	Laws mandate manufacturers to provide parts, tools and documentation to independent repair shops and consumers.	Federal amendments to the Copyright Act have cleared legal paths for repair by removing copyright infringement, which had prevented consumers from performing repairs. Quebec's Bill 29 protects consumers from planned obsolescence and promotes durability/repair.	No federal R2R mandate exists, but the LGEC 2026 encourages reparability as part of mandatory producer Circular Management Plans and Mexico City's Circular Economy Act Art. 28 which establishes a preference for repair over product substitution.	Seven states have active consumer electronics R2R laws that cover mobile phones. Recent bills now focus on banning parts pairing to ensure independent shops can use non-OEM components without software blocks.	Expands repair access but does not by itself ensure products are designed for durability, modularity or reparability.
Procurement preferences	Government policies that require or encourage purchasing products meeting criteria for circular design and value retention (e.g., EPEAT, refurbished, Product-as-a-Service).	2022–2026 Federal Sustainable Development Strategy, via Public Services and Procurement Canada, requires all mobile phone standing offers to include circularity criteria, effectively making reparability and end-of-life repurposing a mandatory part of bid evaluations.	LGEC establishes Circular Management Plans and recognition mechanisms that may support future circular procurement criteria, potentially for mobile phones, while some municipalities have adopted green purchasing policies.	Agencies are required to prioritize EPEAT-registered devices, and shift to “refurbished-first” for non-critical mobile devices and to leasing models. Similar state-level programs are in place for mobile phones in at least seven states, including reparability score preference in NY.	Creates demand-side signals for certified, refurbished or service-based devices, but depends on how strongly circularity criteria are specified and enforced.

Note: Please see Appendix 1 for the full comparison of international, national and subnational instruments affecting electronics circularity in North America.

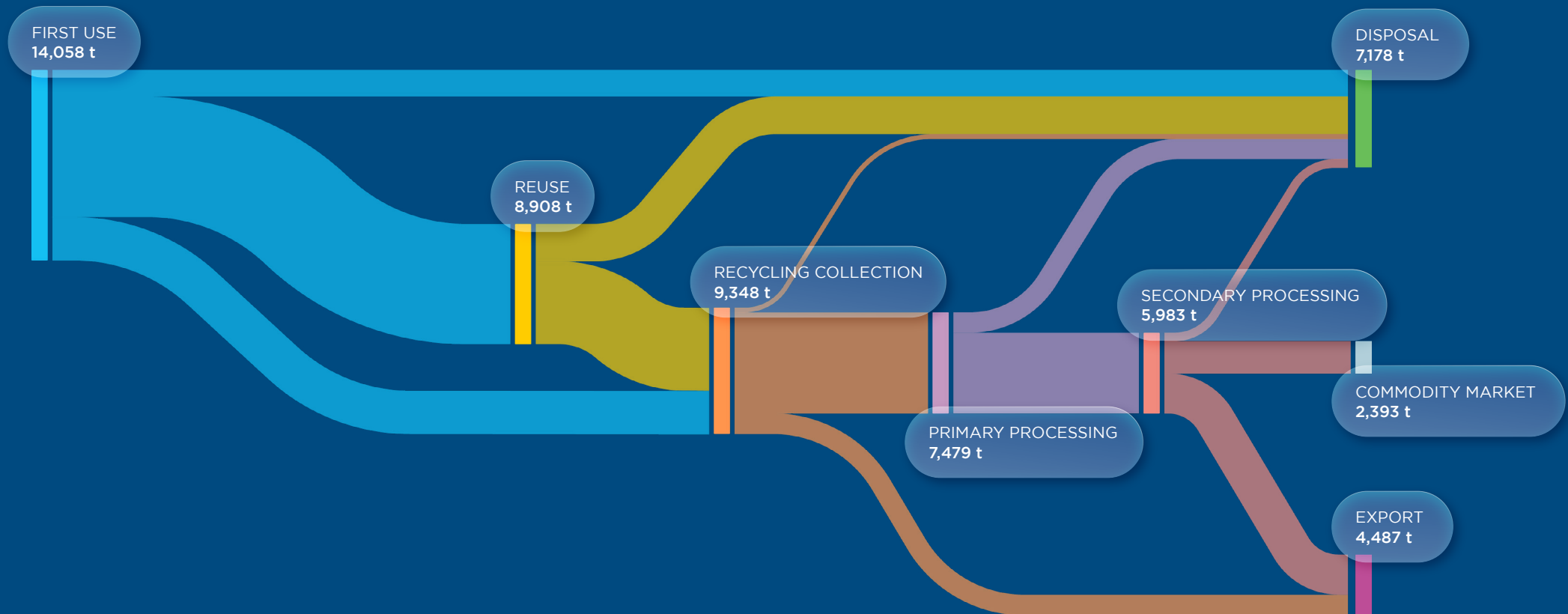
**3A.****CANADA**

Current patterns of mobile phone movement in Canada feature strong second use through pathways such as repair, refurbishment, remanufacture, passdown and resale (64% of phones enter these pathways). Once phones reach end of life, however, only a limited share (17%) of device material is likely to reach domestic commodity markets (Figure 5). By 2040, RTI modeling projects about 180 million phones will reach end of life in Canada under current conditions, representing a substantial opportunity to retain economic and material value by routing these devices into reuse and recovery pathways.

Canada's policy landscape is evolving across government levels. Though downstream collection is well established through provincial EPR programs—operated through producer responsibility organizations such as the Electronic Products Recycling Association (EPRA) (Bright Spot 4)—recent federal, provincial and territorial measures are starting to address repair rights, consumer protection, procurement and material reporting. Together these provide a basis for shifting incentives beyond tonnage-based collection and recycling toward longer use and more traceable value retention.

FIGURE 5.

THE PROBABILISTIC MOVEMENT OF MOBILE PHONES (IN TONNES) THROUGH CANADA GENERATED VIA RTI INTERNATIONAL'S CHARGE MODEL



Note: See Appendix 3 for definitions.

