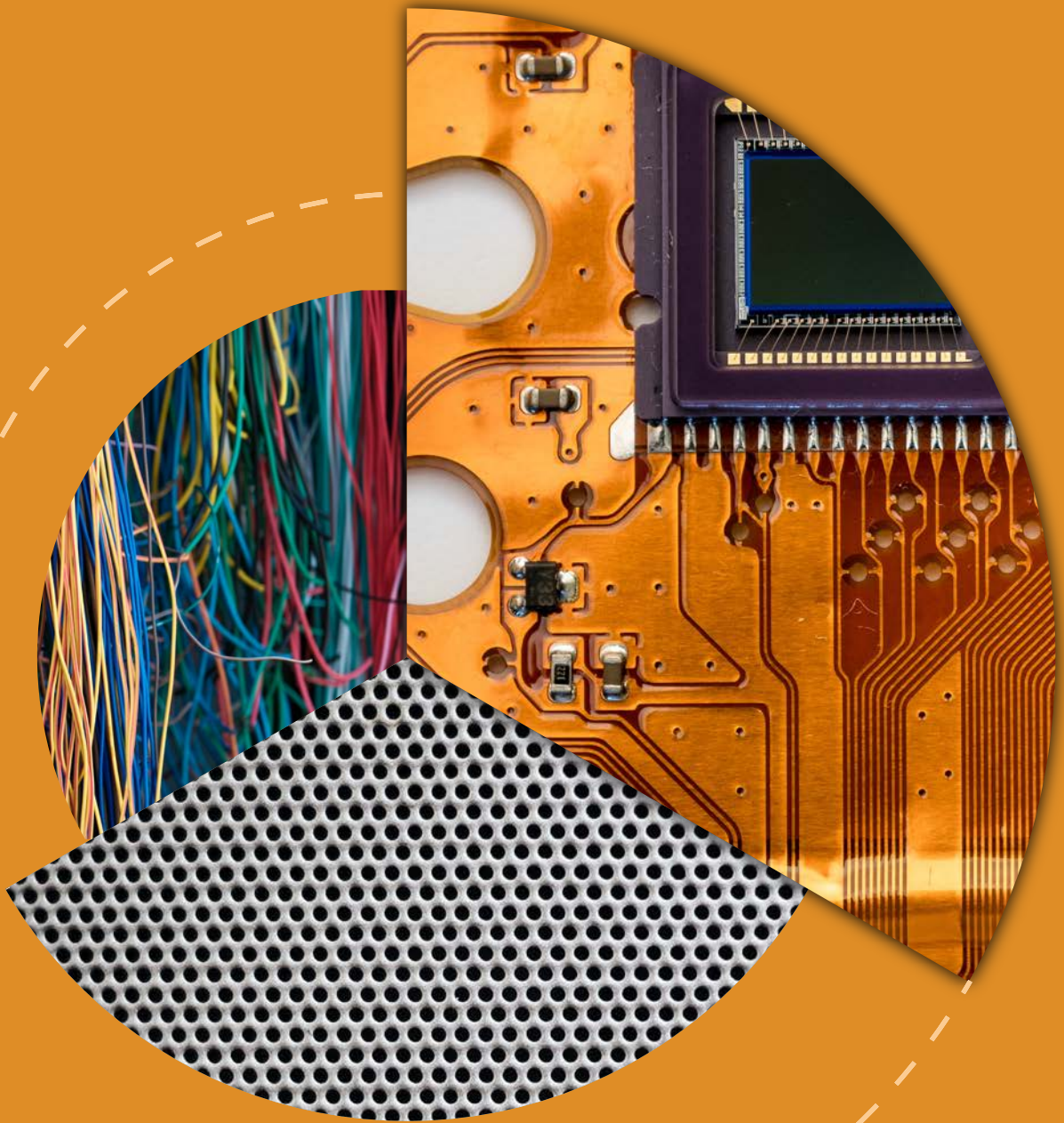


# Strengthening Sustainability *in the E-Waste Industry*



**IFC**

**International  
Finance Corporation**  
WORLD BANK GROUP

*Creating Markets, Creating Opportunities*

## About IFC

IFC—a member of the World Bank Group—is the largest global development institution focused on the private sector in emerging markets. We work in more than 100 countries, using our capital, expertise, and influence to create markets and opportunities in developing countries. In fiscal year 2020, we invested \$22 billion in private companies and financial institutions in developing countries, leveraging the power of the private sector to end extreme poverty and boost shared prosperity. For more information, visit [www.ifc.org](http://www.ifc.org).

## Authors

This report was written by IFC Manufacturing, Agribusiness & Services (MAS) staff members Juan Villar Mallagray, Investment Analyst; Samu Salo, Senior Industry Specialist; Li Tu, Global Sector Lead and Senior Investment Officer; and Sabine Schlorke, Global Manager. For additional information about this report, please contact Li Tu at [ltu@ifc.org](mailto:ltu@ifc.org).

## Acknowledgments

Special thanks to Gary Seidman and Kathy Chen for their involvement in producing this series. In addition, Irina Sarchenko, IFC communications analyst managed the design process, and Aliza Marcus, IFC senior communications officer for manufacturing, agribusiness, and service, assisted in the preparation and finalization.

