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E-waste and How Consumer Choices Can Help to Reduce It

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Executive Summary

Millions of tons of electronic wastes are generated each year, often in the form of devices that are prematurely discarded after only several years of use. The result is far greater environmental impact of electronics than if more rational patterns of use and end-of-life strategies were employed. Changes in consumer behavior to keep devices longer before discarding, learning how or where to replace batteries, donating devices for restoration and reuse at the end of first life, and properly recycling when warranted can go a long way toward significant reduction in impacts linked to production and use of electronics. Changes in state and federal laws could also help to reduce global environmental impacts. This report provides insights into current environmental impacts from various sources of electronic waste, and diverse strategies for improving the situation. Links to organizations that accept used devices for reuse and recycling are also provided.

An Electronics Love Affair and its Many Environmental Consequences

In the United States alone about 295 million electronic computing and communication devices were purchased in 2017, an impressive number for a nation of 329 million people. The total included 62 million desktop and laptop computers, 46 million tablets, and 187 million smartphones. These figures do not include smart TVs, smartwatches, CD and MP3 players, video gaming units, digital cameras, printers, and other electronic devices.

The Pew Research Center reported in early 2018 that 95% of Americans owned cell phones, and that 77% owned smartphones. In addition, three quarters of U.S. adults owned desktop or laptop computers, while about half owned tablet computers. Approximately one in five adults had E-readers.

The electronics phenomenon is not, of course, limited to the U.S. Globally in 2017 smartphone sales totaled 1.5 *billion*. In addition, 260 million desktop and laptop computers, and 164 million tablets were sold worldwide.

The vast majority of computers, tablets, and smart phones purchased are replacement upgrades, leading to retirement and/or discard of hundreds of millions of electronic devices each year. Replacements are triggered by wear and tear, obsolescence (including planned obsolescence), and a focus on trendsetting. For the most part, upgrades occur well before the end of useful life of the devices being replaced. Upon retirement of devices, some are given a second life through donation, some are placed in drawers and closets to gather dust, some are taken to recycling centers, while others are simply dumped in the trash for transport to landfills. An estimated 3.1 million metric tons of electronics wound up in the municipal waste stream in the United States in 2015; of this, 1.2 million tons were recovered for recycling, leaving 1.9 million tons unrecovered. Most of these devices contain an array of metals, including heavy metals, and when deposited in a landfill these materials can leach into groundwater and soils, creating problems for decades to come. Moreover, the metals contained within them, which in many cases were obtained from high environmental impact mining and refining processes, are effectively lost to the possibility of recovery, triggering yet more mining for use in replacement devices.

There is a significant difference between estimates of how long electronic devices should physically last and how long, on average, they are actually kept in service. Smartphone upgrade statistics provide a case in point.

Americans keep their smartphones for about 28 months. Average time to replacement is even shorter in Europe and Asia. But averages do not necessarily tell the whole story. Averages for the U.S. have been found to mask a sharp difference in upgrade habits across American consumers. In a 2015 Gallup survey 54% of U.S. smartphone users reported that they would upgrade only when their phones stopped working. Yet, 44% reported that they upgraded as soon as providers allowed it (usually every two years), and another 2% tended to upgrade as soon as a new model appeared on the market – typically every year. Very similar numbers were found in a 2013 Canadian study of wireless device replacement cycles in that country.

German scientists from the Ō̈ko-Institut and Bonn University, investigated physical lives of a number of electronic devices and average replacement cycles in their home country, finding that "perfectly good" smartphones and other devices were being junked simply for the purpose of obtaining the latest models. Noting large and negative environmental impacts of product replacement, study authors indicated a need for improved product labels that would include estimates of product life, and for consumers (and manufacturers) to assume greater responsibility for environmental impacts of consumption when making replacement decisions.

According to the U.S. EPA (EPA), every one million smartphones contain 35,274 pounds of copper, 772 pounds of silver, 75 pounds of gold, and 33 pounds of palladium, in addition to lesser quantities of a number of other chemical elements. To put these numbers in perspective, it was reported in Chemical and Engineering News in 2016 that electronics in landfills contained more rare earth metals than were in all known global reserves. The 2017 Global E-waste Monitor report estimated the value of all raw materials in E-waste globally at €55 billion (US$65 billion).

