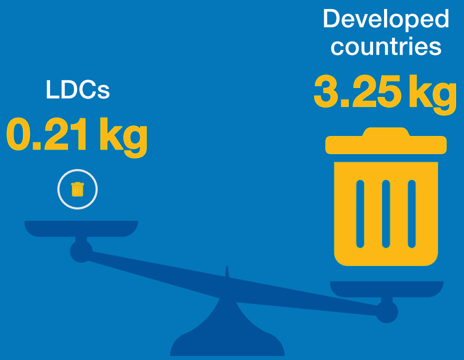
Chapter IV

End of the cycle? Digitalization-related waste and the circular economy

This chapter focuses on the last stage of the life cycle of digitalization. It describes global trends in digitalization-related waste, highlighting that these can represent challenges and opportunities from an economic and an environmental sustainability perspective.

Current waste management practices are insufficient, and marked by inadequate recycling and informal handling, especially in developing countries. Addressing this situation is necessary to deal with environmental and health impacts of improper disposal of digital devices.

The chapter calls for a more circular digital economy, which would enable longer lifespans of devices and more efficient recycling, to reduce waste. This would not only help to alleviate pressure on raw material supplies but could also enable economic opportunities. The challenge involves developing coordinated global efforts and robust policies for waste treatment and circularity along the life cycle of digitalization.



Per capita generation of digitalization-related waste in 2022

People in developed countries generate on average **15 times** more digitalization-related waste than those in LDCs.

A. Introduction

The last stage of the digitalization life cycle is when users either no longer want or can use digital devices or ICT infrastructure. From a sustainability perspective, there is an urgent need to minimize the generation of waste related to digitalization. In addition, there is a need to ensure that when these devices reach the end of life, they are recycled in a way that allows for valuable resources to be recovered.

Digitalization-related waste is a complex waste stream. It has a dual character, as it contains both hazardous substances and valuable parts and materials. This waste needs to be managed in an environmentally sound manner to ensure that the dangerous materials are treated safely and dealt with separately. If not properly managed, it can result in significant negative environmental, health and other social impacts, often affecting the most vulnerable. When digitalization-related waste is managed effectively, valuable materials can be recovered. These can provide economic and environmental benefits, by increasing the supply of secondary raw materials and substituting the primary supply of minerals and metals for the manufacturing of new equipment.

Moreover, a circular economy that adheres to the principles of "reduce, reuse and recycle" can reduce waste generation, by extending device lifespans and reducing the need to extract raw materials needed to produce new devices. Services connected to activities in the circular economy can also provide economic development potential, including job opportunities, in developing countries.

In a circularity context, the end of a cycle becomes the beginning of another. Circular economy activities can lead to a more rational demand for digital products. Addressing overconsumption of ICT goods in some parts of the world, especially among the wealthier population, is key for reducing the overall environmental footprint of digitalization. However, environmental issues related to energy and water use, as well as mineral extraction, cannot be solved solely through recycling and recovery at the end-of-life stage. Reducing overconsumption is essential for achieving sustainable consumption and production.

This chapter addresses trends in the generation and management of digitalization-related waste and associated challenges, as well as the potential opportunities that can emerge from a circular digital economy. The definition of digitalization-related waste is discussed in section B. Section C looks at trends in this waste, while section D explores the factors behind the trends observed. Environmental, health and other social consequences of digitalization-related waste, typically linked to unsound waste management, are presented in section E. Section F explores the elements of a circular digital economy. International flows of digitalization-related waste are discussed in section G. Section H looks at the potential opportunities that developing countries can leverage from the circular digital economy, while section I presents concluding observations.

B. What is digitalization-related waste?

Defining digitalization-related waste is not straightforward. It is related to the term "electrical and electronic waste", also known as "e-waste" or "waste electrical and electronic equipment" (WEEE) and "e-scrap". Definitions for these terms usually refer to the process of a physical object becoming waste, which then determines whether it is classified as e-waste. A complication in the definition of e-waste is that there does not seem to be a clear distinction between what constitutes "waste" and what does not, nor when an item becomes waste.[1] Further, it may be misleading to consider "e-waste" as items that could potentially be disassembled into useful parts that could re-enter the production process. Similarly, it is not evident that products that contain valuable materials that can be recycled and recovered can be considered as "waste".

There are two broad global definitions of e-waste, which vary depending on the context in which they are applied: the legal definition and the statistical definition

There are two broad global definitions of e-waste, which vary depending on the context in which they are applied: the legal definition and the statistical definition. In the legal context, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal,[2] which was adopted in 1989 and entered into force in 1992, has historically defined WEEE as electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste.[3] The Convention defines wastes as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" (article 2, paragraph 1).

At the fifteenth session of the Conference of the Parties in 2022, the Parties adopted amendments to annexes of the Basel Convention that add precision to the definition of e-waste, particularly when listing hazardous and non-hazardous e-waste, which could prevent illegal trade activities. The amendments cover more than WEEE by including "components" and "waste arising from processing" within the definition of electrical and electronic waste (box IV.1).

In the statistical context, the Global E-Waste Statistics Partnership follows the definition outlined by "Solving the E-waste Problem" (StEP, 2014): "e-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of reuse"; EEE refers to a range of products "with circuitry or electrical components with power or battery supply".[4] This definition was developed by the UN Partnership for Measuring ICT for Development. StEP has provided statistical guidelines (Forti et al., 2018) which are followed by the Global E-Waste Statistics Partnership and

[1] This depends on national legislation; countries may define items as non-waste, e-waste and their parts, when these can be repaired or refurbished. Also, parts of e-waste that can be disassembled and enter back into the production process may or may not be considered waste.

[2] See https://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf and https://www.basel.int/.

[3] See https://www.basel.int/Implementation/Ewaste/Overview/tabid/4063/Default.aspx.

[4] See https://globalewaste.org/ and https://www.step-initiative.org/.

Box IV.1
Amendments to annexes of the Basel Convention

Under the new binding definition of electrical and electronic waste, which is to become effective on 1 January 2025, non-hazardous electrical and electronic waste includes:[a]

- WEEE not containing or not contaminated with constituents as established by the Convention annexes, or in which none of the components contain or are contaminated with such constituents;
- Waste components of electrical and electronic equipment (e.g., certain circuit boards, certain display services) not containing and not contaminated with constituents as established in the annexes;
- Waste arising from the processing of WEEE and electronic equipment or waste components of electrical and electronic equipment (e.g., fractions arising from shredding or dismantling) not containing and not contaminated with constituents as established in the annexes.

Hazardous electrical and electronic waste includes:

- WEEE containing or contaminated with cadmium, lead, mercury, organohalogen compounds or other constituents as established in the annexes;
- WEEE with a component containing or contaminated by constituents as established in the annexes.

Moreover, to facilitate the way in which it is applied, the most recent Basel Convention technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment have a particular focus on the distinction between waste and non-waste.[b] These guidelines, which are non-binding, note that "national provisions concerning the definition of waste may differ and, therefore, the same material may be regarded as waste in one country but as non-waste in another country". In this case, the Parties agreed that, when a transboundary movement occurs, the most stringent definition applies.

Source: Basel Convention.

[a] See https://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP15/tabid/8392/Default.aspx.
[b] The guidelines are available at https://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP16/tabid/9311/Default.aspx.

used in monitoring progress in achieving the Sustainable Development Goals.[5]

This statistical definition of e-waste is similar to that of WEEE under the Basel Convention, without the most recent amendments mentioned above. In this context, e-waste statistics from the Global E-Waste Statistics Partnership through UNITAR (SCYCLE),[6] which are developed in cooperation with ITU and UNEP, cover six categories:

1. *Temperature exchange*: Temperature exchange equipment, more commonly referred to as cooling and freezing equipment, such as refrigerators, freezers, air conditioners and heat pumps;
2. *Screens, monitors*: Items such as televisions, monitors, laptops, notebooks and tablets;
3. *Lamps*: Including fluorescent lamps, high intensity discharge lamps and LED lamps;

[5] Building on the Partnership on Measuring ICT for Development, in 2017, ITU, United Nations University – Sustainable Cycles (UNU-SCYCLE) and the International Solid Waste Association, jointly created the Global E-waste Statistics Partnership to address the challenges associated with managing e-waste. Since January 2022, SCYCLE has been a programme under the United Nations Institute for Training and Research (UNITAR). The Global E-Waste Statistics Partnership is managed by ITU and UNITAR-SCYCLE, see https://globalewaste.org/about-us/.

[6] See https://www.scycle.info/.

4. *Large equipment*: Items such as washing machines, clothes dryers, dish-washing machines, electric stoves, large printing machines, copying equipment and photovoltaic panels;
5. *Small equipment*: Equipment such as 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 and small monitoring and control instruments; and
6. *Small IT and telecommunications equipment*: Items such as mobile phones, global positioning systems (GPS), pocket calculators, routers, personal computers, printers and telephones.

Given rapid progress in digital technologies, and in particular IoT, the **definition of digitalization-related waste** is a **moving target**

Given the focus of this report, it would be desirable to have a subset of the e-waste statistical scope that matches digitalization-related waste. This would require separating electronic equipment from electrical equipment to monitor electronic equipment separately. However, e-waste or WEEE cannot be easily divided into two mutually exclusive categories of "waste electronic equipment" and "waste electrical equipment", as there is no statistical definition for these separate categories.

Based on the six categories listed above, category 2 (screens and monitors) and category 6 (small IT and telecommunications equipment) are considered to be the most relevant for the purposes of this report. They are therefore used as a proxy for digitalization-related waste. Their composition and prime functionality mostly rely on aspects related to digitalization, such as automated data processing and visualization. Thus, the statistical analysis in this chapter focuses on these two categories, which together are referred to as "waste of screens, computers and small IT and telecommunications equipment", or "SCSIT waste".[7]

This proxy does not cover all aspects of digitalization-related waste. Conceptually, white goods and refrigerators that are connected to the Internet should fall under digitalization-related waste, as should the e-waste of data centres and servers. However, it is neither possible to extract such information from statistical data sets, nor to make reasonable estimates at the country level.[8] Given rapid progress in digital technologies, and in particular IoT, the definition of digitalization-related waste is a moving target. Non-electrical and electronic equipment or equipment that in the past was electrical, have become, or are becoming electronic goods. For instance, vacuum cleaners are increasingly digital and becoming robotic, and white goods are increasingly becoming connected to the Internet. This could also be the case for vehicles in the future as they are increasingly manufactured with electronic components, although to date they have been classified in statistics as end-of-life vehicle waste and not as e-waste.

Moreover, current e-waste statistics do not include batteries, which follow a different waste management path and are often regulated under dedicated battery waste legislation. However, it can be expected that the waste from batteries in electronic equipment will show similar trends as the equipment itself. Nevertheless, waste from batteries is covered separately under the

7 The terms "digitalization-related waste" and "waste of screens, computers and small IT and telecommunication equipment" (SCSIT) are used in this report only for analytical purposes and do not imply any position from UNCTAD either from the legal or the statistical perspective. Moreover, although some of the discussions in this chapter may equally apply to e-waste and to digitalization-related waste, the latter term is used, given the focus of the report.

8 The detailed description of the product classification, presented in Forti et al. (2018), includes United Nations University subcategory 0307, professional IT equipment (e.g., servers, routers, data storage, copiers). However, statistics are not available for all the components that allow for the calculation of e-waste. The underlying data sets of the Global E-Waste Monitor show that the amount of sub-category 0307 equipment in e-waste generation globally is less than 5 per cent of the total of the aggregate of SCSIT waste. Thus, the latter may still be considered a suitable proxy.