CANADA

CURRENT POLICIES WITH IMPLICATIONS FOR CIRCULAR ECONOMY OUTCOMES

- Copyright Act reforms (Bill C-244 and C-294):** Constitute two distinct federal levers that enhance the ability of Canadians to repair products. Bill C-244 establishes a Copyright Act exception that removes barriers to diagnosis, maintenance and repair activities, reducing legal risk around technological protection related to repair (Parliament of Canada 2024a). Bill C-294 addresses interoperability, supporting compatibility and functionality across device lifetimes (Parliament of Canada 2024b). These reforms strengthen the enabling conditions for independent/third-party repair and longevity.
- Quebec's right-to-repair legislation (Bill 29):** Amends the Consumer Protection Act to prohibit planned obsolescence and establish obligations around parts and repair information for specified goods, including mobile phones (National Assembly of Quebec 2023). Coverage is limited by the provision allowing a merchant or manufacturer to opt out of these obligations if they disclose, prior to sale, the services and repair information that will not be provided. Quebec's stronger reporting and traceability requirements can increase oversight and public trust, but may raise compliance and transaction costs for smaller operators.
- Federal green procurement commitments (Policy on Green Procurement; Greening Government Strategy):** Create demand-side signals for refurbished or remanufactured IT (Government of Canada 2022) and for devices meeting environmental performance standards (Government of Canada n.d.). These levers influence purchasing and disposition norms at scale, reinforcing expectations around certification, data security and downstream handling, rather than mandating design changes directly. Canada also participates (via Treasury Board of Canada Secretariat) in the Circular and Fair ICT Pact, an international partnership designed to use the collective purchasing power to drive the market for more sustainable electronics.
- Province- and territory-led electronics EPR programs, guided by the Canada-wide Action Plan for EPR:** In place for mobile phones in all provinces and the Yukon,¹⁴ these programs define covered products, reporting rules, collection obligations and performance metrics, and fund the collection and recycling system through producer responsibility organizations. However, weight-based compliance measures often focus exclusively on (low-value) recycling, incentivizing it over higher-impact circular strategies such as reuse and refurbishment. At the same time, it can be more expensive to recycle and reuse small devices that are collected, graded and redistributed outside major metropolitan areas owing to Canada's large landmass and dispersed population. Refurbishment and resale activity therefore cluster around urban hubs, making consistent access to these circular activities harder in northern and rural regions.¹⁵
- Federal mobile phone reduction initiatives (Shared Services Canada 2026):** Intended to reduce telecommunications costs, these initiatives aim to decrease the number of government-issued mobile devices across the federal public service (Shared Services Canada 2026). Although they do not directly address product design, reuse and recovery, reducing demand for new devices represents the highest level of the value-retention hierarchy and may reduce waste, pollution, reliance on virgin production and device turnover while extending the use of existing phones.
- Federal Plastics Registry and the Canada-wide Strategy on Zero Plastic Waste:** The registry requires electronics producers to report material flows from 2025, strengthening the federal evidence base for material accountability. This complements broader efforts under the strategy to improve material circularity and transparency. Improved reporting can support more transparent routing and enable stronger verification across reuse and processing stages.
- Critical Minerals Production Alliance (2025):** Part of the G7 Critical Minerals Action Plan, this Canadian-led partnership signals growing federal focus on materials security and standards-based markets for critical minerals. The first 25 shortlisted projects unlock C\$6.4 billion in critical minerals projects, several of which are located in Canada with the intent to broaden processing inputs with e-waste and tailings (Natural Resources Canada 2025). Though not phone-specific, this initiative could support longer-term efforts to strengthen domestic processing and critical mineral recovery capacity, including potential use of secondary sources.

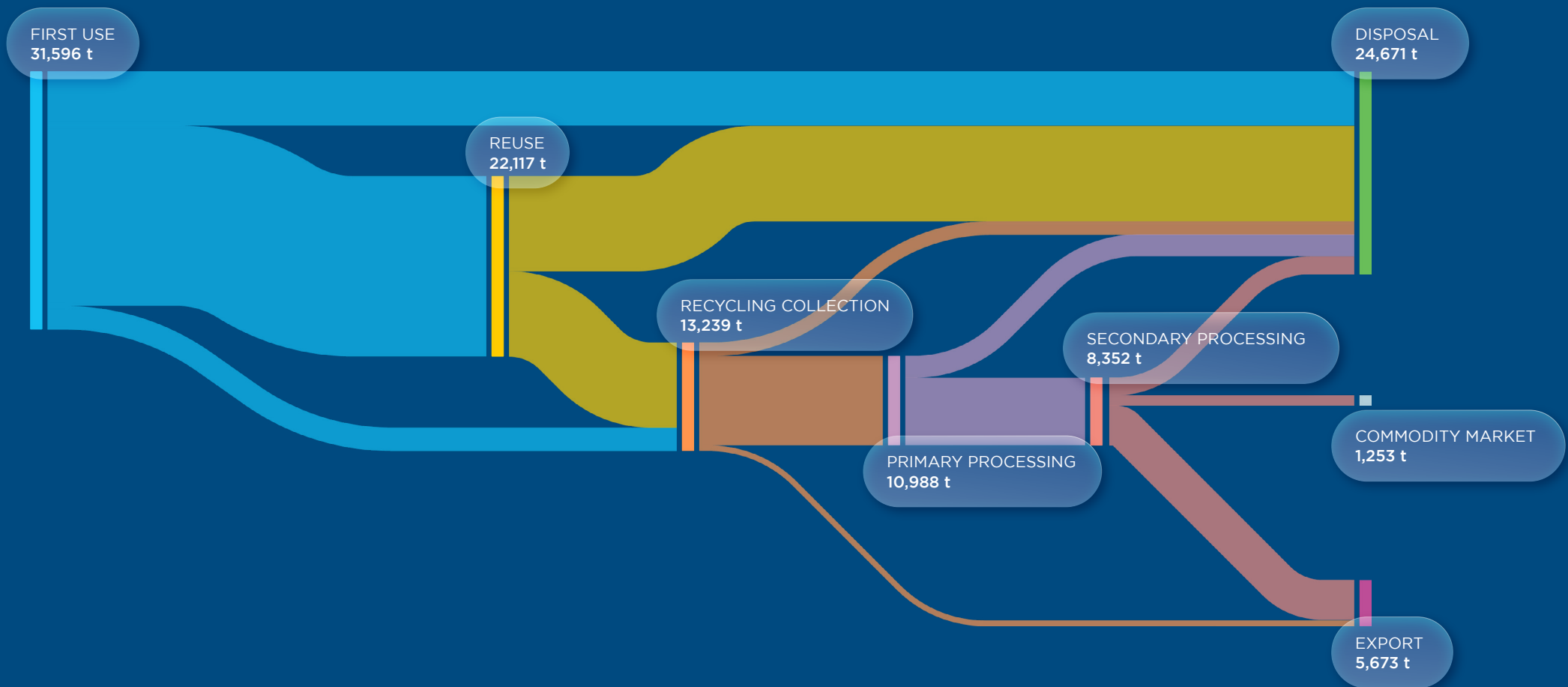
**3B.****MEXICO**

Mexico has the highest share of phones entering reuse (70%) in the region, but relatively lower formal collection (about 42% eventually entering recycling) and low domestic material recovery (about 4%), meaning most material is not retained in the country (Figure 6). Most repair, refurbishment and resale occur in the informal sector, which provides essential value-retention services, but limited traceability and oversight can make end-of-use routing and material recovery inconsistent. Under RTI's baseline conditions, 410 million phones are projected to reach end of life by 2040.

Mexico's circular economy policy landscape has shifted with the entry into force of the General Act on Circular Economy (*Ley General de Economía Circular—LGEC*) in January 2026. Federal direction is now clearer, and municipalities remain central to solid-waste management and an active informal sector still handles much of e-waste recovery. Progress will depend on whether federal measures, supported by enforcement and incentives, align with subnational institutions and on-the-ground material recovery practices.

FIGURE 6.

THE PROBABILISTIC MOVEMENT OF MOBILE PHONES (IN TONNES) THROUGH MEXICO GENERATED VIA RTI INTERNATIONAL'S CHARGE MODEL



Note: See Appendix 3 for definitions.