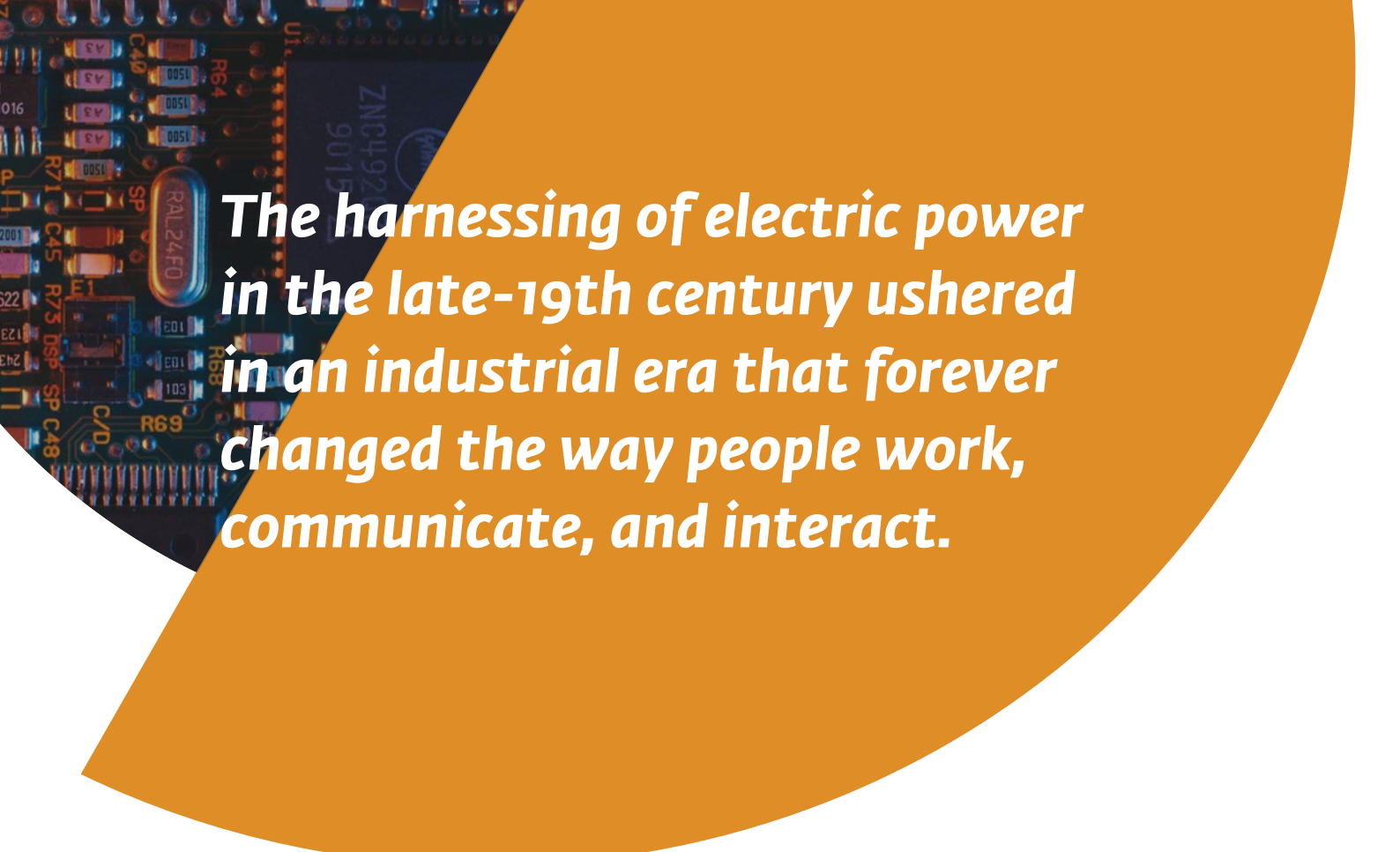
## Disclaimer

The findings, interpretations, views, and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the Executive Directors of IFC or of the World Bank or the governments they represent. While IFC believes that the information provided is accurate, the information is provided on a strictly “as-is” basis, without assurance or representation of any kind. IFC may not require all or any of the described practices in its own investments, and in its sole discretion may not agree to finance or assist companies or projects that adhere to those practices. Any such practices or proposed practices would be evaluated by IFC on a case-by-case basis with due regard for the particular circumstances of the project.

## Rights and Permissions

© International Finance Corporation 2020. All rights reserved. The material in this work is copyrighted. Copying and/or transmitting portions or all of this work without permission may be a violation of applicable law.

***Growing global concerns over climate change are putting an increasing focus on sustainability. This report is part of an occasional series on sustainability in industry which examines the opportunities and challenges facing various industrial sectors and the role that the International Finance Corporation can play to support their efforts and contribute to a greener planet.***



**The harnessing of electric power in the late-19th century ushered in an industrial era that forever changed the way people work, communicate, and interact.**

4

From refrigerators and cell phones to pacemakers and production lines, today's electronics not only contribute to the conveniences of everyday life, but also play an indispensable role in ensuring the health, wealth, and wellbeing of people around the world.