Basel Convention, as it contains hazardous materials and is highly flammable.

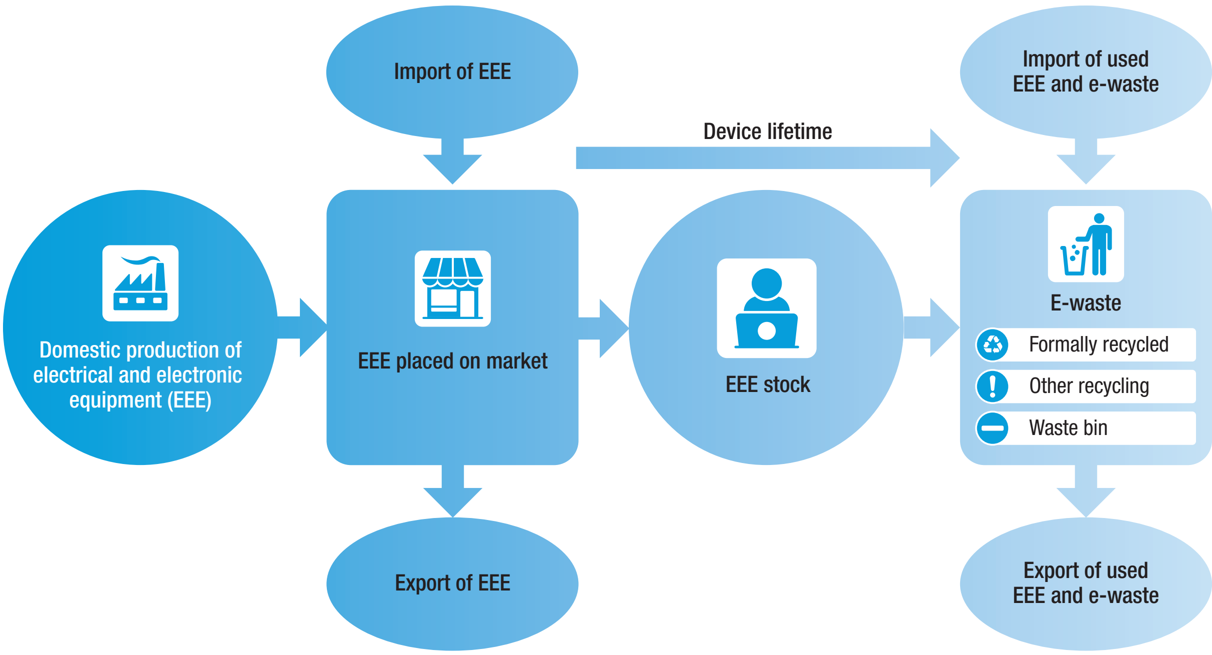
In addition, the waste that Internet and telecommunications satellites generate in outer space can also be considered digitalization-related waste (see section C) but is not included in e-waste statistics.[9]

Overall, it can be concluded that not all e-waste is categorized as digitalization-related waste, nor does all digitalization-related waste qualify as e-waste. The framework for measuring e-waste statistics developed in Forti et al. (2018), shown in figure IV.1, provides a useful basis for understanding how digitalization-related waste is generated.

Electrical and electronic equipment placed on market is the result of domestic production plus imports, minus exports. The equipment sold is added to the stock of EEE in use by consumers, businesses and the public sector, i.e. users. This use lasts for the lifespan of the equipment, including second-hand reuse, repair within the country and dormant time. However, if a second-hand functioning product is exported, it leaves the stock of the exporting country, while entering the stock of the importing country for the remainder of its lifetime (see section G). At the end of its lifespan, EEE is discarded and becomes "e-waste generated", which is the total amount of e-waste before any waste management activity takes place.

Out of the overall volume of generated e-waste, there is a part that is environmentally soundly managed. This is collected separately by formal entities, which can be designated organizations, producers, recyclers or the public sector. Collected e-waste is processed in dismantling and treatment facilities as regulated under the corresponding national legislation on e-waste. This can be considered formally managed waste.

Figure IV.1
From electrical and electronic equipment to e-waste



Source: UNCTAD, based on Forti et al. (2018).

9 An additional element would be the waste generated by military electronics, but this issue is beyond the scope of this report.

However, the remaining part, which is normally substantial, can follow different management routes:

- E-waste may be disposed of and managed together with metal-containing waste to reclaim the ferrous metal and easy to reclaim non-ferrous metals;
- Valuable items may be selectively scavenged by the informal sector and separately treated;
- E-waste may be disposed of in residual waste bins to be managed by incineration facilities or end up in landfills; and
- E-waste can be exported to other countries.

C. Trends in digitalization-related waste

Having statistics that properly reflect the situation with regard to digitalization-related waste is essential for its management

Tracking the entire life cycle and global trends in digitalization-related waste is not an easy task. Most e-waste, including the part related to digitalization, is not formally managed, recorded or documented, escaping scrutiny or monitoring. This is because there are significant e-waste activities in the informal sector and in the context of illegal trade. Many users do not follow formal procedures to dispose of this waste to ensure that it is properly managed in an environmentally sound manner.

Nevertheless, there has been progress in measuring e-waste, especially in the context of the Global E-Waste Statistics Partnership and the e-waste statistics measurement guidelines (Forti et al., 2018). The Global E-Waste Monitor series, which is led by UNITAR, ITU and other partners, was launched by the UNU-SCYCLE programme in 2015 and represents the main source of statistics on e-waste, globally.[10] This measurement framework provides a standard methodology for statistics to be available and comparable around the world. The Global E-Waste Monitor for 2020 highlights that only 41 countries were using this methodology and producing their own national statistics (Forti et al., 2020). Statistics for the remaining countries are estimated by UNITAR, using a similar methodology and official statistical data sets from those countries. Having statistics that properly reflect the situation with regard to e-waste, as well as other digitalization-related waste, is essential for policymakers and other relevant stakeholders to make informed decisions and to manage such waste in an environmentally sound manner. Countries should strengthen their efforts to measure such waste to better deal with risks and to reap the potential benefits arising from proper waste management.[11]

As indicated in the previous section, the proxy used in this analysis is the sum of categories 2 and 6 of e-waste statistics, SCSIT waste. Although the results are to be taken with caution, they provide a useful indication of the evolution of digitalization-related waste globally and by region, in terms of development levels. When extrapolating these trends, it is likely that overall digitalization-related waste trends follow similar geographical patterns as those presented in table IV.1, even if the amounts are larger than for SCSIT waste alone.

The table shows the evolution of SCSIT waste in absolute volumes as well as in per capita terms between 2010 and 2022. During this period, the volume increased globally by 30 per cent, from 8.1 million

[10] See https://ewastemonitor.info/global-e-waste-monitors/.

[11] Challenges in relation to e-waste statistics, as part of overall waste statistics, are discussed in UNECE (2022a).

tons to 10.5 million tons.[12] In developed countries, the increase was 11 per cent and in developing countries, 48 per cent. Lower growth in developed countries reflects the fact that these markets may be close to maturity in relation to existing digital devices and equipment, while developing countries are still expanding their digital sectors and reducing digital divides to be able to benefit from rapid digitalization trends. Accordingly, the share of developed countries in global SCSIT waste generation decreased from 48.6 to 41.5 per cent between 2010 and 2022.

The top three generators of such waste in 2022 were China (20.9 per cent), the United States (13.9 per cent) and the European Union (12 per cent). In absolute volume terms, these three economies generated more than 4.9 million metric tons of SCSIT waste, which was almost half of the world total.

The share of developing countries in global SCSIT waste generation increased from 51.4 to 58.5 per cent over the same period. Developing countries in Asia generated most of such waste in 2022, with China representing almost half of the waste generated in this region. India exhibited the highest growth rate in the volume of such waste, at 163 per cent, more than doubling its share in the world total, from 3.1 to 6.4 per cent.

By contrast, the share of developing countries in Latin America and the Caribbean in global SCSIT waste generation was relatively stable, reaching 9 per cent in 2022. Africa accounted for the lowest share in the world total, at 5.9 per cent. In developing countries in Oceania, the volume of SCSIT waste was negligible. Moreover, LDCs generated very small volumes, accounting for just 2.3 per cent in 2022.

A more complete picture of the evolution of SCSIT waste emerges from considering per capita trends in kilograms. Between 2010 and 2022, SCSIT waste per capita increased globally from 1.16 to 1.33 kg, a growth of 14 per cent, with significant differences between countries. In developed countries, it was 3.25 kg in 2022, 3.5 times the per capita SCSIT waste in developing countries (0.93 kg). This significant gap reflects the digital divide between developed and developing countries in terms of access, affordability and use of digital devices and equipment, and the higher level of demand in developed countries (see chapter II).

This may also reflect overconsumption of digital devices and equipment in developed countries, which suggests greater potential to reduce the generation of waste through more environmentally responsible and rational consumption and use. Overconsumption can be defined as “excessive consumption or use of goods and services (energy, land, water or materials) that cause harm or detrimental effects to humans and/or the environment, namely by exceeding the carrying capacity and life-supporting systems of the planet and its ecosystems”.[13] To define excessive consumption, defining sustainable consumption would be required.

Sustainable Development Goal 12 focuses on ensuring sustainable consumption and production patterns. Sustainable consumption and production refers to “the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations”. In other words, this can be summarized as “doing more and better with less”.[14]

Overconsumption in the digitalization era can, for example, be linked to the frequent

[12] As a comparison, according to the Global E-Waste Monitor 2024, total e-waste amounted to 62 million tons in 2022 (Baldé et al., 2024).

[13] See https://www.eionet.europa.eu/gemet/en/concept/15382.

[14] See https://www.unep.org/explore-topics/resource-efficiency/what-we-do/sustainable-consumption-and-production-policies.