MEXICO

CURRENT POLICIES WITH IMPLICATIONS FOR CIRCULAR ECONOMY OUTCOMES

- LGEC (published Jan 2026):** Establishes a national circular economy framework and makes EPR a mandatory instrument to be operationalized through sector- or product-specific agreements. For electronics, its significance lies in the regulatory pathway it creates to introduce requirements for repairability, traceability and verified recovery as implementing instruments are developed. LGEC defines repairability to include access to information, parts, tools and repair options, and identifies the avoidance of product obsolescence as an objective for future implementation agreements. If these agreements prioritize repair, reuse and verified recapture alongside collection targets, they could strengthen accountability and traceability for end-of-use phones.
- General Law for the Prevention and Integral Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*):** Provides the overarching waste governance structure across federal, state and municipal authorities, distinguishing urban solid waste, “special management waste” and hazardous waste (International Energy Agency 2025b). The integration of circular economy principles through recent reforms may enable closer alignment between waste management and circular objectives over time—including the Basel framework—though institutional responsibilities remain distributed.
- NOM-161-SEMARNAT-2011 and related environmental standards:** Define the criteria for classifying waste electrical and electronic equipment and other special management waste, and require large generators to prepare and register waste-management plans. Similar products may fall under municipal (urban waste), state (special management waste) or federal (hazardous waste) oversight. This makes handling end-of-use electronics complex, but also creates multiple formal entry points into the waste system for devices.
- Subnational collection and coordination programs:** Provide periodic capture channels and coordination models for waste electrical and electronic equipment. Examples include Mexico City’s *Recicladrón* and Querétaro’s Circular Economy System (*Sistema Estatal de Economía Circular*) (Mexico Business News 2025). They demonstrate institutional experimentation but do not yet constitute a consistently accessible national collection network.
- Collection and infrastructure:** Formal collection infrastructure remains uneven. Official data indicate that recyclable material collection centers are present in 21 of 32 states, with 11 states reporting none (Semarnat 2020). As a result, many mobile phones flow through mixed municipal or informal pathways.
- Informal recovery ecosystem:** Most electronics recovery in Mexico occurs through informal dismantling and manual materials extraction. This activity enables material capture and income generation, but often operates outside standardized environmental controls, traceability systems and verified quality protocols, limiting the confidence for scaling secondary markets and compliant recycling. Industry-led initiatives such as the Mexican Association of Electronic Waste Recyclers (Asociación Mexicana de Recicladores de Residuos Electrónicos) and the LGEC’s Circular Economy Seal signal efforts to professionalize practices and improve auditability.

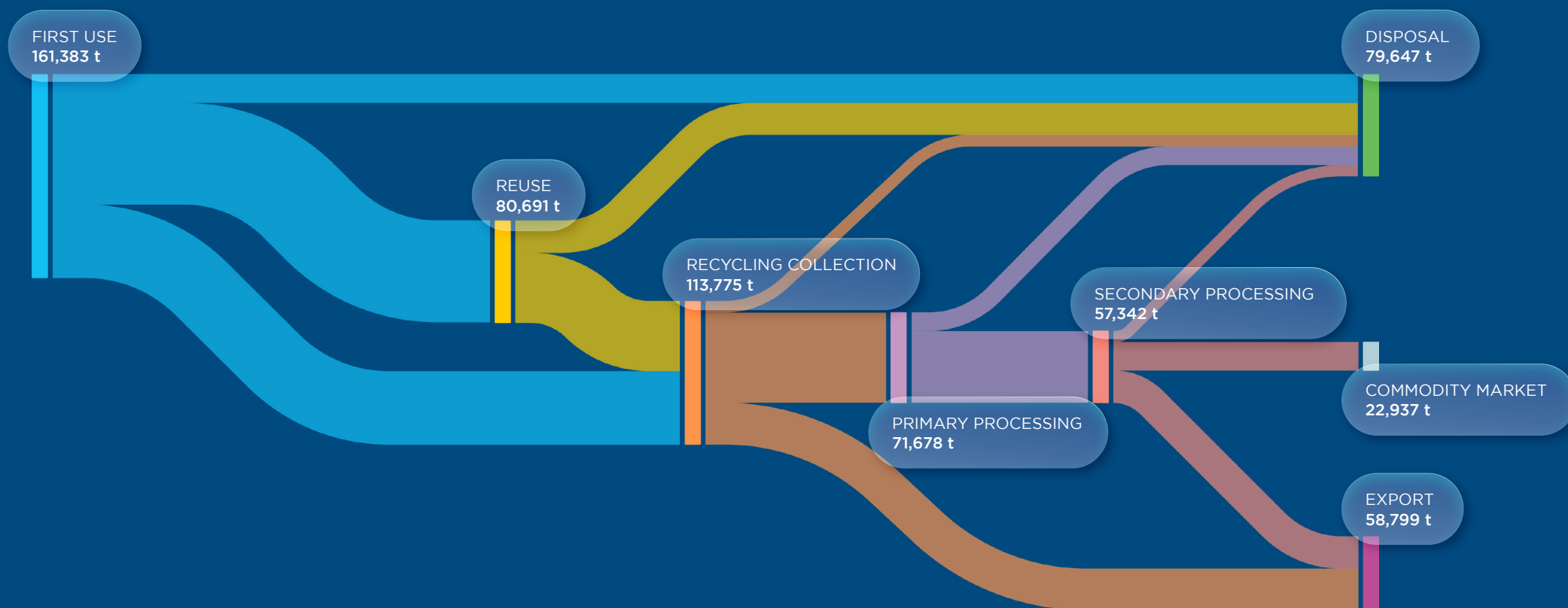
**3C.****UNITED STATES**

North America's largest mobile phone market, the United States is projected to see roughly 2 billion phones reach end of life by 2040, according to RTI's modeling. About half of mobile phones enter reuse pathways and 70% pass through formal collectors, but only around 14% of material is ultimately retained in the country (Figure 7). The country also holds the region's largest stock of hibernating smartphones—approximately 223 million (reBuy n.d.)—reflecting both the market scale and features of its dominant upgrade and financing model, which accelerates device turnover and leaves substantial material value idle and many devices outside consistent collection pathways.

In the absence of binding federal coordination, state laws set many of the operating rules for end-of-use handling, and private-sector channels serve as the country's de facto collection infrastructure. The result is substantial throughput without a consistent public-policy baseline for how devices should be routed, verified and accounted for across the life cycle.

FIGURE 7.

THE PROBABILISTIC MOVEMENT OF MOBILE PHONES (IN TONNES) THROUGH THE UNITED STATES, GENERATED VIA RTI INTERNATIONAL'S CHARGE MODEL



Note: See Appendix 3 for definitions.