It takes a lot of copper, plastic, lithium, and cobalt—and a slew of other ingredients—to make the electronics that power today's digital economies. At least 70 elements from the periodic table can be found in a typical smartphone, and most never get recovered, reused, recycled, or resold.<sup>1</sup>

By 2030, there will be many times more electronics on the planet than today, consuming far more material resources and contributing far more waste.

The UN's *Global E-waste Monitor 2020*

estimates that in 10 years the world will be discarding 75 million tons of e-waste annually compared with 53.6 million tons in 2019—everything with a plug or battery that has outlived its usefulness.<sup>2</sup> E-waste is the fastest-growing waste stream in the world.<sup>3</sup>

Currently, there is no comprehensive, environmentally responsible plan for reducing and managing electronic waste globally. Most worn-out electronics rust in landfills or are incinerated. But as pollution anxiety rises and demand for electronics surges, the increasing scarcity of raw materials is encouraging electronics manufacturers to adopt circular economy approaches for conserving resources, controlling costs, reducing waste, and reusing

materials. The effort aims to shrink the industry's environmental footprint by transforming e-waste into a renewable resource.

Right now electronics are being manufactured faster than ever as the global economy transitions into a digital future. At the International Finance Corporation (IFC), industry specialists are working with companies across the electronics value chain to

invest in initiatives that transform existing concepts of products and industrial processes to reduce waste while meeting demand for "greener" electronics. It will take broad support from consumers, companies, governments, and multilateral organizations to manage the flow of e-waste and turn it into a regenerative resource that has value and can be fed back into the system.

## Sector Background

The electric age began in the early 1880s with the construction in London and New York of the first commercial power plants to distribute electricity. That ushered in a period of dynamic industrial invention and innovation that led to computerization and the digital age. Today, electronics manufacturing is one of the largest, fastest-growing, and most important industries on the planet, producing everything that runs on electric current and everything that contains a semiconductor.

The Business Research Company estimates that the global electronic-products industry (which includes semiconductors, audio and video equipment, and products that store, generate, or transmit information in electronic form) will grow to nearly \$1.3 trillion by 2025 from about \$950 billion in 2020.<sup>4</sup> Apple is the world's

largest electronics producer and the world's most valuable company, with revenues of \$378 billion and a market capitalization of \$2.5 trillion at the end of 2021.<sup>5</sup> The top 10 biggest electronics manufacturers include a mix of American, Japanese, South Korean, Chinese, and Taiwanese companies, including NVIDIA, Samsung, and Huawei.

The industry is fueled by explosive sales of personal electronics and rapid product churn. Because of the increasing importance of devices to modern life and the decline in prices, the average smartphone in the U.S., China, and EU is replaced within 18 to 24 months.

Another factor contributing to the industry's growth is the shift away from fossil fuels for energy to electricity. Industry forecasters

## BOX I: *Five Ways Consumers Can Minimize E-Waste*

**1** Take inventory of your products and reevaluate your electronic needs. Do you really need an extra gadget? Can you find a device with multiple functions?

**2** Protect and extend the life of your electronic products. Buy a case, keep your devices clean, and avoid overcharging their batteries.

**3** Seek out environmentally friendly electronics. Look for products labeled “Energy Star” or certified by the Electronic Product Environmental Assessment Tool (EPEAT).

**4** Repair rather than replace malfunctioning or broken devices when possible.

**5** Donate your used electronics to social programs, or give them away to extend their useful life.

estimate, for example, that more than 149 million electric vehicles will be on the roads by 2030,<sup>6</sup> compared to 11 million in 2021.<sup>7</sup> Matthew Wilks at Rystad Energy, a Norwegian energy research company, estimated that 2021 sales of electric batteries rose 26 percent to \$80 billion globally from a year earlier, and that by 2030, sales will double to \$160 billion.<sup>8</sup>

All of this growth carries an environmental cost. By 2040, the production and use of electronics will account for 14 percent of total emissions, according to the World Economic Forum’s New Circular Vision for Electronics.<sup>9</sup> But e-waste and the prevailing “make, take, and discard” business model that has dominated the electronics industry for decades is the most pressing concern. The UN says that the volume of e-waste piling up in landfills presents immediate

health and environmental hazards. E-waste contains toxic and hazardous substances such as mercury, which can impair brain function and which at high doses can be fatal to humans.<sup>10</sup> An estimated 50 tons of mercury—found in fluorescent tubes, flat screen monitors, and electronic devices—are contained in unregulated e-waste every year.<sup>11</sup>

Companies are starting to rethink product design to be less wasteful and more resource-conservative. At the same time, the e-waste management business is expanding quickly, with Allied Market Research projecting the market will nearly triple in size to \$144 billion by 2028 from 2020, led by companies that recover and resell materials for reuse.<sup>12</sup>