Table IV.1
Digitalization-related waste, by volume and per capita, selected country groupings, countries and years

	Volume (Millions of metric tons)				Growth (Percentage)	Share in world (Percentage)				Per capita (kg)				Growth (Percentage)
	2010	2015	2019	2022	2010–2022	2010	2015	2019	2022	2010	2015	2019	2022	2010–2022
World	**8.070**	**9.801**	**10.345**	**10.508**	*30*	**100.0**	**100.0**	**100.0**	**100.0**	**1.16**	**1.33**	**1.34**	**1.33**	*14*
Developed economies	**3.924**	**4.515**	**4.511**	**4.358**	*11*	**48.6**	**46.1**	**43.6**	**41.5**	**3.02**	**3.41**	**3.36**	**3.25**	*7*
United States	1.233	1.477	1.498	1.466	*19*	15.3	15.1	14.5	13.9	3.92	4.50	4.43	4.29	*10*
European Union	1.223	1.351	1.322	1.261	*3*	15.2	13.8	12.8	12.0	2.77	3.04	2.96	2.81	*1*
Japan	0.466	0.507	0.484	0.453	*-3*	5.8	5.2	4.7	4.3	3.63	3.98	3.84	3.66	*1*
United Kingdom	0.279	0.297	0.302	0.282	*1*	3.5	3.0	2.9	2.7	4.44	4.54	4.50	4.16	*-6*
Republic of Korea	0.103	0.137	0.152	0.159	*54*	1.3	1.4	1.5	1.5	2.11	2.68	2.94	3.06	*45*
Canada	0.130	0.155	0.157	0.152	*17*	1.6	1.6	1.5	1.4	3.84	4.34	4.19	3.96	*3*
Australia	0.085	0.109	0.113	0.110	*30*	1.0	1.1	1.1	1.0	3.84	4.58	4.47	4.21	*10*
Developing economies	**4.146**	**5.286**	**5.834**	**6.150**	***48***	**51.4**	**53.9**	**56.4**	**58.5**	**0.73**	**0.87**	**0.91**	**0.93**	***27***
Developing economies, Africa	0.425	0.560	0.606	0.621	*46*	5.3	5.7	5.9	5.9	0.40	0.47	0.46	0.44	*8*
Egypt	0.091	0.115	0.124	0.128	*40*	1.1	1.2	1.2	1.2	1.05	1.18	1.17	1.15	*10*
Nigeria	0.047	0.080	0.091	0.097	*108*	0.6	0.8	0.9	0.9	0.29	0.44	0.45	0.44	*53*
South Africa	0.062	0.077	0.081	0.081	*29*	0.8	0.8	0.8	0.8	1.21	1.38	1.39	1.35	*12*
Developing economies, Asia	3.031	3.863	4.304	4.584	*51*	37.6	39.4	41.6	43.6	0.76	0.91	0.98	1.02	*35*
China	1.547	1.918	2.092	2.195	*42*	19.2	19.6	20.2	20.9	1.15	1.38	1.47	1.54	*34*
India	0.254	0.402	0.549	0.668	*163*	3.1	4.1	5.3	6.4	0.20	0.30	0.40	0.47	*131*
Indonesia	0.259	0.315	0.327	0.328	*27*	3.2	3.2	3.2	3.1	1.06	1.22	1.21	1.19	*12*
Developing economies, Americas	0.688	0.860	0.921	0.941	*37*	8.5	8.8	8.9	9.0	1.20	1.42	1.46	1.46	*22*
Brazil	0.246	0.309	0.325	0.325	*32*	3.1	3.2	3.1	3.1	1.25	1.51	1.53	1.51	*21*
Mexico	0.148	0.177	0.194	0.206	*39*	1.8	1.8	1.9	2.0	1.31	1.48	1.55	1.61	*23*
Argentina	0.058	0.073	0.077	0.077	*32*	0.7	0.7	0.7	0.7	1.42	1.70	1.72	1.69	*19*
Developing economies, Oceania	0.002	0.003	0.004	0.004	*54*	0.0	0.0	0.0	0.0	0.24	0.29	0.29	0.29	*19*
Papua New Guinea	0.001	0.002	0.002	0.002	*119*	0.0	0.0	0.0	0.0	0.13	0.18	0.20	0.21	*64*
Fiji	0.001	0.001	0.001	0.001	*10*	0.0	0.0	0.0	0.0	1.11	1.34	1.31	1.19	*8*
Solomon Islands	0.000	0.000	0.000	0.000	*106*	0.0	0.0	0.0	0.0	0.11	0.15	0.17	0.17	*54*
Commonwealth of Independent States	**0.278**	**0.341**	**0.354**	**0.359**	**29**	**3.4**	**3.5**	**3.4**	**3.4**	**1.24**	**1.48**	**1.50**	**1.51**	**21**
Russian Federation	0.210	0.252	0.260	0.263	*25*	2.6	2.6	2.5	2.5	1.47	1.74	1.78	1.81	*24*
Memo items														
Developing economies, excluding China	2.599	3.369	3.742	3.954	*52*	32.2	34.4	36.2	37.6	0.60	0.72	0.75	0.77	*27*
LDCs	0.145	0.200	0.227	0.241	*66*	1.8	2.0	2.2	2.3	0.17	0.21	0.22	0.21	*24*
Developing economies, excluding LDCs	4.000	5.087	5.607	5.909	*48*	49.6	51.9	54.2	56.2	0.83	1.00	1.05	1.08	*30*

Source: UNCTAD calculations, based on data from UNITAR-SCYCLE.

Notes: Digitalization-related waste refers to SCSIT waste which is the sum of categories 2 and 6 of the e-waste statistics. Countries inside the regions are ranked in terms of absolute value of waste generated.

replacement of functional devices, driven by consumerism and aggressive marketing that promotes marginal upgrades. Another example is the destruction of unsold electronics (Hynes, 2022). Such behaviours not only fuel demand for materials but also contributes to e-waste. Programmed obsolescence further exacerbates this issue by diminishing the durability and repairability of ICT goods (see section D).

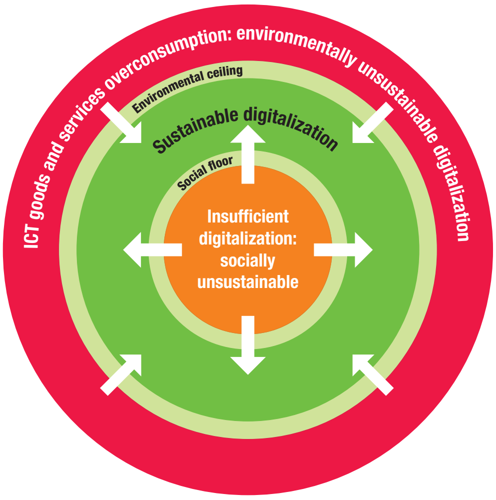
This pattern of excess consumption is closely related to broader socioeconomic inequality, of which digital divides are both a symptom and a cause (see chapter II). While in most developing countries only a limited number of digital devices (predominantly mobile phones) are used to meet various needs, households in developed countries often have multiple devices per person.

Moreover, digital corporations' strategies to extend user engagement and monetize the data generated perpetuate overconsumption (Marry and Souillot, 2022; Wu, 2017). There are now therefore more calls to embrace a sufficiency-oriented lifestyle that prioritizes meaningful needs-based consumption that can mitigate the environmental impact of overconsumption (Wiedmann et al., 2020).

Moving towards sustainable digitalization would require that those overconsuming moderate their consumption of devices, so that the part of the global population that is not sufficiently connected can continue to digitalize for development. This can be illustrated as in figure IV.2, which is based on the concept of doughnut economics (Raworth, 2017).[15] In this context, there would be moves towards increasing digitalization among those countries lagging behind, and efforts to reduce the excessive consumption of digital products in more affluent parts of the world. The inner circle illustrates the scenario of insufficient digitalization – which is socially unsustainable – and which falls below the threshold of what could be considered as the social floor, or baseline of digitalization.

This does not imply that the objective should be to reach the unsustainable levels of digitalization and overconsumption of digital devices. Such a scenario would require mining several Earths to meet the associated material demand.[16] On the contrary, overconsumption of ICT goods and services, represented by the outer circle of the figure, should be reduced to avoid bypassing the Earth's environmental ceiling. The objective of society should be to attain the middle circle of sustainable digitalization. This would also be in line with ideas of "digital sufficiency" and "digital sobriety" (Santarius et al., 2023; Hynes, 2022; Ferreboeuf, 2019). IPCC (2022b: 35) defines sufficiency policies as "a set of measures and daily practices that avoid demand for energy, materials, land and water while

Figure IV.2
Conceptual illustration of sustainable digitalization



Source: UNCTAD, based on Wiedmann et al. (2020).

Achieving sustainable digitalization requires the moderation of overconsumption, allowing those not sufficiently connected to digitalize for development

[15] The doughnut concept highlights the dependence of human well-being on a healthy environment and stresses the need for improved equity in incomes and resource use, and greater efficiency in the latter. It has been used in the context of evaluating progress on achieving the Sustainable Development Goals and by several United Nations organizations. See, for instance, UNEP (2019a: 20).

[16] As noted by Consumers International (2020), if everyone lived the lifestyle of the average person in Western Europe, there would be a need for three planets; if the lifestyle of the average person in the United States was the model, there would be a need for five planets.

delivering human well-being for all within planetary boundaries".

In developed countries, the highest levels of SCSIT waste generated per capita in 2022 were reported for Norway (5.06 kg) and Switzerland (4.66 kg).[17] Among the countries included in table IV.1, an average inhabitant in Australia, the United Kingdom and the United States generated more than 4 kg of such waste in the same year.

All developing economy regional groupings, except Africa, exhibited higher growth in per capita terms compared with developed economies and the world. The highest amount of SCSIT waste generated per capita among developing countries in 2022 was in Latin America and the Caribbean, with 1.46 kg, which can be compared with 0.29 kg in Oceania. In China, the amount of such waste generated was, on average, 1.54 kg. Per capita SCSIT waste in Africa was 0.44 kg, but this average masks large differences in the region, for example, the amount in Egypt was 1.15 kg, while it was 1.35 kg in South Africa. Moreover, in LDCs, the amount of per capita SCSIT waste increased from 0.17 kg in 2010 to 0.21 kg in 2022. Accordingly, in 2022, the average citizen from developed economies generated 15.5 times more SCSIT waste than the average citizen in LDCs.

Unequal waste trends between developed and developing countries are expected to continue, driven by asymmetries in demand for devices

These unequal waste trends are expected to continue, driven by the growing demand for electronic devices and equipment, and their asymmetric distribution between developed and developing economies (see chapter II).

Digitalization-related waste is expected to continue to grow rapidly as it has done in recent years. According to Baldé et al. (2024), e-waste amounts are projected to further increase from 62 million tons in 2022 to 82 million tons in 2030. For SCSIT waste, the increase is projected to be from 10.5 to 11.2 million tons, over the same period.[18]

Another aspect of digitalization-related waste, which is not reflected in the statistics of the Global E-Waste Statistics Partnership, is the growing concern with waste in outer space. As discussed in chapter II, satellites are increasingly used for digitalization-related purposes. This is contributing to the problem of "space debris" (box IV.2).

Waste from data centres is another important component of digitalization-related waste, which is not fully captured in e-waste statistics. Fast data centre growth has a significant environmental impact through the increased generation of associated waste (Murino et al., 2023). Rapidly refreshing technologies in data centres contributes to the global e-waste challenge (ITU and World Bank, 2023; ITU, 2021). While some operational good practices to improve energy efficiency with existing equipment are being implemented (see chapter III), significant energy efficiency gains have been achieved by replacing older, less efficient hardware with newer, more efficient hardware. Servers in large data centres are typically replaced every three to five years, which can result in increased operational energy efficiency.[19] While hardware refresh cycles may be getting longer, the potential waste from data centres could be significantly reduced if companies could slightly compromise on having the latest and greatest machines, to allow for a longer usable lifespan (Swinhoe, 2022). An additional major factor for large generation of waste in data centres is the destruction of hard drives for reasons of data security. Progress in data sanitization methods and techniques can allow for fast and secure removal of all data on a device, enabling second use and reduced waste (Hands et al., 2022).[20]

A significant activity in some data centres is cryptocurrency mining. Bitcoin mining with specialized mining hardware, which

17 UNCTAD analysis based on UNITAR-SCYCLE.

18 Data provided by UNITAR-SCYCLE.

19 According to the survey by Davis et al. (2022), the typical time between refreshes was five years in 2022, compared with three years in 2015.

20 See also *Financial Times* (2022).

Box IV.2
Digitalization-related waste in outer space

The outer space environment has been impacted by major trends over the last decade, including renewed exploration and use of outer space, a growing number of objects in orbit, decreasing costs of launching them and the increasing presence of the private sector. This can provide significant opportunities for humanity, but also heightened risks. The increase in space debris that this entails is a major global concern. The large number of satellites being launched into low-earth orbit, which tend to have shorter life spans than other types of satellites, will aggravate this challenge. However, there is no international mechanism to monitor space debris or facilitate its retrieval yet.