UNITED STATES

CURRENT POLICIES WITH IMPLICATIONS
FOR CIRCULAR ECONOMY OUTCOMES

- **National Strategy for Electronics Stewardship (2011):** Sets goals for electronics design, collection and responsible end-of-use handling, reducing harms associated with exports of non-functional devices. The Strategy's practical role is "soft" infrastructure: a reference point that agencies, states and voluntary programs can use to align language and definitions.
- **State right-to-repair laws:** Where applicable, they require OEMs to provide parts, tools and documentation for covered device categories, setting the conditions for independent repair, parts access and post-sale servicing. Minnesota's statute broadly covers electronic devices, including mobile phones, whereas California, Colorado and New York exempt specific product types or components essential to phone repair. Where laws apply to mobile phones, product design choices such as limited modularity and software pairing can still impede outcomes, so access rights do not reliably translate into repair at scale without complementary eco-/circular design requirements that raise the baseline for disassembly, durability and long-term support. OEM obligations are also uneven in practice, leaving consumers and independent repairers with limited access to affordable parts, tools and documentation.
- **Federal procurement and disposition requirements (Federal Acquisition Regulation and EPEAT):** Federal purchasing rules steer agencies toward electronics that meet recognized environmental criteria (including EPEAT registration). Separate disposition requirements and agency practice channel retired devices through certified recyclers and IT asset disposition providers, which standardizes expectations around data wiping and chain of custody for large institutional fleets, even though consumer end-of-use pathways remain insufficient.
- **Critical minerals and rare-earth supply initiatives:** Led by the Department of Energy and complemented by the Department of Defense investments in domestic mine-to-magnet supply chains, these initiatives fund domestic processing and recovery capacity, including recovery from end-of-life magnets and other secondary sources. In February 2026, the administration announced a US\$12 billion critical minerals stockpile ("Project Vault"), reinforcing the policy priority placed on materials security (Center for Strategic and International Studies 2026).
- **Environmental Protection Agency Extended Battery Producer Responsibility Framework (2026):** A draft framework that sets out key elements for battery EPR, including recycling goals, cost structures for mandatory recycling, reporting requirements, product design, collection models and transportation of collected materials. It is intended to establish a federal-level framework, though its effect on mobile phones will depend on how the framework is taken up in practice, since the rules governing collection and reporting are currently set at the state level.
- **State electronics recycling/EPR laws across 24 states and the District of Columbia:** Establish state-level requirements that define covered electronics, eligible collection channels, performance metrics and reporting. Some laws cover electronics generally (with some exclusions for mobile phones), some cover embedded batteries including mobile phones, and some are specific to mobile phones. These laws translate to numerous and inconsistent end-of-use pathways for mobile phones and limit how many devices enter formal collection and how much material is recovered at high value.

04



RECOMMENDATIONS

04

RECOMMENDATIONS

Despite the differences between the three countries' mobile phone systems, the modeling and analysis reveal the same underlying pattern. Value is lost where product design, collection pathways, cross-border movement, processing capacity and end-market demand favor replacement over value retention. The largest gains in circularity occur when upstream measures are combined with sufficient domestic capacity for material recovery and predictable demand for recovered materials.

The following recommendations set out practical actions to move toward an ambitious scenario that builds on the modeled outcomes and increases the circularity of mobile phones in North America. Designed for decision makers across government and business, they can be adapted to national and subnational contexts while pursuing the same outcomes: retaining more value, strengthening supply chain resilience, reducing the reliance on virgin materials and mitigating environmental degradation.

1.

DESIGN MOBILE PHONES FOR REPEATED AND LONGER USE AND LATER SEPARATION

BARRIER

CURRENT DESIGN AND MARKET INCENTIVES ALLOW PRODUCTS TO ENTER THE MARKET THAT ARE DIFFICULT TO REUSE, REPAIR AND RECOVER AT HIGH VALUE

Governments:

- Set reparability and disassembly requirements in product regulation, drawing on precedents such as the EU's Ecodesign for Sustainable Products Regulation, so phones can stay in use longer and be disassembled without damage when reuse is no longer viable.
- Enable consumer and third-party access to diagnostic tools and repair information by requiring manufacturers to remove the technical and intellectual property restrictions that limit independent repair.
- Set minimum software support periods so phones remain functional and durable for longer.
- Set key goals through procurement rules (design certifications) and updated EPR (including fee modulation and other incentives for repair, refurbishment and higher-value recovery) so that longer-lasting designs are rewarded over products that promote early replacement.

Businesses:

- Design phones for long-term serviceability and reuse through durable and modular components, sustained battery health, long-term software support and non-destructive disassembly.
- Make durability and reparability information visible at the point of sale.
- Align upgrade and financing models with business strategies that generate value from repair, refurbishment and reuse rather than from a single device sale. In the absence of policy incentives, businesses can take these measures to retain value across use cycles and build customer loyalty through reliability.

In Canada, these actions could be included in future federal reforms to repair restrictions and in discussions around EPR reform; in Mexico, in provisions under LGEC and design of emerging EPR programs; in the United States, in emerging state-level right-to-repair legislation.

2.

BRING PHONES BACK INTO CIRCULATION THROUGH TRUSTED COLLECTION CHANNELS

BARRIER

INSUFFICIENT INCENTIVES FOR RETURNING PHONES AND LIMITED ACCESS TO COLLECTION POINTS, AS WELL AS UNVERIFIABLE DATA HANDLING, LEAD TO HIBERNATING PHONES, DELAYING REUSE AND MATERIAL RECOVERY

Governments:

- Require take-back or equivalent collection options to be offered at locations where people currently purchase, replace or service their phones.
- Set clear and verifiable data-wiping and -handling requirements, aligned with recognized standards, so phones can enter collection, resale and reuse without risk to consumers or downstream operators.
- Use incentives and program conditions to increase collection through approved channels at the point of upgrade or replacement and prevent delayed storage or premature disposal.

Businesses:

- Offer take-back when customers replace their phones, including through upgrades.
- Provide upfront information on data removal, device value and return options.
- Adopt consistent grading and testing practices so device condition is verifiable across collection and resale pathways.
- Connect trade-in and take-back channels with refurbishment and certified reuse systems, ensuring interoperability across retailers, carriers and refurbishment networks.

In Canada, this could build on provincial collection systems through EPRA; in Mexico, on (formal and informal) repair and resale networks; in the United States, on carrier-led trade-in and upgrade programs at the point of replacement.



3.

IMPROVE TRACEABILITY OF CROSS-BORDER AND SECONDARY-USE FLOWS

BARRIER

LACK OF INTEROPERABLE REQUIREMENTS FOR CLASSIFICATION, TESTING, GRADING AND DOCUMENTATION AND RISK DIVERTING FUNCTIONAL PHONES AWAY FROM HIGH-VALUE REUSE

Governments:

- Develop interoperable documentation requirements and support shared testing and grading practices for phones destined for reuse, repair, refurbishment and recovery pathways, consistent with applicable national rules and international controls.
- Require digital product passports or equivalent interoperable records that enable relevant information to accompany phones through successive use, repair, refurbishment and recovery stages, including functionality and repairability status, material and component composition, data-wiping verification and chain of custody.
- Consider opportunities to streamline digital documentation and compliance processes for legitimate cross-border movements of used phones, components and materials destined for reuse or recovery while maintaining protections for human health and the environment.

Businesses:

- Adopt shared grading standards, chain-of-custody documentation, condition and end-of-use routing data so phones can move across resale, repair and material recovery pathways with verifiable information attached.
- Share product, condition and end-of-use routing data with downstream operators so phones can be effectively routed into reuse and refurbishment across formal and informal markets.
- Work with national governments to develop expedited pathways for shipments of verified functional devices based on standardized testing and certification to reduce delays associated with waste classifications.

In Canada, this could build on Basel-aligned controls and existing reporting systems; in Mexico, on extending traceability across repair and resale markets; in the United States, on existing trade arrangements and documentation practices for used electronics.





4.

BARRIER

EXPAND DOMESTIC PROCESSING CAPACITY TO RETAIN VALUE WITHIN THE REGION

LIMITED PRIMARY AND SECONDARY PROCESSING CAPACITY FOR END-OF-LIFE MOBILE PHONES LEADS TO EARLY EXPORT OF RECOVERABLE MATERIALS AND LOSS OF THEIR ASSOCIATED VALUE FROM THE REGION

Governments:

- Use public investment instruments to expand dismantling, sorting and other primary processing activities in hubs for end-of-life phones.
- Tie funding and permitting to separation outcomes that preserve reusable parts and recover components such as printed circuit boards and batteries to a standard suitable for domestic reuse or secondary processing.
- Ensure dismantling and storage activities operate under environmental safeguards, including fire prevention, pollution reduction and safe handling of hazardous materials.