These trends, combined with new regulations and increasing consumer

demand for sustainable products, are beginning to encourage manufacturers to evolve their thinking about how their products are made, used, reused, and recycled or discarded. The task today is to think about how to tackle this rapidly expanding mountain of e-waste before it breaches dangerous thresholds. Circular economy proponents are focusing on strategies aimed at encouraging manufacturers to design electronics that never become waste, while developing

efficient processes for reclaiming, recycling, reselling, and reusing parts from old electronics to manufacture new products. If cars could be made to last 800,000 miles rather than 120,000, and phones 12 years instead of two, a lot of waste would never be generated and more durable parts, components, and materials could be recirculated into the product mix, reducing pressure to produce new products

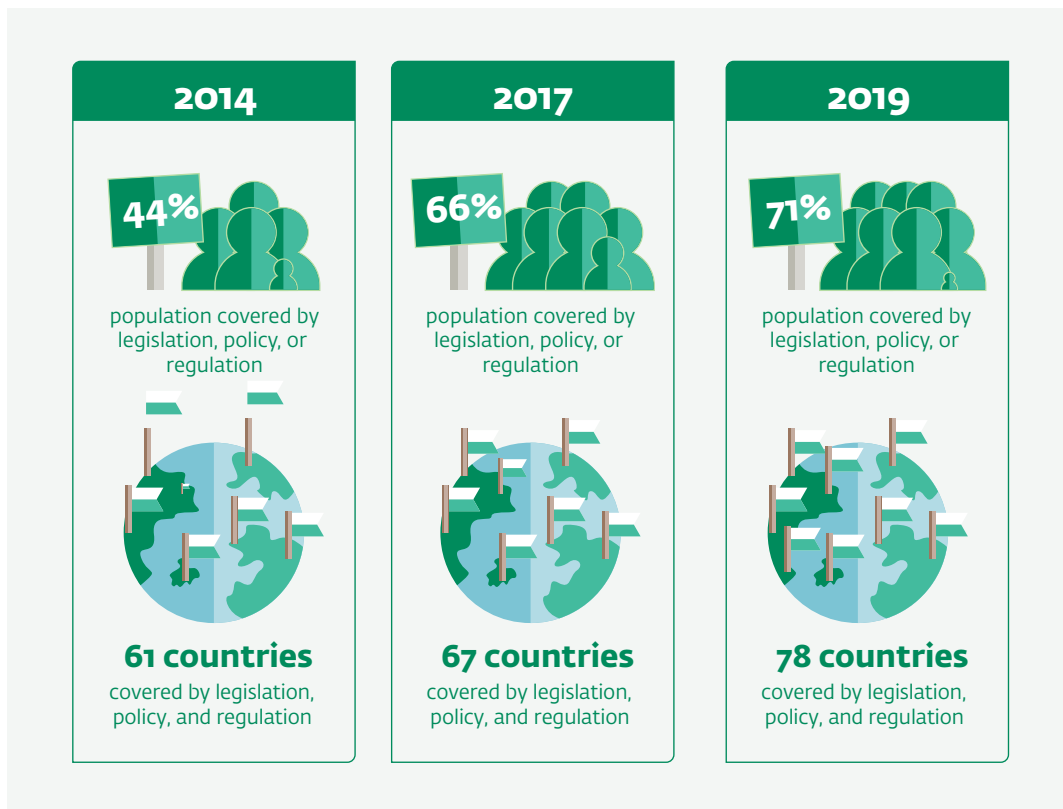
## Sustainability

A central strategy for building a more sustainable industry involves achieving circular electronics manufacturing. The three pillars of a circular electronics-manufacturing strategy are: (1) design out waste and pollution so that products, components, and materials can be broken down and reassimilated into the manufacturing loop; (2) enable efficient circular systems by keeping materials in use longer; and (3) optimize the use of materials that can be safely returned to the environment or to production processes.

**Extending the longevity of products and their components through reuse, repair, and recycling is key to managing the accumulation of waste.** Some manufacturers have begun to phase out practices that

contribute to waste such as “planned obsolescence,” a deliberate strategy to manufacture products that quickly become obsolete and need replacing (epitomized by the 1924 Phoebus cartel regulating light bulbs<sup>13</sup>). Other companies have begun redesigning products that require fewer natural resources to make and can reuse parts and pieces from previously used products, or experimenting with alternative materials that can cleanly return to nature when they wear out. Chemical engineers at Stanford University, for instance, have begun developing the first fully biodegradable electronic circuit.<sup>14</sup> Another group of scientists have been working on a method of pulverizing e-waste into nanodust that could make it easier to reuse materials.<sup>15</sup>

## Countries Covered by E-waste Regulation



Source: <https://ewastemonitor.info/gem-2020/>.

Producers should also integrate modularity into product design, to allow parts of a product to be replaced and swapped for next-generation updates (instead of discarding the entire device). According to a 2020 European Environmental Bureau study, “extending the lifespan of all electrical and electronic products by just one year would lead to annual savings of around 4 million tons of carbon dioxide by 2030, which is equivalent to taking over 2 million cars off the roads for a year.”<sup>16</sup>

**Companies are starting to implement more aggressive recycling regimens that can recover valuable materials and reduce demand for raw**

**resources.** Though it isn't necessarily easy to extract and recover materials from e-waste, concerns about the future availability and price of raw materials are incentivizing companies to implement more aggressive recycling regimens. Recycling facilities that can safely and efficiently separate, categorize, disassemble, shred, and extract valuable materials from e-waste and then render them available to reenter the value chain as materials for new products need to be more fully developed. In developing countries, collection and recycling is often dislocated and unsafe. In developed countries, collecting used electronics is often haphazard and confusing. It takes a lot of effort, there



are little or no incentives to recycle, and there are few established protocols. People are reluctant, for example, to even turn in their old PCs for recycling, because they don't know how to wipe personal data off the machine.