Strategies for Reducing Environmental Impacts

Lengthen Replacement Cycle

In 2009 the EPA estimated that extending the useful life of personal computers from four to six years would annually reduce resource consumption by 439,000 tons, carbon dioxide-equivalent emissions by over 25 million tons, and waste disposal in landfills by 632,000 tons. Although computers are not as bulky today as in 2009, meaning that increased computer life would result in less waste reduction, longer life would nonetheless serve to reduce both wastes and overall environmental impact. Longer lives of smartphones, tablets, and other electronic devices would similarly be beneficial.

Individual consumers can:

- Keep devices for a longer period of time.
    - Keeping a smartphone an extra year or more beyond what has been done previously can save money while also significantly reducing environmental impacts. Ditto for desktops, laptops, and tablets.
    - Purchase devices that have replaceable batteries.

  - Learn how to replace batteries in devices not advertised as having replacement capability (many videos are available on-line illustrating do-it-yourself replacement of batteries and screens in smartphones), or locate companies that will replace batteries for you.[1]
  - Invest a bit more at the point of purchase when buying desktops and laptops in order to obtain greater memory capacity and screen resolution than low-end products. Doing so can help to avoid rapid obsolescence as more demanding software is introduced.
  - Consider upgrading the hardware or software of computers or laptops, rather than purchasing a brand new product.

- Donate devices for reuse in order to extend their useful lives.
  - Ask the vendor when buying a new device whether used devices have trade-in value or are accepted for possible reuse or recycling.
  - Drop off devices at companies which accept used electronics for reuse. The US EPA maintains a list of companies which have permanent in-store or dedicated drop off centers, host collection events, or offer mail-in programs. (see www.epa.gov/recycle/electronics-donation-and-recycling).
  - Donate used cell phones to *Cell Phones for Soldiers*. This non-profit sells collected phones either to restoring or recycling centers, depending upon condition of the devices. Proceeds are then used to purchase prepaid international calling cards for troops, and to provide emergency financial assistance. (see www.cellphonesforsoldiers.com)
  - Donate personal devices directly to individuals or organizations that could use them.

Recycle Electronics When Ready to Replace Them

Electronic devices contain a myriad of metals, plastics, and other materials that have been obtained at high environmental cost. Recovering these components reduces impacts linked to mining and processing of virgin ore, and keeps heavy metals out of landfills or incinerators where leaching can result in soil, water, and air pollution.

- Take used devices to electronics recycling centers or drop-off sites.
  - If unsure whether a device to be discarded can be successfully restored for reuse, donate nonetheless to an organization that is in the restoration business (see above). If the device is found unsuitable for reuse, it will be recycled.
  - If the device is an obvious candidate for recycling, be sure to take to a recycling center and not to the trash. The same US EPA listing of companies that accept phones for restoration and reuse also identifies companies which

[1] Batteries Plus is a nationwide company which offers battery replacement for smartphones, tablets, and other devices.
[2] Manufacturers that provide models with replaceable batteries include LG Electronics, Motorola, Nokia, and Samsung.
[3] A nationwide company that offers smartphone battery replacement is Batteries Plus.

accept used electronics for recycling. Many states, as well as large city governments, also maintain websites directing citizens to electronics drop-off sites.

- Check the internet to find sites offering to buy used smartphones, laptops, desktops, and other devices.

Consider Purchase of Used, Restored Electronics

Restored desktops, laptops, tablets, and smartphones can reliably serve casual users for many years, and offer considerable savings in comparison to buying new equipment. As a bonus, giving a second life to discarded equipment substantially reduces the environmental impact of each device.

- Before purchasing new, check out the used device market
  - Type in the words "Used, restored computers for sale" and links to many vendors of restored desktops and laptops will appear – some of them the same retailers that sell new equipment. Similar searches for restored tablets and smartphones reveals the same thing. Searching further will show that these devices sell for one-third to one-half the price of new units.
- Inform others about potential savings in purchasing restored devices.

Push for E-waste recycling programs and policies

Exportation of e-waste often results in accumulation of wastes in developing countries where it is sometimes handled by untrained workers using crude tools to retrieve valuable components. In other cases the waste, and the heavy metals contained within it, is simply transported to unregulated dumps. In either case, components can pose a threat to the local environment and to humans and animals in the vicinity.