Businesses:

- Invest in dismantling, sorting and separation capacity aligned with product design, available feedstock and downstream processing and refining capacity.
- Establish coordinated downstream pathways for recovered parts and materials, including agreements with refurbishers, processors and downstream buyers so that recovered outputs are used rather than exported or stockpiled.

In Canada, this could focus on expanding processing capacity for higher-value recovery of end-of-life phones; in Mexico, on implementing Circular Management Plans under LGEC to channel devices into domestic processing; in the United States, on aligning processing capacity with existing industrial demand for recovered materials.

5. CREATE STABLE DEMAND FOR RECOVERED MATERIALS TO SUPPORT INVESTMENT

BARRIER

INVESTMENT IN RECOVERY SYSTEMS IS LIMITED OWING TO THE LACK OF CERTAINTY AND PREDICTABILITY IN DEMAND FOR RECOVERED MATERIALS

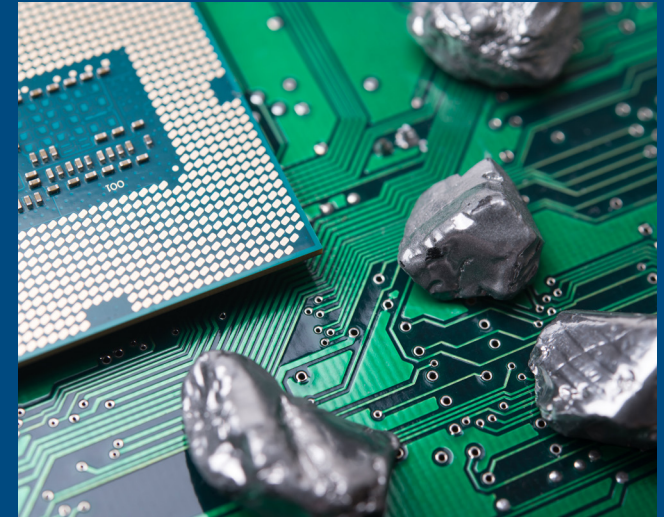
Governments:

- Use public procurement—particularly for government IT fleets and publicly supported manufacturing—to stimulate demand for recovered materials from mobile phones, particularly for critical minerals used in electronics and battery supply chains.
- Direct public funding and manufacturing support toward recovered materials where they meet cost and performance thresholds, so investment reduces reliance on virgin materials.
- Set targeted requirements or incentives for the use of recovered materials at the point of product design, manufacturing and procurement where feasible, particularly for critical minerals, while ensuring that reuse and repair remain preferable where products and parts can stay in circulation.

Businesses:

- Make long-term purchasing commitments that specify volumes and quality, providing processors and refiners with predictable demand and greater certainty in order to invest in recovery capacity.
- Define and publish technical specifications identifying where recovered metals and components can be incorporated into products, including clear grading criteria that allow processors to invest in appropriate sorting and refining technologies.
- Work with processors and suppliers to align material quality and volumes with downstream manufacturing needs, including through public-private partnerships that improve alignment between supply and demand.
- Where possible source from suppliers that meet recognized standards for responsible electronics recovery and recycling (e.g. R2 and e-Stewards).

In Canada, this could connect to federal, provincial and territorial procurement; in Mexico, to Circular Management Plans affecting material flows; in the United States, to critical minerals and advanced manufacturing policies affecting material demand.



To some extent, North America already operates as a single economy for electronics production and trade. Mobile phones are assembled across borders and their parts and components move through shared supply chains. What remains underdeveloped is the reverse flow—how phones, parts and materials are brought back into domestic supply after use. Under current conditions, too many devices hibernate, are exported without returning value to domestic supply chains, or fail to reach processors with the scale and quality needed for high-value material recovery. Regional cooperation, through government and business action, could provide the feedstock certainty and scale needed for investment and reduce reliance on export-dependent processing. With consistent collection, processing and end-market demand, underutilized e-waste can become a dependable source for refurbishment and secondary materials for manufacturing.

Still, the biggest gains for the economy and environment can only be achieved by keeping phones and components in use longer through more durable design, repair, reuse and refurbishment before material recovery becomes necessary. Under an ambitious scenario of targeted actions, including those outlined in the recommendations, North America can return an estimated US\$2.2 billion in recoverable critical minerals to regional supply by 2040 and reduce the environmental and community impacts of a loss-heavy system.

05

APPENDIX

APPENDIX 1.

TABLE OF POLICIES RELATING TO MOBILE PHONE CIRCULARITY IN NORTH AMERICA

INTERNATIONAL POLICIES IN NORTH AMERICA

POLICY MECHANISM	GENERAL DESCRIPTION	CANADA	MEXICO	UNITED STATES
Canada–Mexico–United States Agreement (which replaced North American Free Trade Agreement)	A regional trade framework that enables the movement of goods and secondary materials between Canada, Mexico and the United States.	Party	Party	Party
Basel Convention	The international treaty controlling transboundary movements of e-waste. It does not apply to mobile phones that are traded for repair, reuse or refurbishment.	Party	Party	Non-party
Stockholm Convention	Focuses on eliminating persistent organic pollutants, including certain flame retardants found in plastics used in mobile phones.	Party	Party	Non-party