**A “right-to-repair” movement is growing, and new rules are mandating that electronic designs be repairable to extend product life.**

Brands have traditionally not made repairs easy, whether invalidating warranties on products that have been fixed through unauthorized repair services, or declining to share

proprietary documentation needed to make repairs. Frustration with limited repair options has spawned a “right-to-repair” movement. In July 2021, U.S. President Biden signed an executive order that tasks the Federal Trade Commission with establishing rules governing when consumers can bypass manufacturers to seek repairs on products they own.<sup>17</sup> The UK has introduced similar rules and the European Commission announced plans for right-to-repair rules covering smartphones, tablets, and laptops.<sup>18</sup> A German Environment Agency study

## BOX II: *What Are Electronics Made Of?*

Electronics are made from components manufactured using an array of natural resources that have characteristics such as conductivity and insulating properties. Copper, for example, is valued for its conductivity and malleability. Nickel, chromium, aluminum, lead, silver, and tin are used to manufacture resistors, capacitors, and transducers. Plastics (made from petroleum or natural gas) and ceramics (made from earthen materials such as clay) are used for insulating. Polystyrene, polyethylene terephthalate (PET), and polyvinylchlorate (PVC) are used to make capacitors and thermistors to store energy and resist heat. Silicon is used to make microchips and semiconductors, and antimony, bismuth, cobalt, fluorite, garnet, gold, magnesium, and talc can frequently be found in modern electronics. Glues and adhesives made from petroleum anchor components in place. The UN's *Global E-waste Monitor* says about \$57 billion of gold, silver, copper, platinum, and other valuable materials that could be reused to manufacture electronics were “dumped or burned” in 2019 because of inadequate collection and reuse systems.<sup>a</sup>

a. Forti Vanessa, Cornelis Peter Baldé, Ruediger Kuehr, and Garam Bel. 2020. *The Global E-waste Monitor 2020: Quantities, Flows and the Circular Economy Potential*. Bonn/Geneva/Rotterdam: United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR); co-hosted SCYCLE Programme, International Telecommunication Union (ITU) and International Solid Waste Association (ISWA). <http://ewastemonitor.info/>.

concluded that extending the life of a computer workstation from three years to six would save 28 percent of its cost.<sup>19</sup> It noted that hard drives, memories, and fans are the most likely components to fail, so such hardware should be designed to allow for repairs or upgrades, to achieve longer use.

**Countries are adopting regulations and policies that require companies to take responsibility for e-waste.**

According to the UN's *Global E-waste Monitor 2020*, 78 countries have adopted a national e-waste policy, legislation, or regulations.<sup>20</sup> And, as of October 2019, 71 percent of the world's population was covered by a national e-waste policy, legislation, or regulation. In the EU, a new Eco-design Regulation requires that products be energy-efficient and recyclable; information be provided on how to use and maintain products to minimize their environmental impact; and manufacturers perform product life-cycle analyses to identify alternative design options and solutions for improvement.<sup>21</sup> The EU's battery regulation requires manufacturers to ensure sustainable supply chains. "With approximately 800,000 tons of EV batteries, 190,000 tons of industrial batteries, and 160,000 tons of consumer batteries entering the EU every year, these regulations will have global implications," according to Rystad Energy.<sup>22</sup> But they still do not go far enough to address the growing problem.

Other potential approaches include the polluter-pays principle, which would "require producers of pollution to bear the costs of handling their pollution."<sup>23</sup> The principle of "extended producer responsibility" would require manufacturers to actively address end-of-life treatment for their products.

**Flexible consumption models can optimize usage time for products.**

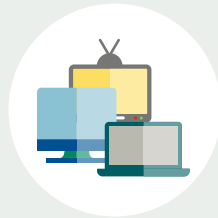
Models such as "product-as-a-service" offer conveniences to consumers and can provide lucrative revenue streams for businesses—laundromats and car rental companies are well-known examples—while allowing the most efficient use of products. Shared-economy innovators such as Uber, Lyft, Mobike, Lime, and Airbnb have tapped into the global inventory of underused and shareable cars, bikes, scooters, and homes, and this model is also starting to be applied to electronics. For example, some local communities have adopted small-scale strategies such as "tool libraries" that allow members to borrow power tools instead of buying them. While this approach obviously wouldn't work for everything, the market for electronics rentals holds potential for growth.

## Types of Electronic Products That Generate E-waste



### 1. Temperature exchange equipment:

more commonly referred to as cooling and freezing equipment. Typical equipment includes refrigerators, freezers, air conditioners, and heat pumps.



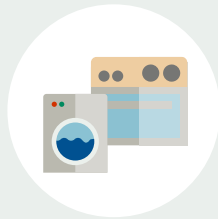
### 2. Screens and monitors:

typical equipment includes televisions, monitors, laptops, notebooks, and tablets.