Keeping E-wastes within the region of origin and incentivizing systems for collecting, restoring, and recycling materials will reduce environmental impacts of electronic devices and protect vulnerable populations from health risks and environmental degradation.

- Urge support for ratification of the Basel Convention which bans export of toxic waste, including E-waste to developing countries (see further discussion, page 10).
- If living in a jurisdiction that does not have Extended Producer Responsibility (EPR) laws governing E-waste, or that does not mandate E-waste recycling (see page 10), urge decision makers to establish recycling programs and policies.

Useful Life and Consumer Preference

Physically damaging an electronic device can obviously shorten its life. Operating in temperature extremes, exposure to moisture and high humidity, and exposure to dirt and dust can also reduce useful life. Planned obsolescence also plays a part, such as recently demonstrated by manufacturer's programmed slowing of older phones, release of new operating systems that will not work on older devices, and withdrawal of technical support after a certain length of time.

Smartphones

In the absence of damage, the primary factor limiting the useful life of smartphones is battery life. This, in turn, is affected by the number of times batteries are recharged; smartphones are generally designed for 300-500 recharges, although as many as 2,000 to 2,500 recharges may be possible if battery power is consistently allowed to run down to about 25% power before recharging. Continued connection to a power source once batteries are fully charged can reduce battery life, as can running of high resolution games and apps. Several estimates indicate that a high quality smartphone under normal use should have a 5-7 year life, yet the average lifespan is about 28 months.

Because battery life is often the determining factor in the life of a smartphone, these devices could have longer service lives if equipped with replaceable batteries. Not all brands offer this feature.[2] However, even for those brands that don't advertise the possibility of battery replacement, there are companies that now offer battery replacement at nominal cost[3], and informational videos are available via the internet that show smartphone owners how to replace batteries themselves.

Desktops and Laptops

Desktop and laptop computers have the capacity to provide satisfactory service for 10 years and more. In actual practice, the average age of desktops at time of replacement in the U.S. in 2017 was about 4.5 years, while laptops were, on average, 5.3 years old.

Consumers in other nations exhibit similar behavior. In Sweden, for example, the Advantage Environment project conducted a survey of a number of agencies and companies in 2012, finding that about half of the organizations scrapped IT equipment every 3 or 4 years.

In that computers after only a few years of use have several to many additional years of useful service life, some companies collect, renew, and resell used computers. Schools, churches, small businesses, non-profit organizations, and individuals make up the primary market.

The useful lives of laptops are strongly influenced by battery life. The useful life is also often limited by insufficient memory and/or screen resolution requirements of increasingly sophisticated software. Devices used primarily for gaming are particularly vulnerable to obsolescence due to increasing memory demands posed by new software. Purchasing models with greater memory and screen resolution and/or with the ability to be modified with add-ons and upgrades to extend use can largely avoid this problem.

Tablets

Expected tablet life, as with smartphones, is subject to intensity of use and to the number of battery charging cycles. And, like smartphones, these devices are more prone to physical damage than stationary devices. The average age at replacement in the U.S. is slightly over 5 years.

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[2] Manufacturers that provide models with replaceable batteries include LG Electronics, Motorola, Nokia, and Samsung.

[3] A nationwide company that offers smartphone battery replacement is Batteries Plus.

Systematic Assessment of Electronics Manufacture, Use, and Disposal

Manufacturing of electronic devices, and the mini-circuits, memory chips, display screens, batteries, casings, and so on that define them require an array of resources, many of which are obtained through high-impact mining and separation processes. Smartphones, provide a prime example. These devices typically contain 40 or more different elements (see sidebar), including all but one of the 17 rare earth metals. A typical smartphone also contains ceramics, epoxy, and several types of petroleum-based plastics. Other types of electronics are similarly reliant on substantial numbers of chemical elements.

The first step in electronics manufacture involves mining to obtain the myriad of metals needed. Mining involves not only extraction of ore, but also the removal of earth and associated vegetation that sits above. The result is that extraction of a ton of ore can require the movement of 20 to 30 tons or more of other materials. The ore itself occurs in varying concentrations. The highest concentrations, in which metals make up a high percentage of the weight of an ore, are referred to as high quality ores; lower quality ores contain a lesser percentage of metal. The magnitude of ore extraction varies widely depending upon what is being mined and the ore concentration. For instance, gold comprises only 0.0000002 percent of the Earth's crust. To economically mine gold with current technologies it must be 4,000 to 5,000 times more concentrated in a seam of ore than in the Earth's crust in general. Even then, however, a ton of such an ore would contain only one-third ounce of gold. In other words, for each pound of gold obtained, 48 *tons* of waste in the form of tailings[4] are produced. A number of other metals used in electronics manufacture have similarly low ore concentrations.