NATIONAL AND SUBNATIONAL POLICIES IN NORTH AMERICA

POLICY MECHANISM	GENERAL DESCRIPTION	CANADA	MEXICO	UNITED STATES
Foundational Policy & Legal Basis	Federal law that provides the legal basis for substances or waste-related controls.	Canadian Environmental Protection Act provides the federal basis for controlling toxic substances found in mobile phones and transboundary movements of hazardous waste. The Canada-wide Action Plan for EPR (CAP-EPR) coordinates provincial stewardship standards.	LGEC, adopted in 2026, establishes a national mandatory framework for circular economy policy and product life cycles, creating a pathway for sector- and product-specific implementation agreements that could later apply to electronics, including mobile phones.	Resource Conservation and Recovery Act serves as the primary federal authority for hazardous waste, providing the framework for states to build specific electronic waste and battery handling requirements.
Landfill Bans	Legal prohibition of the disposal of specific electronic devices in municipal solid waste landfills; increasingly being superseded or integrated into more comprehensive EPR frameworks that address the entire product life cycle.	Not explicit, but provincial waste regulations create a functional ban by making it illegal for waste haulers to accept electronics covered by mandatory EPR programs.	LGEC introduces a progressive national reconversion mandate requiring all landfills to phase out the acceptance of “valorizable” materials within a 5-year implementation window.	23 states and DC have enacted explicit legal prohibitions against disposing of covered electronics or lithium-ion batteries in municipal landfills. (CA, CO, CT, DC, HI, IL, IN, ME, MD, MI, MN, NC, NH, NJ, NY, OR, PA, RI, SC, VT, WA, WI, WV, WY+DC)
Extended Producer Responsibility (EPR)	Programs require manufacturers to finance/ manage e-waste end of life.	CAP-EPR adopted in 2009 provides a comprehensive framework for EPR programs. Provincial EPR is in place for mobile phones in all provinces, completed when Saskatchewan added cell phones to the list of covered products in 2025. Yukon became the first territory to have an EPR program in 2024. The programs are operated by industry-led producer responsibility organizations. Coverage, metrics and funding vary by province.	LGEC mandates a federal EPR system based on shared responsibility, to be implemented through Semarnat sector/product agreements (electronics scope pending). Requires producers to register and implement life-cycle Circular Management Plans alongside consumer and government participation. Mexico City’s <i>Recicladrón</i> and Querétaro Circular Economy System are leading municipal efforts, but similar programs could be implemented nationally.	State-level EPR in place in 24 states plus DC. Covered products, collection metrics and funding vary significantly by state. Some laws cover electronics generally (and only Texas’ law excludes mobile phones), some cover embedded batteries including mobile phones and some are specific to mobile phones. (CA, CO, CT, DC, HI, IL, IN, ME, MD, MI, MN, MO, NC, NJ, NV, NY, OK, OR, PA, RI, SC, UT, VT, WA, WI, WV+DC)
Digital Right to Repair (R2R)	Laws mandate manufacturers provide parts, tools and documentation to independent repair shops and consumers.	Federal amendments to the Copyright Act have cleared legal paths for repair by removing copyright infringement as an obstacle that prevented consumers from performing repairs. Quebec’s Bill 29 protects consumers from planned obsolescence and promotes durability/repair.	No federal R2R mandate exists; however, the 2026 LGEC encourages repairability as part of mandatory producer Circular Management Plans and Mexico City’s Circular Economy Act Art. 28 which establishes a preference for repair over product substitution.	Seven states have active consumer electronics R2R laws that cover mobile phones. Recent bills now focus on banning parts pairing to ensure independent shops can use non-OEM components without software blocks. (CA, CO, CT, MN, NY, OR, WA)
Procurement Preferences	Government policies that require or encourage purchasing products meeting circularity criteria (e.g., EPEAT, refurbished, Product-as-a-Service).	2022–2026 Federal Sustainable Development Strategy, via Public Services and Procurement Canada, requires all mobile phone standing offers to include circularity criteria, effectively making repairability and end-of-life repurposing a mandatory part of bid evaluations. Provincial governments also drive market demand (often EPEAT or equivalent). (BC, NS, ON, QC)	LGEC establishes Circular Management Plans and recognition mechanisms that may support future circular procurement criteria, potentially for mobile phones, while some municipalities have adopted green purchasing policies. Some municipal-level green purchasing policies are also in place.	Agencies are required to prioritize EPEAT-registered devices, and shift to “refurbished-first” for non-critical mobile devices and to leasing models. Similar state-level programs are in place for mobile phones in at least seven states, including repairability score preference in NY. (CA, CO, MA, MN, NY, OR, WA)

POLICIES ADOPTED IN EUROPE

REGION/POLICY	OFFICIAL ADOPTION	MECHANISM	NORTH AMERICAN APPLICABILITY (EXTRATERRITORIAL IMPACT)
EU Batteries Regulation 2023/1542 <i>Succeeded by the Ecodesign for Sustainable Products Regulation (ESPR)</i>	2023	Sets binding requirements on battery performance, durability, recycled content and supply chain due diligence, alongside the phased introduction of digital product passports carrying sustainability and circularity information.	Applies to batteries placed on the EU market, including those in imported devices, requiring North American producers to meet EU standards for performance, information and traceability when exporting.
EU Ecodesign 2023/1670 <i>Succeeded by the Ecodesign for Sustainable Products Regulation (ESPR)</i>	2023	Requires smartphones to meet standards like 800+ battery cycles and 5 years of OS updates starting in 2025 and is a direct precursor to the ESPR framework.	Establishes a global circular baseline and may drive manufacturers to adopt EU durability standards as the de facto production baseline for the North American market.
2024/1781 Chapter III Digital Product Passport (DPP) <i>Part of EU ESPR</i>	2024	Creates a digital product record containing standardized life-cycle data for product groups brought within the ESPR framework, with implementation beginning for batteries and expanding progressively through delegated acts. The DPP is not currently foreseen for consumer electricals and electronics. The European Commission has indicated that products currently covered by the European Product Registry for Energy Labelling database will not be a priority for the DPP.	Provides data infrastructure and is likely to influence North American supply chain tracking. However, until the specific information requirements for each product sector are defined in a Delegated Act, there will be no DPP for these products, and no new information will be made available.
EU Energy Labelling Regulation 2023/1669	2023	Harmonizes point-of-sale transparency by requiring standardized repairability and reliability scores across the EU starting in 2025, eventually streamlining national indices.	Provides a unified methodology for performance benchmarking, allowing North American key actors to track product value using a consistent, third-party verified metric.
EU Right to Repair Directive 2024/1799	2024	Prohibits software hurdles like parts pairing and mandates post-warranty repair access, starting in July 2026.	Provides a policy precedent for US state laws and Canadian federal policy addressing repair access and parts pairing.
French Repairability & Durability Indices <i>Part of France's Anti-waste law for a circular economy</i>	2020	Mandated a 1-10 repairability score for smartphones and from 2021 to improve repairability and address systemic obsolescence. Since 2025, smartphones have been covered by the EU's harmonized ecodesign and energy-labeling requirements.	Requires global brands selling smartphones in the EU to disclose repairability data, providing a market signal that potentially streamlines circular design documentation and product value chains in other markets (Bright Spot 3).

APPENDIX 2. CRITICAL AND HIGH-VALUE ADVANCED RESOURCES FROM GREEN E-WASTE METHODOLOGY

CHARGE is a life-cycle modeling framework designed to estimate when clean energy products reach end of life, where they flow after use and how much valuable material can ultimately be recovered. It was developed to address a practical planning gap: rapid growth in batteries and other clean energy technologies is creating a future wave of e-waste, but governments, investors and industry often lack a clear way to forecast timing, quantities and recovery potential.

At a high level, CHARGE follows products from entry into the market through first use, possible reuse and then end-of-life pathways such as recycling collection, processing, commodity recovery, export or disposal. Rather than assuming that all products fail at the same fixed age or follow a single linear pathway, the model treats product lifetimes and post-use decisions as uncertain and probabilistic. This allows the model to better reflect real-world variation in product durability, repurposing, collection efficiency, processing outcomes and the possibility that materials leave the domestic system for treatment or recovery elsewhere.

A core feature of CHARGE is that it uses an absorbing Markov chain to represent how products and materials move through the system over time. In this framework, each stage of the life cycle is represented as a state, and products transition between states according to defined probabilities. The “absorbing” feature is important because some destinations are terminal: once material reaches them, it does not re-enter the modeled domestic system. In CHARGE, these absorbing destinations include commodity recovery, disposal and export. This structure is well suited to clean energy waste systems because it captures both the stepwise progression of materials through the chain and the fact that some outcomes are permanent endpoints.

Within this structure, products move through states such as first use, reuse, recycling collector, primary processor and secondary processor before reaching one of the absorbing outcomes. Export is treated as an absorbing destination that can be reached from the recycling collector, primary processor and secondary processor stages. This is especially important in settings where some collection or early-stage processing happens domestically, but downstream refining, material recovery or final treatment occurs abroad. By representing export explicitly, CHARGE can distinguish between material that contributes to domestic circularity and material that exits the local system.

The model combines three main elements. First, it uses Weibull lifetime distributions to estimate when products leave active service, reflecting the declining probability that smartphones remain in use over time. Second, it uses the absorbing Markov chain framework to simulate how those products move across reuse, collection, processing, export, recovery and disposal states over time. Third, it applies material content and recovery assumptions so that product flows can be translated into estimates of recoverable lithium, cobalt, nickel, graphite, copper, aluminum and other materials.