According to the United Nations (2023a), there are more than 24,000 objects of 10 cm or larger in space and circling the Earth. There are 1 million objects smaller than 10 cm, and likely more than 130 million objects smaller than 1 cm. Another important problem with space debris is its velocity. Even very small objects, travelling at more than 28,000 km per hour, can cause significant damage. The potential destruction of ICT-related satellites could dramatically affect communications on Earth. The Inter-Agency Space Debris Coordination Committee (2023) reports that post-mission disposal compliance remains low.

Moreover, the risks are compounded by what is called the “Kessler syndrome” (United Nations, 2023a); with an increasing density of objects in orbit, the likelihood of collisions increases, with each one creating more debris in a chain reaction, leading to exponential increases. This raises the challenge of orbital pollution. Overall, security, safety and sustainability in space are compromised.

Objects without control in space may end up falling to Earth, which can be a danger for people and the planet. Part of the mass may vanish through combustion when entering the atmosphere. But part of it will reach Earth. For controlled deorbiting of space debris, Point Nemo in the Pacific, the location in the ocean that is farthest from land, is considered the “spacecraft cemetery”. This has impacts on the local marine environment (De Lucia and Iavicoli, 2019).

There is increasing congestion and competition in outer space. Considering that space is a global commons, its governance goes beyond the jurisdiction of a single State. The private sector is exploring the development of constellations of thousands of new satellites, which can hamper access and use for future generations. Technology for space debris removal or remediation is currently in development. Yet there are important legal issues that need to be considered, such as jurisdiction, control, liability and responsibility for space pollution. And, given the cost of recovery or recycling, there may not be enough incentives for the private sector to ensure recovery. Increasing concerns about space sustainability and the need to address the space debris challenge are illustrated by the fact that the United States Federal Communications Commission (2023) has issued its first fine to a company that violated its anti-space debris rule. Moreover, this can be considered as sending a strong signal to other companies (O’Callaghan, 2023).

Governance arrangements for outer space need to be updated, as most of the existing rules were established when activity in space was exclusively carried out by States. Moreover, these rules only provide general guidance. Some progress has been made, for example with the 2019 Guidelines for the Long-term Sustainability of Outer Space Activities, but more needs to be done. The guidelines highlight that the “proliferation of space debris, the increasing complexity of space operations, the emergence of large constellations and the increased risks of collision and interference with the operation of space objects may affect the long-term sustainability of space activities. Addressing these developments and risks requires international cooperation by States and international intergovernmental organizations to avoid harm to the space environment and the safety of space operations”. The United Nations Committee on the Peaceful Uses of Outer Space pays particular attention to the issue of preventing and minimizing the creation of space debris. For example, it prepares a compendium of space debris mitigation standards adopted by States and international organizations (United Nations Office for Outer Space Affairs, 2023).

The increase in space debris is a major global concern, aggravated by large numbers of satellites being launched into low-earth orbit

In the report, *Our Common Agenda*, the United Nations Secretary-General notes that "consideration could be given to a multi-stakeholder dialogue on outer space as part of a Summit of the Future… bringing together Governments and other leading space actors. The dialogue could seek high-level political agreement on the peaceful, secure and sustainable use of outer space, move towards a global regime to coordinate space traffic and agree on principles for the future governance of outer space activities" (United Nations, 2021a: 62).

Source: UNCTAD, based on sources cited.

cannot be easily repurposed for other computing tasks, has a considerable impact on e-waste generation. Given the enormous amount of energy use in bitcoin mining, operators are incentivized to use the latest, most powerful and energy-efficient hardware. Although this can reduce energy use, it comes at the expense of e-waste. It has been estimated that bitcoin mining operations generate over 3.7 tons of e-waste annually (de Vries and Stoll, 2021).

D. Factors driving the growth of digitalization-related waste

The linear model of production leads to a **throwaway culture without incentives to limit** the generation of digitalization-related waste

The growth of digitalization-related waste can be related to a number of factors:

- *Increasing consumption* of electronic devices and ICT equipment due to society digitalizing at a rapid pace. This is linked to population and economic growth, higher levels of disposable income and more people being connected to and using the Internet, as well as changing lifestyles. Moreover, as incomes increase, individuals are more likely to own several devices;
- *Declining prices* of digital devices and ICT equipment;
- *Limited awareness* among the population about the waste associated with digital devices and ICT infrastructure and its adverse effects on human health and the environment when this is not properly disposed of; and about potential benefits for society when e-waste is properly managed;
- The *linear model of production*, based on take/extract–make–use–waste, leads to a throwaway culture that does not incentivize consumers or producers to prevent or reduce the generation of digitalization-related waste. A lack of or insufficient implementation of policies to enable and regulate activities linked to reducing, reusing and recycling digitalization-related waste also plays a major role;
- *Inability to repair* devices and equipment and a lack of repair options. This is linked to the complexity in design of the products. In most devices, components cannot be separated because they are glued together. As the components are not assembled into a modular product, it is not possible to easily replace parts or components (e.g., batteries) and extend the life of devices. Similarly, barriers to disassembling devices or equipment limit the possibility of using components that could still be functional if they were properly separated and reintegrated back into the production cycle for remanufacturing or refurbishing. A design that favoured such activities would help reduce the consumption of electronic products and decrease digitalization-related waste generation. Large manufacturers may also impose

limitations on independent repairers. Although some manufacturers may offer self-repair kits, devices remain difficult and costly to repair;

- *Shorter life cycles* of the devices and ICT equipment, in what may be called "fast tech", reflecting the tendency to change the equipment increasingly often. For example, the European Environmental Bureau (2019) notes that typical product lifetimes are four to five years for laptops and three years for smartphones; this contrasts with estimates suggesting that an optimal lifetime to mitigate the global warming potential of such products would be in the range of 20 to 44 years for laptops and between 25 and 32 years for smartphones.[21]

The "fast tech" factor is probably one of the most significant contributors to the increased generation of digitalization-related waste in recent years. The rapid evolution of digital technologies can shorten the lifespan for the use of digital devices and ICT equipment, as new, better-performing models replace existing ones and render them obsolete. Commercial practices by private companies, such as promotions by telecommunications companies offering devices at a low cost or for free as part of subscriptions, negatively affect digitalization-related waste reduction efforts. Moreover, manufacturers often lock devices to specific peripheral components, such as cables and chargers that are not standardized and therefore do not allow for interoperability with devices from different manufacturers.

Some activities heavily rely on digital devices and ICT equipment and require more frequent replacement. This is the case of data centres, including data centres for cryptocurrencies and other blockchain technologies, as they operate at all hours and require technologies that cannot easily be repurposed for other uses, as discussed above.

Overall, the lifespan of devices and equipment is linked to the concept of obsolescence. If this is intentionally integrated by the manufacturer, it is known as planned, programmed or built-in obsolescence, which is commonly used in the market of consumer electronics (Bisschop et al., 2022). This business strategy results in devices and equipment being manufactured in such a way that they prematurely grow out of use. Thus, high repair costs, difficulties in repairing, limited availability of spare parts and marketing tactics all lead consumers into product replacement instead of keeping the devices for longer (box IV.3). It is estimated that in Europe, average actual lifetimes of electronic devices are at least 2.3 years shorter than either their designed or desired lifetimes (European Environment Agency, 2020).

The origin of the idea of planned or built-in obsolescence can be traced to December 1924, when the world's largest producers of incandescent light bulbs colluded to artificially limit the lifespan of their products. This practice was developed during the crisis years at the end of the 1920s and was a way to induce people to buy an ever-increasing variety of consumer goods, not only for practical use but to stimulate the faltering economy at the time.[22]

Different types of obsolescence have been identified, such as:[23]

- *Technical, functional or structural obsolescence*, which is when a device no longer works because one of its essential components has a limited lifespan and cannot be removed and replaced;
- *Software obsolescence*, which relates to software updates and support. Technical support may be limited or there is incompatibility between versions.

The rapid evolution of digital technologies shortens the lifespan of devices as new models render existing ones obsolete

[21] See also https://quantumlifecycle.com/en_CA/blog/whats-the-average-lifespan-of-your-electronics.

[22] See Bisschop et al. (2022), Franklin-Wallis (2023) and *The Guardian* (2020).

[23] For more discussion on the obsolescence of electronic goods, see Alfieri and Spiliotopoulos (2023), Bachér et al. (2020), Bhanarkar (2022) and https://www.stopobsolescence.org/.

Updating may impact the functionality of devices; and

- *Aesthetic, psychological, perceived or cultural obsolescence* is linked to a constant search for innovation, for producers to always manufacture and commercialize new, rapidly changing devices and for consumers to have the latest model. This need for the newest model is encouraged by marketing and advertising by manufacturing companies to boost sales, even though advances in these new devices may be marginal. This kind of obsolescence is linked to fashion movements that promote having the latest devices and upgrades.

Box IV.3
The reality of programmed obsolescence

The concept of programmed obsolescence remains controversial. Some may be argued that there is insufficient evidence to support its existence. In fact, demonstrating intention to shorten the lifespan of a product is not possible as manufacturers are unlikely to affirm it. However, this does not imply that it does not exist. Millions of consumers around the world have witnessed the declining life of devices and experienced difficulties in repairing them. Moreover, various digital device manufacturers have shown that devices can be designed for a longer life, while being easily repairable at a reasonable cost, or reused, remanufactured, refurbished or recycled (*The Washington Post*, 2022a). Thus, since there are ways to prolong lifespans of devices, it may be inferred that those devices with shorter lifespans are designed with such an intention.

Moreover, there are some documented cases of programmed obsolescence, whereby manufacturers have faced lawsuits and decisions by authorities, which have led companies settling or being fined. A well-known case, referred to as "batterygate", involved an agreement by Apple to pay $500 million, starting in 2024 following charges of intentionally slowing down older mobile phone models (Brady, 2023; Cooper, 2024). Apple and Samsung have both been fined by the Competition Authority of Italy, and Apple has also faced fines in France. The companies were charged for intentionally slowing down phones through software updates that forced consumers to replace batteries or purchase new devices. Similarly, Apple was fined in Chile on smartphone programmed obsolescence.[a] Epson settled a class action suit on the suspension of the function of printers even when cartridges were not yet empty, as has Hewlett Packard, with regard to a chip that indicated that ink cartridges were to be replaced before they were empty (Bisschop et al., 2022; Malinauskaite and Erdem, 2021). Regarding software support-related obsolescence, the abandonment of Windows 10 support by Microsoft could render obsolete about 40 per cent of the personal computers in use; estimates of the numbers of personal computers to be discarded range from 240 to 400 million, depending on the source (Gutterman, 2023a; *Reuters*, 2023a).

Additionally, the United States Federal Trade Commission (2021) highlighted various repair restrictions used by manufacturers, including physical restrictions; unavailability of parts, repair manuals, and diagnostic software and tools; designs that make independent repairs less safe; application of patent rights and enforcement of trademarks; disparagement of non-original equipment manufacturer parts and independent repair; software locks, digital rights management and technical protection measures; and end-user licence agreements. The report concludes that "there is scant evidence to support manufacturers' justifications for repair restrictions". Reasons that companies have cited to oppose repairs include the protection of intellectual property rights and reputation; as well as effects on safety and security (Stone, 2023).