A Partial List of Metals Contained in <u>Smartphones</u>

Copper
Silver
Gold
Palladium
Iron
Zinc
Nickel
Silicon
Tin
Lead
Tantalum
Cobalt
Aluminum
Antimony
Magnesium
Lithium compounds
Bromine compounds
Phosphorous
Molybdenum
Rare earth metals

Extraction and refining of metallic elements is followed by the environmental impacts of transport to a manufacturing facility, component production, and assembly. Wastes are generated at each stage. While electronics are in use the primary input is energy.

Systematic evaluation of the environmental impacts from raw material extraction through use and final disposal show that the greatest impacts occur at the raw material extraction and manufacturing stages. This is true with respect to generation of waste, energy consumption, and a range of other impacts.

While this report focuses on electronic waste, it is important to keep in mind that as large as E-wastes are, they are but a fraction of the total waste burden generated during the life cycle of an electronic device.

Waste which occurs in resource extraction, primarily in the form of tailings, is as much as 200 times greater in volume than that which occurs at the point of end-of-life disposal. Wastes generated in component manufacturing and assembly are 20-25 times greater than

[4] Mine tailings are not only significant in volume, but often in subsequent environmental impact when leachate finds its way into surface and ground waters.

those at end-of life. So while this report focuses on electronic waste, it is important to keep in mind that as large as E-wastes are, they are but a fraction of the total waste burden generated during the life cycle of an electronic device.

Energy consumption throughout the life of an electronic device is also concentrated in the raw material extraction and manufacturing processes, with about 60% of energy consumed in these stages. Use accounts for 29-35% of energy consumption. Environmental impact measures such as global warming potential, ozone depletion potential, acid rain potential, and human toxicity potential are closely linked to energy consumption, and are therefore dominantly linked to the raw material extraction and manufacturing process.

Fate of Products at the End of Useful Life

Ideally the production, use, and end-of-life sequence of electronics would follow a path as outlined in the figure below, with end-of-useful product life followed by complete recycling of components for use in production of new electronic devices. In this idealized scenario landfilling of materials would be zero or very minimal.

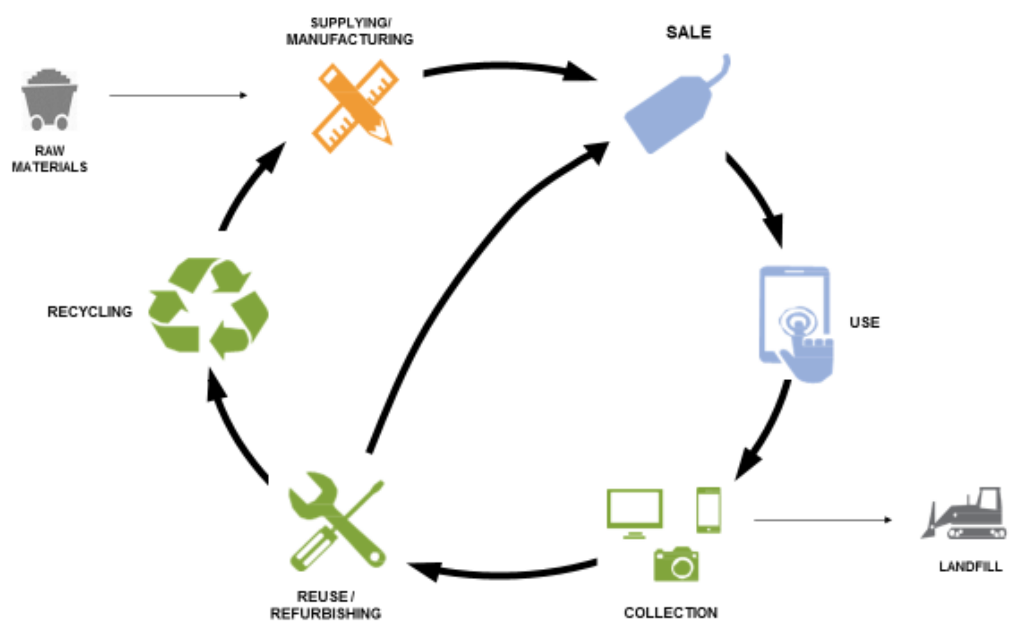

Figure 1. Life Cycle of Electronics
Source: EPA (2018)
(https://www.epa.gov/smm-electronics/basic-information-about-electronics-stewardship)