The result is a forward-looking tool that produces time-based estimates of e-waste generation, reuse volumes, collection and processing flows, export volumes, disposal volumes and recoverable critical minerals. Because the framework is scenario-based, CHARGE can also test how outcomes change under different policy or market conditions. For example, it can show how stronger collection systems, greater reuse, expanded domestic processing, or lower dependence on export could reduce disposal and increase domestic material recovery and value capture.

In practice, CHARGE is meant to support strategic decision-making. For governments, it can inform circular economy planning, producer responsibility systems, domestic processing strategies and infrastructure needs. For donors and development partners, it can help identify where investment in collection, reuse, processing or trade-related systems may have the greatest payoff. For private-sector actors, it can support planning around reverse logistics, processing capacity, export dependence and future feedstock availability.

APPENDIX 3. DEFINITIONS

Disclaimer: These definitions are to support the interpretation of this research and do not represent endorsed definitions. The terms specific to this report's modeling are explained in Appendix 2 on methodology.

Bright spot: a specific activity (e.g., regulation, standard, commitment) that shows the most promising opportunity with the potential to have an impact at scale. It often builds on existing efforts and best practices, with scalability evidenced by implementation beyond pilot stage and creation of cascading effects.

Circular business model: a business model designed to create and capture value by keeping products and materials in use at their highest value. Examples of circular business models include rental, repair, refurbishment and remanufacture.

Circular design: a product design approach that integrates durability, maintenance, repairability, upgradeability, disassembly and recyclability from the outset, so that products, components and materials can stay in use at their highest value for as long as possible.

Collection: devices entering a formal pathway/channel, including take-back, drop-off and mail-back, for onward sorting and routing. (In CHARGE this is captured partially by the "Second Use" node for materials sorted for reuse, repair and refurbishment and the "Recycling Collector" node for materials bound for recycling).

Commodity market (domestic): the point at which recovered device material has been processed to a tradable output within the same country where the device reaches end of use and is therefore counted as retained supply rather than lost to disposal or export. CHARGE uses this as the end point for "recovered" material in its commodity capture rate metric (i.e., the percentage of device material that ends up in domestic commodity markets).

Consumer electronics: electronic devices sold directly to individuals for personal use, including mobile phones, laptops and tablets, often characterized by short product lifetimes and significant embedded material value.

Critical minerals: high-value materials deemed essential to key technologies and economic systems—including energy, digital technologies and mobility—and sensitive to supply disruption owing to rising demand, supply-chain concentration or geopolitical risk, creating a need for resilient and circular value chains. In mobile phones, examples include lithium and cobalt in batteries and rare earth elements such as neodymium in magnets.

Design for longevity: designing products so they remain functional and useful for as long as possible through durability, maintainability, repairability and adaptability to maximize lifetime value and minimize waste.

Design-for-disassembly: a design approach that enables products to be easily and systematically taken apart at end of life so that components and materials can be repaired, reused, remanufactured or recycled.

Downstream: the stage of the mobile phone life cycle where recycling capability, export availability or disposal conditions determine whether materials re-enter productive use or are lost from the system.

Durability: the ability of a product to withstand wear, pressure or damage and remain functional and repairable throughout an extended period of use, supporting longer product lifetimes.

E-waste: discarded electrical and electronic equipment and components at the end of their useful life, often containing hazardous materials that can harm human health and the environment if not properly managed.

End-of-use pathway: the route a product, component or material follows after its initial use phase—such as reuse, repair, refurbishment, remanufacture, recycling or disposal—determining how much of its embedded materials, energy and labor is retained rather than lost as waste.

Export: products such as electronic devices, parts, components, materials and processed fractions that have been produced or sold in one country and are transported to another country for sale, use, processing or disposal.

Extended Producer Responsibility (EPR): a policy approach that extends producers' responsibility to the post-consumer stage of a product's life cycle, requiring them to finance and/or manage the collection and treatment of products at the end of use.

Formal pathways: regulated and authorized systems for the collection, repair, refurbishment, recycling or disposal of consumer electronics, these pathways operate in compliance with fiscal, environmental, labor and safety standards and help to improve the traceability of material flows.

Hibernation: when an electronic device is stored away by its owner instead of being actively used, resold, repaired or recycled.

High-value materials: materials contained in mobile phones that retain significant economic value owing to their market price, concentration or recoverability, creating an incentive for recycling and material recovery at end of life (e.g., gold in circuit boards and connectors, copper in wiring, aluminum in casings).

Informal pathways/handling: collection, repair, refurbishment, dismantling, processing or disposal occurring outside regulated/authorized systems and without consistent environmental, safety, fiscal or traceability controls.

Informal sector: economic activities carried out by individuals or small enterprises that operate outside governmental regulation.

Interoperability: the degree to which two or more products, programs or systems can be used together, or the quality of being able to function effectively with one another.

Life extension strategies: strategies that extend the useful life of products by keeping them in use longer through durability, maintenance, repair, reuse and refurbishment.

Maintenance: actions taken to keep a mobile phone in working condition and prevent failure, such as cleaning, software updates and routine checks, without significantly changing its function or performance.

Midstream: the stage of the mobile phone life cycle where collection, grading, repair, refurbishment and logistics determine whether devices retain value or degrade.

Mobile phones: a broad category of handheld wireless communication devices that operate over cellular networks, with smartphones constituting a dominant subclass.

Modular design: a design approach in which electronic products are structured so key components—such as batteries, screens, cameras or processors—can be independently removed, replaced, upgraded or repaired without discarding the entire device, supporting longer product lifetimes and higher value retention.

North America: encompasses Canada, the United Mexican States and the United States of America.

Original equipment manufacturer: a company that produces parts or equipment that may be sold either directly to consumers under its own brand or to another company to be included in that company's finished products.

Parts pairing: a manufacturer practice that links specific spare parts to an individual device through software using unique serial numbers. If a paired part is replaced, the device may reject it or limit its functionality unless the manufacturer reauthorizes it digitally. This practice can restrict independent and self-repair by preventing replacement parts from functioning fully without manufacturer approval.

Perceived obsolescence: a condition in which a product is regarded as outdated or less desirable despite remaining functional, driven by the introduction and promotion of newer models.

Planned obsolescence: a deliberate practice in which products are designed with technical, functional or stylistic limitations that shorten their useful life and encourage early replacement.

Primary processing: the processing of collected devices, such as decontamination, dismantling, shredding and mechanical separation/sorting of parts and materials.

Producer responsibility organization: an entity that manages collection, recycling and compliance obligations on behalf of manufacturers to help them meet EPR requirements.

Product-as-a-Service: a business model in which a provider retains ownership of a product (such as an electronic device) and delivers access or performance to users, aligning incentives for longer use and end-of-use value capture. (Device-as-a-Service is a subset of Product-as-a-Service.)

Recapture: the re-entry of devices into formal pathways after hibernation, informal handling or other periods outside the formal system. This is distinct from collection and recovery.

Recovery: the outcome where device material is successfully extracted and retained from end-of-life devices. In CHARGE, the key performance indicator is the mass of material that re-enters domestic commodity markets (i.e., becomes secondary feedstock).

Recycling: the system of activities intended to recover materials from end-of-use phones. In this report, "recycling" is an umbrella term encompassing primary processing and secondary processing. It can still result in losses to disposal or export.

Refurbishment: the process of restoring a used mobile phone to good working condition by repairing or replacing faulty or worn components and addressing cosmetic defects, such as replacing a battery or screen and cleaning or refinishing the casing.