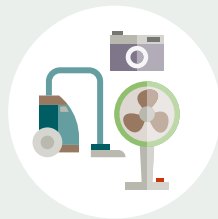
### 3. Lamps:

typical equipment includes fluorescent lamps, high intensity discharge lamps, and LED lamps.



### 4. Large equipment:

typical equipment includes washing machines, clothes dryers, dishwashing machines, electric stoves, large printing machines, copying equipment, and photovoltaic panels.



### 5. Small equipment:

typical equipment includes vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring, and control instruments.



### 6. Small IT and Telecommunication equipment:

typical equipment includes mobile phones, Global Positioning System (GPS) devices, pocket calculators, routers, personal computers, printers, and telephones.

Source: <https://ewastemonitor.info/gem-2020/>.

## BOX III: *The Cobalt Conundrum*

Many raw materials critical to electronics manufacturing come from the world's poorest countries where conditions can be dangerous and unhealthy.<sup>a</sup> Two-thirds of known cobalt deposits are in the Democratic Republic of Congo. The silver-white metallic element is in high demand for smartphones, laptops, and electric car batteries. According to the World Energy Council, only about 30 percent of cobalt is reclaimed through recycling although technologies exist that can recycle 95 percent. Mining cobalt is perilous. The mining process releases radioactive emissions,<sup>b</sup> cancer-causing particles, and particles which may cause vision and other health problems.<sup>c</sup> The Lancet reported that the African Copperbelt, a mining region in Zambia and the Democratic Republic of the Congo, ranks among the world's 10 most polluted areas, largely due to metal mining for electric cars and mobile phone batteries.<sup>d</sup>

a. World Economic Forum. 2019. "A New Circular Vision for Electronics: Time for a Global Reboot," p.11. [https://www3.weforum.org/docs/WEF\\_A\\_New\\_Circular\\_Vision\\_for\\_Electronics.pdf](https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf).

b. To learn more about radioactive emissions, refer to this website: <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/radioactive-emission>.

c. Farjana, Shahjadi Hisan, Nasmul Huda, and M. A. Parvez Mahmud. 2019. "Life Cycle Assessment of Cobalt Extraction Process." *Journal of Sustainable Mining* 18 (3): 150–61. <https://www.sciencedirect.com/science/article/>

<pii/S2300396018301836#:~:text=Particles%20emitted%20during%20cobalt%20mining,heart%20problems%2C%20and%20Thyroid%20damage>.

d. Ngombe, Leon Kabamba, Paul Musa Obadia, Daniel Kyanika Mukoma, Koen Van Herck, Dirk Avonts, Koen Devriendt, Erik Smolders, Celestin Banza Lubaba Nkulu, and Benoit Nemery. 2020. "Metal Mining and Birth Defects: A Case-Control Study in Lubumbashi, Democratic Republic of Congo." *The Lancet* 4 (4): E158–67. [https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196\(20\)30059-0/fulltext](https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30059-0/fulltext).

## Challenges and Opportunities

Lessons from previous environmental blunders are starting to compel countries, companies, and consumers to take e-waste seriously and incorporate innovative ideas about how products are designed, used, and reintegrated into production streams.

The good news is that momentum is building. Apple announced that its latest iPhone will use "100 percent recycled gold in the plating of the main

logic board and the wire in the front camera and rear cameras."<sup>24</sup> It said the rare earth elements in all magnets, tungsten in the Taptic Engine, and tin in the solder of the main logic board and battery management unit of the phone are completely recycled. "Our goal is to one day source all of these valuable resources only from renewable and recycled alternatives," the company said, adding that "2.6 million metric tons of mined rock

equivalent have been avoided by using recycled content in iPhone 13.”

Rystad Energy expects mined lithium for batteries to be in short supply beginning in 2027 and possibly triple in price this decade due to demand for electric vehicles.<sup>25</sup> It will be necessary, Rystad says, to establish industries that “promote second-life battery use.” While the majority of lead acid batteries are recycled, lithium batteries have so far generally not been designed “with material recovery in mind” and the recycling process can be energy intensive if using pyrometallurgy. However, new recycling innovations have emerged and capitalize on the growing demand for batteries.

Today, less than half of countries in the world have national e-waste policies. Even countries with established systems have relatively low collection and recycling rates, in part because of a scarcity of drop-off sites for used electronics and consumer confusion about rules, regulations, and preparation for recycling worn-out products. The UN estimates that just 17.4 percent (9.3 million tons) of the world’s e-waste was collected, recycled, and formally documented in 2019. The whereabouts of the remaining 82.6 percent (44.3 million tons) is uncertain because just 41 countries collect data.<sup>26</sup> Mismanaged disposal of refrigerators and air conditioners alone adds the equivalent of 98 million tons of carbon dioxide to the atmosphere.

## IFC Role

IFC’s strategy is to incentivize companies to embrace circular economy practices by offering financing for sustainable ventures that must overcome uncertainties associated with new technologies and new ways of doing business.