Concerns about planned obsolescence and limits to the right to repair are increasing around the world. Civil society movements such as Stop Planned Obsolescence, Right to Repair and Public Interest Research Group are active in raising awareness on this matter, putting pressure on manufacturers and policymakers to address the issue.[b] This is translating into the design and adoption of policies to address planned obsolescence and the related right to repair in many countries. After having opposed the right to repair for some time (Green, 2021), device manufacturers seem to be starting to turn the tide towards supporting it (Stone, 2022). For

Concerns about planned obsolescence and limits to the right to repair are increasing around the world

example, Microsoft released an independent report highlighting the environmental benefits of fixing devices in terms of the reduction of both waste and emissions associated with manufacturing new devices (Oakdene Hollins, 2022). However, various remaining barriers to repair indicate that there is still a long way to go (Stone, 2023).

The Consumer Information for Sustainable Consumption and Production Working Group on "Product Lifetime Extension to Advance Circularity", under the One Planet Network's SDG 12 Hub led by UNEP and the Akatu Institute, has researched existing policy instruments that aim to make products more repairable and to communicate product reparability information to consumers. Product lifetime extension reduces the replacement of products, lessening resource use and digitalization-related waste generation, as well as preserving the economic value embedded in devices. It also has a beneficial economic development impact as low-income consumers cannot afford to frequently replace devices. In general, consumers would benefit from savings related to keeping devices for longer. The use of removable batteries in Europe would save consumers about $20 billion and reduce GHG emissions by 30 per cent compared with business as usual, according to the International Institute for Industrial Environmental Economics and the European Environmental Bureau (2021). Similarly, in the United States, Proctor (2023) estimates that product lifetime extensions could reduce household spending on electronics and appliances by 21.6 per cent.

UNEP (2017) provides recommendations on the opportunities available to consumers, the private sector and Governments in both developed and developing economies to address product lifetime extensions. Access to product repairability and effectively communicating repairability information to consumers are central factors for achieving the Sustainable Development Goals, in particular targets 12.2 (on the sustainable management and efficient use of natural resources), 12.5 (on the reduction of waste generation) and 12.8 (on ensuring that people have the relevant information and awareness for sustainable development).[c]

UNEP and the Akatu Institute (2021) map countries' policies and regulatory measures, aiming to prolong product lifetimes by designing more durable products, extending desirability or use through maintenance, upgrades and repurposing, and by recovering broken products through repair, refurbishment or remanufacturing. They conclude that engagement in the creation and promotion of policies to encourage resource efficiency as well as policies on waste management have increased over the past two decades. However, more attention needs to be directed to products' design and use phases, as well as measures to address psychological obsolescence. In this context, Consumers International (2019) highlights the following policy and industry actions to increase product lifespan and reduce waste: a law against planned obsolescence, minimum durability criteria, product lifetime labelling, affordable and accessible repairs, right-to-repair legislation, monitoring of trends in product lifetimes and consumer education and information.

Coutherut et al. (2022) show that there are increasing initiatives to address programmed obsolescence. Policies and regulations in this area are emerging, notably in the United States and the European Union.[d] Among developing countries, countries in Latin America appear to be the most active in this policy area. In Asia, India is making advances in moving towards the right to repair (Ray, 2023). Policies can promote the repair of products to extend their lifespan while reducing the purchase of new products. Such policies also send a signal to market players to avoid deliberately destroying new devices or reducing device lifespans through programmed obsolescence (Dalhammar et al., 2023).

There have been various calls to ban programmed obsolescence, including by the European Economic and Social Committee (2013) and by various authors, such as Becher and Sibony (2021) and Malinauskaite and Erdem (2021). France was the first country to ban planned obsolescence in 2015 (Perreau, 2023). In Canada, the provincial government of Quebec banned planned obsolescence in 2023.[e] According to Bisschop et al. (2022), programmed obsolescence, whether through hardware, software or difficult repairs, should be considered a form of corporate crime.

All of these actions and initiatives, by both civil society organizations and policymakers, show that programmed obsolescence is a real and serious concern for socioeconomic and environmental reasons and needs to be addressed.

Policies can promote product repair to extend their lifespan, reduce new purchases and avoid programmed obsolescence…

...which is a real and serious concern that needs to be addressed

Source: UNCTAD, based on sources cited.

[a] See https://www.dw.com/es/apple-pagar%C3%A1-en-chile-34-millones-de-d%C3%B3lares-tras-demanda-colectiva/a-57127927.

[b] These organizations, together with media reports, provide, for example, repairability indices and information on product failures, which are useful for consumers to take informed decisions (see Gutterman, 2024; *The Washington Post*, 2022b and https://www.test-achats.be/trop-vite-use). They may also lead manufacturers to produce devices that last longer (Gutterman, 2023b).

[c] See https://www.oneplanetnetwork.org/programmes/consumer-information-scp/product-lifetime-extension, and https://www.oneplanetnetwork.org/news-and-events/news/search-more-repairable-products-policies-aim-make-products-more-repairable.

[d] For the United States, see https://www.whitehouse.gov/briefing-room/statements-releases/2021/07/09/fact-sheet-executive-order-on-promoting-competition-in-the-american-economy/, Seddon and West (2021) and Senkowski et al. (2023). In the European Union, the Parliament adopted the right-to-repair directive on 23 April 2024 (see https://www.europarl.europa.eu/news/en/press-room/20240419IPR20590), as part of the Circular Economy Action Plan. The plan includes various measures to ensure that products become more durable and repairable, and that consumers are empowered to make more sustainable decisions (see https://www.consilium.europa.eu/en/policies/circular-economy/). The European Union is also funding activities by the PROMPT Consortium on Premature Obsolescence Multi-Stakeholder Product Testing Programme (see https://www.oneplanetnetwork.org/knowledge-centre/resources/prompt-consortium-releases-premature-obsolescence-multi-stakeholder-0).

[e] For France, see https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000032225325/2020-02-12, and for Canada, see https://www.publicationsduquebec.gouv.qc.ca/fileadmin/Fichiers_client/lois_et_reglements/LoisAnnuelles/en/2023/2023C21A.PDF.

E. Environmental, health and other social impacts

Digitalization-related waste contains **hazardous materials** which, if not properly handled, can damage the environment and human health

Digitalization-related waste contains hazardous materials which, if not properly handled and treated, can have damaging effects on the environment and human health. Toxic materials include heavy metals and substances such as arsenic, cadmium, lead, and mercury, as well as persistent organic pollutants. At the same time, this rapidly growing stream of solid waste requires special treatment as it also contains valuable parts and materials that can be recovered and recycled. Thus, this treatment can provide livelihoods to workers and incomes to enterprises involved in these activities.

A large part of digitalization-related waste is handled in informal settings, particularly in developing countries. At such informal sites, MSMEs and workers use rudimentary tools and techniques to refurbish the equipment for a second sale or dismantle and process parts to extract valuable material. Such activities contribute to reducing poverty and digital divides as the latter are made more affordable.

However, the suboptimal processes often used in this context lead to the inefficient and insufficient recovery of valuable resources. Workers often lack the necessary skills and knowledge about how to effectively manage digitalization-related waste to recover the maximum potential value. They also experience poor working conditions linked to weak labour rights, lack of social protection schemes and limited opportunities to organize and improve their livelihoods (ILO, 2019b).[24]

When women participate in such informal digitalization-related waste management sectors, they often occupy positions at the lower levels of the working hierarchy. Gender stereotypes may perpetuate misconceptions about their abilities, including assumptions about women being less skilled or having less physical strength. This leads to reduced participation in more lucrative activities. As a result, women are not properly compensated for their time and efforts. Moreover, they often face discrimination and harassment. Overall, women are often marginalized into high-labour, low-paying jobs with little opportunity for growth and progress (UNEP and International Environmental Technology Centre, 2022a, 2022b).[25]

Several unsafe and environmentally unsound practices in the management of digitalization-related waste in informal settings have been observed. These include scavenging, dumping waste on land or in water, landfilling along with regular waste, open burning or heating, acid baths or acid leaching, stripping and shredding plastic coatings and manual disassembling of equipment without proper security measures. As such, informal workers are more exposed to injuries from the manual work they carry out because they often lack protective equipment.

These activities also release toxic pollutants that contaminate air, soil, dust, water, and food, both at digitalization-related waste recycling sites and in neighbouring communities. Burning or heating is considered one of the most hazardous activities due to the generation of toxic fumes. Toxic effects observed in human health include neurodevelopmental, renal, cardiovascular and reproductive damage, as well as cancers, allergies, bone, liver and lung damage, neurogenerative diseases, DNA damage, and endocrine disruption.[26] In addition, when waste is not collected but is disposed of with regular household garbage it leads to the loss of materials and components. The ashes from incineration and residues of landfills also have a high concentration of hazardous elements and require special treatment.

Children and pregnant women are especially vulnerable to the effects of hazardous pollutants from informal digitalization-related waste recycling activities. Exposure to such waste can be associated with various health effects during pregnancy, in infants and among children. These include adverse neonatal outcomes such as increased rates of stillbirth and premature birth; negative neurodevelopmental, learning and behaviour outcomes, especially linked to lead released through informal waste recycling; and reduced lung and respiratory function and increased asthma incidence, which may be due to high levels of contaminated air pollution in many recycling sites. It is estimated that between 2.9 and 12.9 million women may be at risk from exposure to toxic e-waste from work in the informal sector. Additionally, over 18 million children of 5–17 years of age could be involved in industries in which child labour is present, with waste processing as a subsector of many of these industries. The exploitation of children in the informal digitalization-related waste sector is mainly because their smallert

[24] In 2019, the ILO Global Dialogue Forum on Decent Work in the Management of E-waste reached points of consensus to promote decent work in this sector (see https://www.ilo.org/resource/record-proceedings/final-report-global-dialogue-forum-decent-work-management-electrical-and). The work of ILO in connection to decent work in e-waste management is detailed in ILO (2023a). From a more practical perspective, ILO (2019c) provides a manual to assist e-waste workers in improving their safety, health and working conditions.

[25] For further discussions on the environmental and health-related impacts of e-waste, see Baldé et al. (2024), Sonny et al. (2023), Ghulam and Abushammala (2023), Jain et al. (2023), Rajesh et al. (2022) and Ankit et al. (2021). Andeobu et al. (2023) consider informal e-waste recycling and environmental pollution in Africa. Lebbie et al. (2021) focus on e-waste as a threat to the health of children and Park et al. (2017) discuss the effects of electronic waste on developing countries.

[26] For a review of the health consequences of exposure to e-waste, see Parvez et al. (2021). See also https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste).

hands allow them to dismantle the waste more easily than adults (WHO, 2021b).

There can be tensions in developing countries arising from the urgent need in the short term to ensure that waste pickers in the informal sector have a living income and in the longer-term to address risks for health and the environment that arise from the inadequate processing of e-waste.

F. Circular digital economy: Turning waste into resources

Rapid growth in the generation of digitalization-related waste is a growing concern globally, both in developed and developing countries. As the former still produce considerably more waste per capita, the latter are rapidly digitalizing, generating a growing part of this waste. However, persisting digital divides also reflect the uneven capacity to manage the associated waste.

When this waste is properly managed in a safe and environmentally sound manner, environmental and health risks can be minimized or avoided. It is therefore important to take action towards strengthening formal systems of collecting digitalization-related waste. This would also promote the more efficient recovery of valuable resources. However, this is not an easy task. Managing digitalization-related waste poses significant challenges. This is particularly the case in developing countries where there is an absence of formal collection systems to handle such waste sustainably, and often also a lack of relevant facilities for the treatment and reuse of components and products as well as the necessary skills. Even in developed countries, despite better formal collection systems, collection rates are not high enough.