However, as indicated earlier, the life cycle of the majority of electronic devices is far from this ideal, with 1.9 million tons of E-waste discarded to landfill in the United States in 2015.

A significant number of electronic devices are reconditioned and resold following discard by the initial purchaser. In 2014 of the 1.8 billion new smartphones sold globally, about 44% were expected to be recovered for resale after several years of use. About the same number were expected to wind up in closets and drawers. Only about 3% would be recycled, with most of the rest going to landfill. The fate of re-used phones at the end of their second lives is unknown, although discard to landfills or recycling (often under inferior and hazardous conditions) is suspected.

With regard to all electronics, the Global E-waste Monitor reported that 49.3 million tons (44.7 million metric tons) of electronic waste was generated globally in 2016, a quantity equal to 13.4 pounds (6.1 kg) for every person in the world. Of this, only 20% was collected and properly recycled. In the United States, generation of E-waste amounted to 42 pounds (19.1 kg) per capita in 2016.

Recovery of electronic devices from the U.S. waste stream is higher than the global average, with about 40% recovery. This percentage is slowly increasing as private sector initiatives are mounted to address the waste problem. Today, many U.S. distributors of electronic devices accept discarded electronics for recycling.[5] Similar collection systems now operate in most developed countries. At least some of these collected materials are then shipped to processing centers where metals and other components are recovered. For instance, the largest U.S. electronic device recycler, California-based ERI, collects hundreds of thousands of tons of E-waste each year which it shreds and sends to smelters for processing. In Europe, the Belgian company Umicore runs a similar operation, recovering a number of different metals while burning plastics to recover energy used to run the recycling facility. Another European and Swedish-based company – Inrego – recognized both the need and opportunity associated with discarded electronics as long ago as the mid-1990s, establishing a company that reconditions and resells used computers. Less than 20 years after its' founding, Inrego took the lead in creating an infrastructure for used information technology (IT) products across Europe. Taking a different approach, Apple announced in its 2018 environmental responsibility report that it has developed a robot to dismantle iPhones and sort components for ease of recycling. Many other companies are involved in electronic device recovery, reuse, and recycling efforts.

While progress is being made on the recycling front, much of the E-waste generated in the U.S. and other developed countries is exported to low income countries. British environmental journalist Fred Pierce has noted that some exportation of E-waste is legitimate, such as ERI's shipments of a portion of its shredded waste to smelters in South Korea. However, the Basal Action Network (BAN), which has partnered with Dell in tracking electronic device discards, reported in early 2018 that some American companies practice what they call "scam recycling" wherein E-waste is simply exported to countries such as the Philippines or Pakistan where workers, including children, use hammers, chemicals, or other means in an attempt to recover some of the recyclable metals. The practice poses health risks to workers and the local area and results in far lower metals recovery than otherwise obtainable.

As a postscript, in 2010, at the 10th Conference of the Basel Convention, 178 countries voted to support a ban on toxic waste exports and particularly electronic or "E" wastes to developing countries. To date, 186 countries have signed on, although not all of them actively enforce the ban. The U.S. was one of 17 countries not supporting the measure and at this writing remains the only developed country to have not ratified this treaty.[6] Bills were introduced in the U.S. House and Senate to ban overseas dumping of E-wastes for the first time in 2010, and have been reintroduced, without result, in every session through 2018.

[5] A noteworthy example is Best Buy Corp., which reports having collected and responsibly disposed of more than 1 billion pounds of electronics and appliances. (https://www.bestbuy.com/site/services/recycling/pcmcat149900050025.c?id=pcmcat149900050025)

[6] Though not a signatory to the Basel Convention, the U.S. does prosecute the illegal export of such waste.