In regard to electronic waste, IFC engages in selective strategic interventions that can yield significant environmental, economic, and community benefits. IFC is helping companies adopt more complex

and forward-looking manufacturing processes to build products that will never become waste and can be reintegrated into the manufacturing production stream. IFC provides guidance and support to help businesses become more circular and manufacture goods that last longer, can be shared and reused, and that can be recycled when they outlive their usefulness.

IFC’s recent investment in GEM Co., Ltd, a leading Chinese waste-treatment

and recycling company, is helping to develop a value chain partner that reclaims and recovers materials from spent electronics and remanufactures the materials into new products.<sup>27</sup> IFC's proposed \$76 million loan to GEM will be used to develop a recycling facility for electric vehicle (EV) lithium ion

batteries. The new plant is projected to recycle 100,000 EV batteries each year. The recycling process will include discharging, disassembling, and testing of battery packs, with reusable battery cells repacked for use such as in energy-storage fields, and dead batteries diverted to metal recovery.

## Conclusion

Policy makers and manufacturers are focusing on the short life cycles of electronics and their associated environmental impacts. This has led to policies encouraging manufacturers to develop more energy- and resource-efficient products. Companies are starting to take action on their own to extend the life of their products, and to make components that are recyclable, reusable, and have value that can be fed back into the system at the end of their lives.

The goal is to disrupt the current linear, extractive, and consumptive manufacturing system with a manufacturing approach that is regenerative and restorative, and ultimately healthier for the planet. However, a systemic approach is critical if the industry is to achieve

a truly circular model where e-waste is eliminated and electronic appliances, devices, and equipment—and the raw materials used to make them—become a renewable resource. Government support for recycling programs and for research on innovative technologies must accompany regulations.

Ultimately, the onus of sustainable electronic stewardship lies with users and consumers of electrical equipment and electronics and their willingness to embrace circular products and circular business models.

At stake is not just the continued availability of electronic products that drive economic development and growth and add convenience to modern lives, but also the health of the world's people and the earth itself.

## References

- Allied Market Research. 2022. “E-Waste Management Market by Application (Trashed and Recycled), Processed Material Type (Metal, Plastic, Glass, and Others), and Source Type (Household Appliance, Consumer Electronics, and Industrial Electronics): Global Opportunity Analysis and Industry Forecast, 2021-2028.” <https://www.alliedmarketresearch.com/e-waste-management-market>.
- Andersen, Terje, and Bjørn Jæger. 2021. “Circularity for Electric and Electronic Equipment (EEE), the Edge and Distributed Ledger (Edge&DL) Model” *Sustainability* 13 (17): 9924. <https://doi.org/10.3390/su13179924>.
- Apple. 2021. «Product Environmental Report : iPhone 13.» [https://www.apple.com/environment/pdf/products/iphone/iPhone\\_13\\_PER\\_Sept2021.pdf](https://www.apple.com/environment/pdf/products/iphone/iPhone_13_PER_Sept2021.pdf).
- CompaniesMarketCap.com. “Largest Electronics Companies by Market Cap.” <https://companiesmarketcap.com/electronics/largest-electronic-manufacturing-by-market-cap/>.
- Decharat, Somsiri. 2018. “Urinary Mercury Levels Among Workers in E-Waste Shops in Nakhon Si Thammarat Province, Thailand.” *Journal of Preventative Medicine & Public Health* 51 (4): 196–204.
- Dockrill, Peter. 2017. “Scientists Say We Can Fix the E-Waste Problem by Pulverizing Electronics into Nanodust.” *Science Alert*, March 24, 2017. <https://www.sciencealert.com/scientists-say-we-can-fix-the-e-waste-problem-by-pulverising-electronics-into-nanodust>.
- Forti Vanessa, Cornelis Peter Baldé, Ruediger Kuehr, and Garam Bel. 2020. *The Global E-waste Monitor 2020: Quantities, Flows and the Circular Economy Potential*. Bonn/Geneva/Rotterdam: United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR); co-hosted SCYCLE Programme, International Telecommunication Union (ITU) and International Solid Waste Association (ISWA). <http://ewastemonitor.info/>.
- Frangoul, Anmar. 2021. “Global Electric Vehicle Numbers Set to Hit 145 Million by End of the Decade, IEA Says.” *CNBC Sustainable Energy TV Shows*, April 29, 2021. <https://www.cnbc.com/2021/04/29/global-electric-vehicle-numbers-set-to-hit-145-million-by-2030-iea.html>.
- GlobeNewswire. 2021. “Electronics Industry Analysis Shows A Slow Recovery Of The Global Electronics Market From The Pandemic Effect.” *Business Research Company report*, August 12, 2021. <https://www.globenewswire.com/news-release/2021/08/12/2279981/0/en/Electronics-Industry-Analysis-Shows-A-Slow-Recovery-Of-The-Global-Electronics-Market-From-The-Pandemic-Effect.html>.
- Godwin, Cody. 2021. “Right to Repair Movement Gains Power in US and Europe.” *BBC News*, July 7, 2021. <https://www.bbc.com/news/technology-57744091>.
- Health and Environment Alliance. 2006. “Halting the Child Brain Drain: Why We Need to Tackle Global Mercury Contamination.” [https://www.env-health.org/IMG/pdf/mercury\\_chapter1.pdf](https://www.env-health.org/IMG/pdf/mercury_chapter1.pdf).
- IFC (International Finance Corporation). 2021. “GEM Loan: Environmental & Social Review Summary.” *IFC Project Information & Data Portal*. <https://disclosures.ifc.org/project-detail/ESRS/43250/gem-loan>.
- Krajewski, Markus. 2014. “The Great Lightbulb Conspiracy.” *IEEE Spectrum*, September 24, 2014. <https://spectrum.ieee.org/the-great-lightbulb-conspiracy>.
- Nylen, Leah. 2021. “Biden Launches Assault on Monopolies.” *Politico*, July 8, 2021. <https://www.politico.com/news/2021/07/08/biden-assault-monopolies-498876>.
- Prime Computer. 2022. “Built-In Expiration Date? Not with Us! We Make Hardware That Lasts.” *TCO Certified*, January 27, 2022. <https://tco-certified.com/circular-electronics-day-case/built-in-expiration-date-not-with-us-we-make-hardware-that-last/>.
- Rohrig, Brian. 2015. “Smartphones: Smart Chemistry.” *American Chemical Society Chem Matters*. <https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2014-2015/smartphones.html>.
- Rystad Energy. 2021a. “Electrical Vehicle Boom to Trigger Spending of \$560 Billion to Build Li-Ion Battery Factories This Decade.” *Press release*, June 3, 2021. [https://www.rystadenergy.com/new-sevents/news/press-releases/electric-vehicle-boom-to-trigger-spending-of-\\$560-billion-to-build-li-ion-battery-factories-this-decade/](https://www.rystadenergy.com/new-sevents/news/press-releases/electric-vehicle-boom-to-trigger-spending-of-$560-billion-to-build-li-ion-battery-factories-this-decade/).