Managing digitalization-related waste is challenging, especially in developing countries

The management of digitalization-related waste primarily targets recycling and resource recovery. These activities are vital for mitigating health-related and environmental risks when performed in an environmentally sound manner. They can also increase the secondary supply of materials, including minerals, for electronics manufacturing. However, recycling and recovery should not be the sole focus. To reduce the generation of waste more effectively, the approach needs to be broadened to include strategies that lower the overall demand for electronic products and their components. This means adhering to core principles within the circular economy, namely reducing consumption and reusing more, with recycling materials and resource recovery as a last resort.

1. Management of digitalization-related waste: Is focussing on recycling and resource recovery enough?

The rapid increase in digitalization-related waste creates significant challenges for its management, notably in developing economies. The analysis of statistics of collected SCSIT waste, presented in table IV.2, shows that globally, formal collection of such waste increased from 1.7 million tons in 2010 to 2.5 million tons in 2022. This represents an increase of 50 per cent over the period, which reflects some progress in this area. However, the increase in global SCSIT waste generation over the same period (2.4 million tons) was about three times the increase in the collection of such waste (0.8 million tons). Thus, progress in SCSIT waste collection for recycling and recovery of materials, including minerals, was not enough to match the increase in the amounts of waste generated.

Developed economies account for about 81.6 per cent of the global formal collection of SCSIT waste, down from 99.6 per cent in 2010. The United States accounted for the highest share, representing 36.5 per cent of the world total collected in 2022, while the European Union accounted for 30 per cent. The share of developing economies was 18.4 per cent, mostly from Asia, which accounted for 17.4 per cent. The share of China was 14.2 per cent of all SCSIT waste collected. The shares of other developing countries are generally negligible.

Additional insights can be obtained from an analysis of collection rates, which are calculated by dividing the volume of SCSIT waste collected by the volume generated (see table IV.1). The collection rate worldwide increased from 20.7 per cent in 2010 to 23.8 per cent in 2022. This implies that less than a quarter of the global SCSIT waste generated in 2022 was formally collected. This leaves more than three quarters of such waste worldwide not formally collected and therefore undocumented.

Collection rates tend to be greater in countries with relatively high levels of waste generation. They are significantly higher in developed economies (averaging 46.8 per cent) than in developing economies (averaging 7.5 per cent). The top collection rates in the world are seen in the United States (62.2 per cent) and the European Union (59.5 per cent). In developing economies, Asia registers the most elevated collection rate (9.5 per cent), with China leading (16.2 per cent). If China is excluded, the average collection rate declines to 2.7 per cent. The collection rate in Africa is 0.8 per cent; with South Africa at 4.3 per cent. In Latin America, the collection rate is 2.1 per cent, with that of Mexico at 3.5 per cent, of Argentina at 2.8 per cent and of Brazil at 0.1 per cent. Thus, there is significant variation within regions. The collection rate for LDCs is 0.2 per cent.

In 2018, ITU member States, as part of the Connect 2030 Agenda for Global Telecommunication/ICT Development, set a global e-waste target for 2023 to increase the global e-waste recycling rate to 30 per cent and to raise the share of countries with e-waste legislation to 50 per cent. They also committed to reducing the volume of redundant e-waste by 50 per cent. Considering the e-waste generated in 2022 and the number of countries with relevant legislation, these targets remain, at present, out of reach (Baldé et al., 2024).

There are several challenges in managing, collecting and recycling digitalization-related waste which are closely linked to the factors explaining growth in such waste (see section D):

- *Complexity of electronic products*: minerals and metals are mixed in alloys, which complicates the separation of the different materials;
- *Recycling and recovering technology*: availability of technology for the recycling and recovery of these complex alloys remains limited;
- *Economic viability*: the high cost of recycling certain metals can outweigh the benefits, even when the technology is available;
- *Legislative framework*: insufficient, or a lack of, legislation leads to low e-waste collection rates, with additional challenges in implementation, monitoring, and enforcement;
- *Limited collection and treatment infrastructure*: infrastructure for proper waste collection and subsequent treatment remains underdeveloped;
- *Worker awareness and training*: particularly in the informal sector, a lack of training in safe and environmentally sound waste treatment practices persists;
- *Consumer awareness*: low awareness of the impacts of improper disposal contributes to reduced recycling rates, exacerbated by sufficient recycling options;

Progress in digitalization-related waste collection for recycling and recovery has not matched the increase in waste generated

Table IV.2
Collection of digitalization-related waste: Volume and collection rate, selected country groupings, countries and years

	SCSIT collected													Legislation		
	Volume (Millions of metric tons)				Growth (Percentage)	Share of global volume (Percentage)				Collection rate (Percentage)				By country	By grouping	Proportion (Percentage)
	2010	2015	2019	2022	2010–2022	2010	2015	2019	2022	2010	2015	2019	2022	2022	2022	2022
World	**1.669**	**2.455**	**2.545**	**2.499**	*50*	**100.0**	**100.0**	**100.0**	**100.0**	**20.7**	**25.0**	**24.6**	**23.8**	..	**82**	*42.9*
Developed economies	**1.663**	**2.048**	**2.106**	**2.039**	*23*	**99.6**	**83.4**	**82.8**	**81.6**	**42.4**	**45.4**	**46.7**	**46.8**	..	**46**	*95.8*
United States	0.590	1.116	0.936	0.911	*54*	35.4	45.5	36.8	36.5	47.8	75.5	62.5	62.2	Yes	..	..
European Union	0.549	0.562	0.794	0.751	*37*	32.9	22.9	31.2	30.0	44.9	41.6	60.1	59.5	..	27	*100.0*
Japan	0.304	0.068	0.068	0.071	*-77*	18.2	2.8	2.7	2.8	65.3	13.4	14.1	15.6	Yes	..	..
United Kingdom	0.109	0.137	0.093	0.079	*-28*	6.5	5.6	3.7	3.2	39.1	46.1	31.0	28.1	Yes	..	..
Republic of Korea	0.027	0.042	0.061	0.076	*178*	1.6	1.7	2.4	3.0	26.5	30.4	39.8	47.6	Yes	..	..
Canada	0.012	0.023	0.020	0.019	*57*	0.7	0.9	0.8	0.8	9.4	14.6	12.7	12.7	Yes	..	..
Australia	0.000	0.012	0.058	0.055	..	0.0	0.5	2.3	2.2	0.0	10.7	51.3	50.3	Yes	..	..
Developing economies	0.006	0.406	0.438	0.460	*7416*	0.4	16.6	17.2	18.4	0.1	7.7	7.5	7.5	..	36	*25.2*
Developing economies, Africa	0.000	0.004	0.005	0.005	*1306*	0.0	0.2	0.2	0.2	0.1	0.8	0.8	0.8	..	11	*20.4*
Egypt	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Yes	..	..
Nigeria	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Yes	..	..
South Africa	0.000	0.003	0.004	0.004	..	0.0	0.1	0.1	0.1	0.0	4.3	4.3	4.3	Yes	..	..
Developing economies, Asia	0.000	0.389	0.415	0.435	..	0.0	15.8	16.3	17.4	0.0	10.1	9.6	9.5	..	15	*33.3*
China	0.000	0.326	0.338	0.355	..	0.0	13.3	13.3	14.2	0.0	17.0	16.2	16.2	Yes	..	..
India	0.000	0.000	0.008	0.010	..	0.0	0.0	0.3	0.4	0.0	0.0	1.4	1.4	Yes	..	..
Indonesia	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No	..	..
Developing economies, Americas	0.006	0.013	0.019	0.020	*239*	0.3	0.5	0.7	0.8	0.8	1.5	2.0	2.1	..	10	*30.3*
Brazil	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	Yes	..	..
Mexico	0.006	0.006	0.007	0.007	*25*	0.3	0.3	0.3	0.3	3.9	3.5	3.5	3.5	Yes	..	..
Argentina	0.000	0.001	0.002	0.002	..	0.0	0.1	0.1	0.1	0.0	1.7	2.8	2.8	Yes	..	..
Developing economies, Oceania	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	..	0	*0.0*
Papua New Guinea	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No	..	..
Fiji	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No	..	..
Solomon Islands	0.000	0.000	0.000	0.000	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No	..	..
Commonwealth of Independent States	**0.000**	**0.017**	**0.023**	**0.024**	..	**0.0**	**0.7**	**0.9**	**0.9**	**0.0**	**5.0**	**6.6**	**6.6**	..	**3**	*37.5*
Russian Federation	0.000	0.016	0.016	0.017	..	0.0	0.7	0.6	0.7	0.0	6.3	6.3	6.3	Yes	..	..
Memo items																
Developing economies, excluding China	0.006	0.080	0.100	0.105	*1613*	0.4	3.3	3.9	4.2	0.2	2.4	2.7	2.7	..	35	*24.6*
LDCs	0.000	0.000	0.000	0.001	..	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	..	7	*15.6*
Developing economies, excluding LDCs	0.006	0.406	0.438	0.459	*7408*	0.4	16.6	17.2	18.4	0.2	8.0	7.8	7.8	..	29	*29.6*

Source: UNCTAD calculations, based on data from UNITAR-SCYCLE.
Notes: Digitalization-related waste refers to SCSIT waste which is the sum of categories 2 and 6 of the e-waste statistics. Countries inside the regions are ranked in terms of absolute value of waste generated. “..” means non applicable. For growth, “..” applies when the increase is from 0.

- *Data and information*: the absence of robust data hampers evidence-based policymaking and the design of effective management systems; and
- *Investment needs*: significant funding, both public and private, is required to address these issues, but is often lacking in developing economies.

Digitalization-related waste collection is therefore highly related to the presence of relevant policies, regulations and legislation. Many Governments around the world have adopted policies and legislation to address the increasing amounts of this waste. To date, 82 countries have an e-waste policy, legislation or regulation in place, representing roughly 43 per cent of countries. This is an increase from 61 countries in 2014 and 78 countries in 2019 (Forti et al., 2020).

While in 2022 there were 46 developed countries covered by legislation, representing 96 per cent of the group total, only 36 developing countries were covered, accounting for just 25 per cent of the total number of countries in the group. In particular, Africa lagged behind, with only one out of five countries having relevant legislation in place. This shows that, while there is ongoing progress, more efforts are needed to design and implement digitalization-related waste policies and regulations.

In a review of recent developments in e-waste legislation around the world, Baldé et al. (2024) show that 68 countries have an instrument containing provisions on extended producer responsibility (EPR). This is one of the most used principles as a foundation of national e-waste management systems. EPR aims to ensure that the producer, importer or distributor has responsibility for a product at the post-consumer stage of its life cycle. Moreover, 62 countries are covered by legislation referring to environment, health and safety standards, 45 countries have e-waste collection targets at the national level and 36 countries have e-waste recycling targets.[27]

E-waste legislation should at least include key provisions addressing clear stakeholder definitions, roles and responsibilities, as well as a clearly defined product scope. There should also be clarity in the stipulations on enforcement measures and penalties for non-compliance, and details on financing mechanisms. Furthermore, there should be clear conditions for organizational mechanisms for electric and electronic equipment producers, together with clear terminology outlining who will cover the cost of managing e-waste (Baldé et al., 2024).[28]

With regard to e-waste, in the European Union, Directive 2012/19/EU on WEEE was being amended in 2023–2024, following a judgment by the Court of Justice in 2022 which declared it partially invalid (European Parliament, 2024).