Remanufacture: the process of restoring a used mobile phone to at least its original performance specification through comprehensive disassembly, component replacement, testing and quality assurance to standards comparable to those of a newly manufactured product.

Repair: the process of fixing a specific fault in a mobile phone to restore it to working order, including replacing failed components or correcting defects, where product design and access to parts, tools and information allow it.

Replacement: the purchase of a new mobile phone to substitute for an existing one, whether because the existing phone fails, is perceived to have lost value or suitability, or is made uneconomic to keep in use (for example because of repair barriers, software support issues, or upgrade/trade-in incentives).

Reuse: the continued use of a product or component for its intended purpose, either by the same user or another user, with or without minor preparation (e.g., testing, cleaning, data wiping). This report treats resale, trade-in, buy-back, passdown repair and refurbishment as pathways that enable reuse.

Right to repair: a legal framework established that strengthens consumers' ability to have products repaired instead of replaced, by improving access to repair services, spare parts, information and fair repair conditions, with the aim of extending product lifetimes and reducing waste.

Routing: the process by which devices are directed into particular pathways after collection, resale, sorting or processing, based on device condition, available infrastructure, verification records and economic incentives.

Rugged and enterprise devices: electronic devices built to withstand demanding environments and intensive use in business or industrial settings. Rugged devices are engineered for increased durability (e.g., resistance to drops, dust, water or extreme temperatures), while enterprise devices are configured for organizational use with enhanced security, manageability and long-term support.

Secondary processing: the metallurgical processing phase (e.g., smelting and/or refining) that extracts metals from processed parts and components and produces marketable outputs.

Smartphones: a subclass of mobile phones characterized by advanced computing capability, internet connectivity, touchscreen interfaces and operating systems that support downloadable applications.

Systemic obsolescence: a process driven by wider system conditions—such as parts pairing, limited access controls and the withdrawal of software support—that inhibit repair, restrict functionality and shorten the window for reuse or refurbishment, even when hardware remains functional.

Take-back: a program through which manufacturers or retailers collect used electronic products from customers to enable reuse, refurbishment, remanufacture or recycling.

Trade-in/buy-back programs: programs through which companies offer customers financial credit, discounts or direct payment in exchange for returning used products, enabling reuse, refurbishment, resale or recycling.

Upstream: the stage of the mobile phone life cycle where product design, supply chain configuration and business model structure shape durability, reparability and recoverability.

Value: the economic, functional and material worth embodied in a device through the resources, energy and labor used to produce it, as well as the services it can continue to provide in use. In this report, “higher-value” outcomes are those that retain more of that value while reducing avoidable impacts—for example by keeping phones in use longer and, when reuse ends, recovering their materials—whereas “lower-value” outcomes are those where value is lost early through hibernation, disposal, informal handling or low-yield recovery.

Value-retention processes: circular strategies that keep products, parts and materials in productive use at the highest feasible value over time (e.g., reuse, repair, refurbishment, remanufacture and parts harvesting) before material recovery. Their feasibility and cost depend on product design and support conditions, including parts, tools, diagnostics and repair information, which determine how long devices can stay in use and whether they avoid premature end-of-use.

Virgin extraction/primary production: the extraction and processing of minerals from natural deposits, including mining, concentration, smelting and refining, to produce metals or materials for first use in manufacturing. (In this study, the term distinguishes material sourced from geological reserves from material recovered through reuse and recycling pathways).

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ABOUT THE ELLEN MACARTHUR FOUNDATION

The Ellen MacArthur Foundation is an international charity that develops and promotes the circular economy in order to tackle some of the biggest challenges of our time, such as climate change, biodiversity loss, waste, and pollution. We work with our network of private and public sector decision makers, as well as academia, to build capacity, explore collaborative opportunities, and design and develop circular economy initiatives and solutions. Increasingly based on renewable energy, a circular economy is driven by design to eliminate waste, circulate products and materials, and regenerate nature, to create resilience and prosperity for business, the environment, and society.

As part of our Critical Minerals Mission, we are working to build a circular economy for critical mineral value chains that power the energy and digital transitions, maximizing value while reducing reliance on virgin resource extraction over time. We will do this by supporting a greater mobilization of capital investment in circular critical mineral solutions and by strengthening policy and governance alignment to foster collaboration.

Further information: ellenmacarthurfoundation.org

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ENDNOTES

- 1 Mobile phone ownership is at near saturation in the [United States](#) and [Canada](#) (over 90% of the population) as well as in [Mexico](#) (80%).
- 2 “Manufacturing yield” refers to the percentage of products that are produced without defects and meet all quality standards the very first time through the production process.
- 3 From 2027, EU rules will require end users to be able to remove and replace portable batteries in many devices. For further information, see: <https://environment.ec.europa.eu/topics/waste-and-recycling/batteries_en>.
- 4 The TCO Certified certification was created by Tjänstemännens Centralorganisation (Swedish Confederation of Professional Employees).
- 5 Based on [London Bullion Market Association](#) precious metal prices (accessed June 2026).
- 6 Based on RTI modeling.
- 7 Examples of such communities include the Yellowknives Dene First Nation living near the [Giant Mine](#) in Yellowknife, Canada; the Quapaw Nation living near the [Tar Creek Superfund Site](#) in Oklahoma, United States; and communities along the Sonora and Bacanuchi rivers affected by the [2014 Beunavista del Cobre mine spill](#) in Sonora, Mexico.
- 8 Google’s study on electronics hibernation identified six significant obstacles to mobile phone recapture. These include data retrieval concerns, data removal concerns, expectations of compensation, emotional attachment or nostalgia, keeping devices as spares and low convenience at the point of handoff.
- 9 In the United States alone, it’s estimated that the average household has 20–25 electronic devices, meaning there could be 6.8 billion devices in homes that will be eventually heading downstream. See: <www.consumeraffairs.com/homeowners/average-number-of-smart-devices-in-a-home.html#devices-by-household>.
- 10 Other frameworks—such as [iFixit’s repairability score](#) and [France’s repairability index](#) (Bright Spot 5)—serve different policy and consumer-facing purposes and do not resolve midstream liability or resale risk.
- 11 Each of these five criteria is awarded up to 20 points, for a total of 100 possible points. The final score is the total points divided by 10, resulting in a score on a scale of 1–10.
- 12 Most North American facilities that handle metal-bearing electronic scrap undertake only sorting and pre-processing. Material is commonly sent to a small number of smelters and refiners for final pyrometallurgical recovery.
- 13 Glencore’s Horne Smelter in Quebec, linked to the Canadian Copper Refinery, is the only fully integrated smelting and refining complex currently handling a substantial share of North America’s legitimate precious metals recovery from printed circuit boards. Its continued operation depends on meeting environmental compliance requirements due in 2027.
- 14 While Yukon’s electronics program operates under a territorial regulatory and stewardship model, it aligns with the principles of the Canada-wide Action Plan for EPR (Canadian Council of Ministers of the Environment 2009) and includes mobile phones as designated products.
- 15 Some circular economy initiatives are reaching said regions, notably Indigenous communities, suggesting local capacity is scalable with targeted investment. For example, the [Electronic Recycling Association](#) has donated refurbished devices to support education and connectivity in Indigenous communities in Northern Alberta. The 2026–2028 [North American Partnership for Environmental Community Action](#) grant cycle, which focuses on community-based circular economy strategies, invites proposals that include local and Indigenous priorities, helping to build capacity for reuse and recovery closer to remote regions.



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