- . 2021b. “Millions of Electric Vehicles May Face Production Delays from 2027 as Lithium Mining Capacity Lags.” Press release, April 14, 2021. <https://www.rystadenergy.com/newsevents/news/press-releases/millions-of-electric-vehicles-may-face-production-delays-from-2027-as-lithium-mining-capacity-lags/>.
- Shanahan, Jess. 2021. “There Are Now More Than 10 Million Electric Vehicles on the Road.” Zap-Map, January 21, 2021. <https://www.zap-map.com/there-are-now-more-than-10-million-electric-vehicles-on-the-road/>.
- Stanford Magazine*. 2017. “A Solution to E-Waste: Chemical Engineers Develop a Biodegradable Electronic Circuit.” <https://stanfordmag.medium.com/a-solution-to-e-waste-d2ce9e779c50>.
- United Nations University. 2017. “E-waste Rises 8% by Weight in 2 Years as Incomes Rise, Prices Fall.” News, December 14, 2017. <https://unu.edu/media-relations/releases/ewaste-rises-8-percent-by-weight-in-2-years.html>.
- World Economic Forum. 2019. “A New Circular Vision for Electronics: Time for a Global Reboot.” [https://www3.weforum.org/docs/WEF\\_A\\_New\\_Circular\\_Vision\\_for\\_Electronics.pdf](https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf).
- Your Europe. 2021. “Ecodesign Requirements.” Your Europe, April 11, 2021. [https://europa.eu/your-europe/business/product-requirements/compliance/ecodesign/index\\_en.htm](https://europa.eu/your-europe/business/product-requirements/compliance/ecodesign/index_en.htm).

## Endnotes

- <sup>1</sup> Rohrig 2015.
- <sup>2</sup> Forti et al. 2020.
- <sup>3</sup> United Nations University 2017.
- <sup>4</sup> GlobeNewswire 2021.
- <sup>5</sup> CompaniesMarketCap.com.
- <sup>6</sup> Frangoul 2021.
- <sup>7</sup> Shanahan 2021.
- <sup>8</sup> Rystad Energy 2021a.
- <sup>9</sup> World Economic Forum 2019.
- <sup>10</sup> Health and Environment Alliance 2006.
- <sup>11</sup> Decharat 2018.
- <sup>12</sup> Allied Market Research 2022.
- <sup>13</sup> Krajewski 2014.
- <sup>14</sup> Stanford Magazine 2017.
- <sup>15</sup> Dockrill 2017.
- <sup>16</sup> Prime Computer 2022.
- <sup>17</sup> Nylen 2021.
- <sup>18</sup> Godwin 2021.
- <sup>19</sup> Prime Computer 2022.
- <sup>20</sup> Forti et al. 2020.
- <sup>21</sup> Your Europe 2021.
- <sup>22</sup> Rystad Energy 2021a.
- <sup>23</sup> Andersen and Jaeger 2021.
- <sup>24</sup> Apple 2021.
- <sup>25</sup> Rystad Energy 2021b.
- <sup>26</sup> Forti et al. 2020.
- <sup>27</sup> IFC 2021.





[www.ifc.org/manufacturing](http://www.ifc.org/manufacturing)



[www.linkedin.com/showcase/ifc-manufacturing](https://www.linkedin.com/showcase/ifc-manufacturing)