Reducing waste, including updating the definition of WEEE mentioned above, is a key aim. In this context, the European Union is revising its rules to better regulate trade in waste, both within the European Union and with non-European Union countries, to ensure that waste exports do not harm the environment and human health, and to address illegal shipments. The European Union aims to create a well-functioning market for secondary raw materials and has set an objective of at least 25 per cent of critical raw materials consumption in the European Union each year to come from domestic recycling.[29]

Despite advanced regulations, the rate of recycling remains low in the European Union. The European Court of Auditors (2021) has highlighted that, although there has been progress, countries often face difficulties in enforcing legislation and achieving set targets. Progress was mostly seen in the 2010s and by 2019, the rate of recycling of

[27] On relevant e-waste legislation, see https://globalewaste.org/map/.

[28] ITU provides useful supporting tools for policy making in the context of e-waste. See, for instance, ITU (2018) and ITU and WEF (2021).

[29] See https://www.consilium.europa.eu/en/policies/circular-economy/.

WEEE had reached 40 per cent. However, it declined to 39 per cent in 2021. This is the lowest recycling rate among the different waste streams in the European Union (European Environment Agency, 2023).

Low recycling rates of e-waste are mirrored by low recycling rates of raw materials, including minerals and metals. While a high proportion of bulk metals and minerals such as aluminium/bauxite, cobalt and copper may have relatively high rates of recovery, many transition minerals have very low rates of recycling and recovery, or are not recycled at all in the European Union (Watkins et al., 2023). Considering that the European Union tends to register some of the highest rates of material recycling in the world, rates in most other parts of the world are likely to be lower.

Policies, regulations and legislation have mostly focused on the management of digitalization-related waste through recycling and resource recovery...

...limited attention has been paid to reducing waste

In summary, policies, regulations and legislation have, to date, mostly focused on the management of digitalization-related waste through recycling and resource recovery, as well as measures against environmental pollution or that support the occupational safety and health aspects of such activities.[30] Thus, the current focus is on increasing the secondary supply of materials and minerals and avoiding the negative impacts of such waste. Limited attention has been paid to reducing the volumes of digitalization-related waste, which is the focus of the next subsection. Recycling should be the last resort, and priority should be given to preventing and minimizing such waste and its final disposal. Moreover, from an economic development perspective, policies should seek to enable developing countries to capture more of the value from digitalization-related waste management.

2. Reducing digitalization-related waste: Prevention as the priority

Beyond increasing the secondary supply of materials to complement the primary supply, it is important to pay more attention to activities that can reduce digitalization-related waste volumes and prevent waste generation in the first place. According to the Basel Convention framework for the environmentally sound management of hazardous wastes and other wastes (UNEP, 2013: 9): "…stakeholders should respect the waste management hierarchy (prevention, minimization, reuse, recycling, other types of recovery, including energy recovery, and final disposal). It is recommended that resources and tools be allocated in accordance with the hierarchy. Waste prevention should be the preferred option in any waste management policy. By not generating wastes and by ensuring that the wastes generated are less hazardous, the need to manage wastes and/or the risks and costs associated with doing so are reduced. Prevention, however, will not solve all the problems associated with waste management. Some wastes are already, or will inevitably be, generated and such wastes should be managed in an environmentally sound manner. When prevention and minimization possibilities have been exhausted, reuse, recycling and recovery techniques that deliver the best overall environmental outcomes, in accordance with the best available techniques, best environmental practices and a life-cycle approach, are to be encouraged".[31]

Activities to prevent and minimize digitalization-related waste in line with the

[30] More attention should be paid to the role of labour market policies and the policies of enterprises, cooperatives, employers, workers and ministers of labour or employment in advancing decent work in the management of digitalization-related waste (ILO, 2019c).

[31] This is further developed in the Basel Convention draft guidance to assist parties in developing efficient strategies for achieving the prevention and minimization of hazardous and other wastes and their disposal (UNEP, 2017).

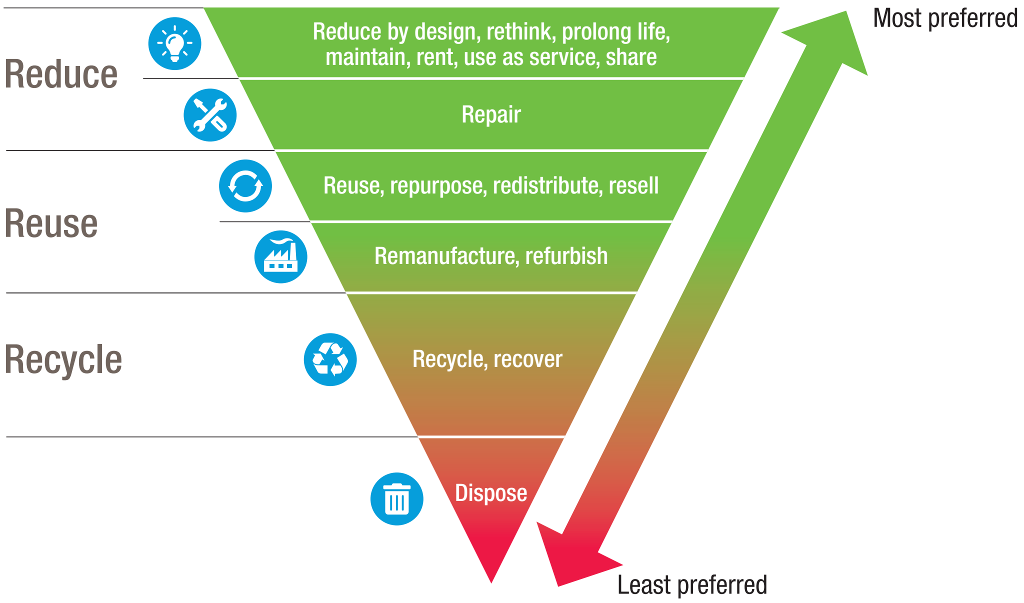
three Rs[32] of the circular economy – reduce, reuse and recycle – include extending the life of devices through sharing, rental or donation; maintenance and repair; resale and redistribution; and remanufacture and refurbish. Such activities can lower demand for new electronic devices and equipment and, in turn, reduce demand for minerals and other materials, ultimately reducing the generation of waste.

This can be illustrated as an inverted pyramid of the digitalization-related waste hierarchy, as shown in figure IV.3. At the top of this inverted pyramid, the preferred options for reducing environmental impact relate to extending the life of devices and equipment, achieved through changes in consumer behaviour and supportive business models. The second most preferred option is repair. Both options align with the overall need to reduce global consumption of electronic products. In the middle of the pyramid, options include reuse-related activities such as reuse, repurpose, redistribute and resell, as well as remanufacture and refurbish. At the bottom of the pyramid, the recycling and recovery of materials are among the least preferred options. Overall, the aim is to minimize the disposal of waste.

There is no generally accepted definition of the circular economy. For instance, Kirchherr et al. (2023) find up to 221 definitions. The circular economy is essentially an alternative model to the linear economy of take/extract–make–use–waste. Resolution 1 adopted by the United Nations Environment Assembly at its fourth session from 11 to 15 March 2019 acknowledges "that a more circular economy, one of the current sustainable economic models, in which products and materials are designed in such a way that they can be reused, remanufactured, recycled or recovered and thus maintained in the economy for as long as possible, along with the resources of which they are made, and the generation of waste, especially hazardous waste, is avoided or minimized,

Reduce, reuse and recycle can lower demand for new devices and, in turn, reduce demand for minerals and other materials, ultimately reducing the generation of waste

Figure IV.3
The digitalization-related waste hierarchy of options for reducing environmental impact



Source: UNCTAD.

[32] Many other circular economy principles based on Rs can be found in the literature. For instance, Uvarova et al. (2023) discuss 60 economy principles classified within the four groups of reduce, reuse, recycle and reverse logistics.

and GHG emissions are prevented or reduced, can contribute significantly to sustainable consumption and production".[33]

A circular economy approach can be seen as an opportunity to recover valuable resources and enable economically beneficial activities

A circular economy approach requires rethinking the whole life cycle of digitalization (see chapter I). It can be seen as an opportunity to recover valuable resources and enable economically beneficial activities. Minimizing the amount of waste generated contributes to environmental sustainability objectives, including reducing the pressure on the primary supply of minerals and other materials. This would help reduce GHG emissions caused by mineral extraction and processing related to manufacturing electronic devices and their final disposal. The following outlines major features of key activities in the circular electronics sector:[34]

Reducing requires that people rethink how they can best meet their needs and achieve their aspirations with minimal impact on the planet and the people around them. This may imply a conscious consumer choice to use functioning items and services for longer, and to buy less frequently.[35] This approach can be implemented at no cost and has significant potential for retaining the value of a product or service for a longer time period. Business models that allow for the rental of devices under "product as a service" schemes can also support consumption reduction.[36]

Refusing is another sustainable lifestyle choice, whereby people buy or use less and decline unnecessary products or services. It can also apply to a specific element of a product, such as refusing to purchase products that have been designed using hazardous substances. Refusing can send a strong signal to the market, helping economies to transition to more circular models.

Direct reuse refers to reusing a product for its original purpose, without needing to repair or refurbish it. Reuse and resell imply that a user chooses to hand the product to another user, usually without an intermediary and without modifying the product or service. It also applies to the use of second-hand products, or products that are reused after refurbishment. Reuse and resell incur little cost and can help the product or service retain its value for longer. As the potential for reuse becomes a selection criterion when purchasing a product, users encourage manufacturers to offer more robust products and materials, with a longer lifetime, hence fostering more sustainable consumption and production patterns.

Repairing refers to fixing a fault in an item (either waste or a product) or replacing defective components, to make the item fully functional again and available for its original purpose. Repair extends the lifespan of a product. A user may send a product to a business intermediary via the retailer to be repaired or take it directly to a repair shop. The product is returned to the user, or provided to a new user, in a fully functional order.

A major barrier to repairing is that most digital devices are not designed to be repaired. Even if a consumer would be willing to do so, it may not be possible. This is linked to programmed obsolescence and a lack of access to repair manuals and components, or costly access to specialized repairers. Thus, the only possibility may be

[33] See https://www.unep.org/environmentassembly/unea-4/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-4 and https://buildingcircularity.org/.

[34] Descriptions of circular economy-related activities are based on the glossary of terms of the Basel Convention (Secretariat of the Basel Convention, 2017) and https://buildingcircularity.org/.

[35] The Product Lifetime Extension Hub of the Programme on Consumer Information of the One Planet Network (available at https://www.oneplanetnetwork.org/programmes/consumer-information-scp/product-lifetime-extension) is a useful tool with which to explore resources that address the extension of the lifetime of products, including in the electronics sector, for a more circular economy.