Various states have taken action, and as of early 2018, 25 states and the District of Columbia had enacted laws mandating statewide E-waste recycling (Figure 2). As of 2016, the U.S. was the world's leading exporter of electronic waste.

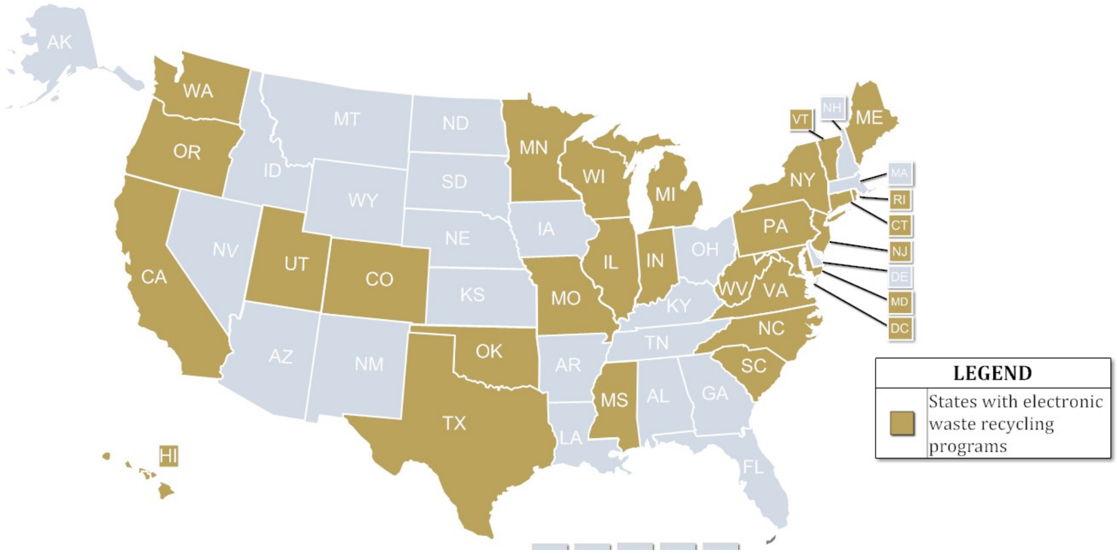

Figure 2. States with Electronic Waste Recycling Programs
Source: Larmer (2018)

Even when electronic devices are recycled, much of the metallic content is not. For example, of the 40 chemical elements commonly contained in a smartphone, only 17 are recovered to a maximum rate of 95% even in the most sophisticated electronics recycling facilities. One third of the component metals are currently not economically recoverable. Only 1% of the high environmental impact rare earth metals are currently recycled.

One approach to dealing with increasing quantities of E-waste is placing responsibility for post-consumer discards on producers. Generally referred to as Extended Producer Responsibility (EPR), this approach most often takes the form of mandated take-back requirements. Assigning responsibility to manufacturers to take back and deal with discards of their products is intended to not only keep wastes out of landfills and promote recycling, but also to provide incentives to prevent wastes at the source, and to promote product design which enables easier dismantling and recovery of components. EPR for electronics was first embraced by Japan through enactment of a national law in 1998. Others soon followed. As of mid-2018, most of the countries of Europe, 24 states of the U.S.[7], and most of the provinces of Canada had electronics take-back laws in place. Similar laws are in effect at the national level in Australia, Chile, India, South Korea, and Thailand.

[7] States having electronics take-back laws are California, Connecticut, Hawaii, Illinois, Indiana, Maine, Maryland, Michigan, Minnesota, Missouri, New York, New Jersey, North Carolina, Oklahoma, Oregon Pennsylvania, Rhode Island, South Carolina, Texas, Vermont, Virginia, Washington, West Virginia, and Wisconsin.

Summary

Volumes of electronic wastes generated each year are measured in the millions of tons. Many devices are discarded after only a few years of use even though the electronics are capable of many additional years of service. E-wastes are often not properly disposed of so as to allow possible restoration and reuse or recycling to recover valuable high-environmental-impact components. The result is far greater environmental impact of electronics than if more rational patterns of use and end-of-life strategies were employed. Changes in consumer behavior to keep devices longer before discarding, learning how or where to replace batteries, donating devices for restoration and reuse at the end of first life, and properly recycling when warranted can go a long way toward significant reduction in impacts linked to production, use, and disposal of electronics.

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