[36] These are still novel concepts for consumers; a survey of consumers in France, Germany, Italy, the United Kingdom and the United States reveals that only 10 to 15 per cent of consumers would be open to renting (see https://www.kearney.com/service/sustainability/article/-/insights/electronics-as-a-service-a-sustainable-alternative-to-business-as-usual).

to replace the item. In response, the "right to repair" movement is actively advocating for the ability to repair products. This movement began in the United States, where the emphasis is on consumer rights, and has been extended to other parts of the world. In the European Union, emphasis is also placed on repair in relation to the circular economy and the environment (ILO, 2023b). However, regulation in this direction has been met with significant opposition, particularly by big technology companies (Moeslinger et al., 2022).[37]

In 2022, the French Government introduced the Repairability Index, which is included in the law against waste and for the circular economy.[38]

All of these actions are creating increasing pressure on manufacturers and promoting healthy competition in this regard (see chapter VI).[39]

Refurbishment refers to the modification of an object – either waste or a product – to increase or restore performance or functionality or to meet applicable standards or regulatory requirements, resulting in a fully functional product suitable for its originally intended purpose or beyond. The restoration of functionality but not value, enables a partially new service life for the product. Comprehensive refurbishment differs from standard refurbishment in that it involves a more rigorous process within industrial or factory settings, with a high standard and level of refurbishment. The addition of value during comprehensive refurbishment enables an almost full new service life for a product. It brings the product up to "state of the art" level, with newer or more advanced components. It also enables access to high-quality products with significantly fewer environmental impacts and lower costs to producers and, potentially, customers.

Remanufacturing refers to a standardized industrial process within industrial or factory settings, in which cores (product or module that has been sold, worn or is no longer functional) are restored to same-as-new, or a better condition and performance level. The remanufacturing process is in line with technical specifications, including engineering, quality and testing standards, and typically yields fully warranted products. This process enables the production of "as new" products, lowering environmental impacts, costs and prices. It implies product improvement, whereby the full structure of a multi-component product is disassembled, checked, cleaned and, when necessary, replaced or repaired in an industrial process.

In **repurposing**, discarded goods or components are reused and adapted for another function so that the material gets a distinct new life cycle. Converting old or discarded materials into something useful returns them into the economy in a way that retains some, if not all, of their value. From a production perspective, repurposing enables financial savings, either by reducing the cost of production by obtaining reclaimed material, or by reducing waste generation and its associated treatment requirements.

Recycling involves processes that prevent materials from being discarded and allows materials to be reused instead. Recycling usually involves reprocessing waste into materials, substances, minerals, and metals. Recycling does not cover operations that only recover energy from waste. Different techniques are used in recycling, including manual work, mechanical work or chemical and metallurgical processes that remove impurities and improve material quality. While recycling is key, it can often be costly, and even impractical in some cases. This is reflected, as

37 See https://repair.eu/. See also Stokel-Walker (2023) for a review of the evolution of laws in relation to the right to repair. The extension of this right around the world is described in Chamberlain (2022).

38 See https://www.ecologie.gouv.fr/indice-reparabilite and UNEP and Akatu Institute (2023).

39 See https://www.bloomberg.com/news/articles/2023-01-19/why-consumers-are-fighting-tech-firms-for-right-to-repair. Some companies appear to be softening their stance in relation to the right to repair; for instance, Apple has expressed support for the related law in California, United States (see https://www.emergingtechbrew.com/stories/2023/09/06/apple-right-to-repair-support.

discussed above, in the low rates of recycling of digitalization-related waste and of recovery of minerals and metals.

Recovery, unlike final disposal, makes use of the resources to obtain some useful benefit from waste, either by bringing materials back into production or recovering energy from them. Recovery of minerals is also called urban mining. Technological progress is leading to the e-waste mining of metals becoming cost-competitive in comparison with virgin mining (Zeng et al., 2018). Thus, it may be preferable to mine e-waste rather than mining the Earth. E-waste may also have higher levels of mineral concentration. The value of metals in SCSIT waste was estimated to be $27.5 billion in 2022.[40]

Unlike fossil fuels, minerals are not lost once used. In theory, they may be reused over and over again. However, achieving full recyclability for all elements of the periodic table is far from realistic. This is not only because of existing technological limitations, but also for reasons related to thermodynamics. Thus, completely closing the cycle, as the circular economy aims to do, is impossible. A term that more accurately reflects this reality is the "spiral economy", which acknowledges that in each cycle, there is inevitably the loss of some materials and energy (Valero and Valero, 2019). Nevertheless, both concepts move in the direction of more sustainable consumption and production. Therefore, the concept of circular economy, which is gaining attraction, serves the achievement of the Sustainable Development Goals.

Circular digital economy activities need to be based on one **crucial overarching principle**; to design electronic products with **circularity in mind**

At the outset, all of these circular digital economy actions require one critical overarching action. The design of electronic products with circularity in mind. Properly designing products according to their end of life is critical. "Reducing by design" leads to products and services that use fewer materials per unit of production, or during their use. This influences all stages of the product or service life cycle: less raw material is extracted; production uses fewer inputs and hazardous materials; consumption patterns and the end of life of products and services are influenced by the design, minimizing waste. Reducing by design requires increasing connections and information exchanges among different actors in a life cycle; for example, recyclers would require relevant information from manufacturers about the material content in order to deal with waste.

Design for circularity should also help to minimize the use of hazardous substances and promote the use of recycled materials. Moreover, products should be designed to avoid over-mixing minerals, and to be easily repaired and disassembled so that components can go back into the production cycle. Designing modular electronic products could be a valuable option (Amend et al., 2022). Designing for effective disassembly and recycling is key, as physical separation offers a more cost-effective solution. All of this would result in a sustainable electronic product, which would be designed to be durable.[41] This can also be supported by legislation; for example, regulating against planned obsolescence. For instance, the European Union is working towards a regulation on ecodesign for sustainable products.[42]

Circularity is also about responding to changing consumers' preferences, as they are increasingly aware of, and concerned about, their environmental impacts. Multiple consumer surveys point to a growing demand for more sustainable electronic

40 Data from UNITAR-SCYCLE.

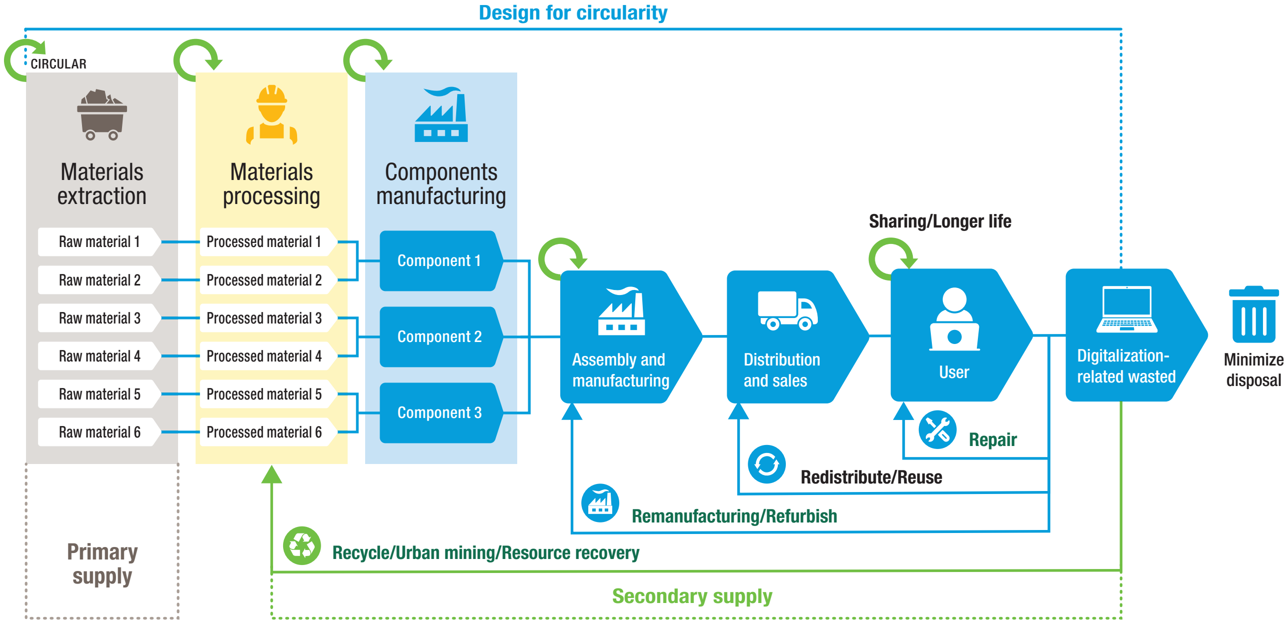
41 There are already some examples in the market, such as Fairphone, see https://shop.fairphone.com/about-us.

42 See https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products-regulation_en#ecodesign-from-an-international-perspective

products.[43] Nevertheless, the cost of devices continues to be a major factor in purchase decisions. In recent years, inflation has significantly influenced the fact that consumers keep devices for longer, repair them or buy second-hand devices.

The circular economy approach for electronic products, taking into account their life cycle, can be compared with the linear model of production presented in chapter II (figure II.16), and further illustrated in figure IV.4. This shows the initial stage of minerals extraction, reflecting the primary supply of minerals and metals. However, a linear model moving from extraction to waste only offers a limited view of potential opportunities. There are various ways to shift towards the circular economy, to close the loop and either increase the supply of materials or reduce demand for materials. Recycling and resource recovery, including urban mining, can be a source of secondary supply for minerals. The remaining activities that promote reintegration back into the production chain would contribute to reducing the demand for ICT goods and, consequently, the raw materials needed to produce them.[44] Therefore, items can move back and forth in the chain. Some items might initially be categorized as "waste", but if they can be reclaimed or repurposed for the production process, they reach "end of waste" status, and are no longer classified as waste. Indeed, end of use does not necessarily mean end-of-life, as the item or its components may continue to be used. Moreover, circularity should apply to all stages of the production chain, not only

Figure IV.4
Circular economy for ICT goods



Source: UNCTAD, adapted from Deloitte (2023).

[43] In the European Union, 79 per cent of citizens think that manufacturers should be required to make it easier to repair digital devices or replace their individual parts, and 77 per cent would rather repair their devices than buy new ones (see https://www.europarl.europa.eu/news/en/press-room/20220401IPR26537/right-to-repair-meps-want-more-durable-and-more-easily-repairable-products). See also Trojan Electronics (2023), Hatchett (2022), Société Générale de Surveillance (2021), Perzanowski (2020) and Society for the Promotion of Consumer Electronics and OliverWyman (2022).

[44] Activities that imply reintegration back into the value chain, in the opposite direction as that of the linear model, are also known as reverse logistics. Their purpose is to collect, disassemble, remanufacture, recycle and minimize disposal of end-of-life electrical and electronic products to mitigate the risk of environmental damage and maximize the extraction of economic value (Ni et al., 2023).

at the user level; there should be circular mining, processing and manufacturing.[45]

Relatively few countries have adopted legislation on circular economy activities, with references to repair or ecodesign. For example, the European Union – which may have the most advanced regulatory regime in this context globally and is a pioneer in e-waste legislation – is taking measures in this regard in its circular economy action plan.[46]

Actions that support the circular economy seek to ensure the development of sustainable products, such as ecodesign, which includes a digital product passport, and right to repair; circularity in production processes; and empowering consumers to have access to reliable information to make the best choices, including on early obsolescence and repairability. Actions also target key sectors including electronics and ICT, with a push to improve durability and recycling and to enable consumers to buy products that are more energy-efficient, durable and easy to repair. Similarly, the European Union has adopted a regulation on batteries to create a circular economy for the battery sector by targeting all stages of the battery life cycle, from design to waste treatment. In addition, the European Union has approved rules to establish a common charger for mobile phones and tablets, in order that consumers may choose to buy a new device with or without a charging accessory. This allows consumers to continue using functioning chargers when buying new devices of different brands.[47]

The potential economic value of the resources recovered depends on the type of equipment. For example, WEEE in data centres contains more high-grade recycling material than small IT devices such as laptops. Data centres use high-grade circuit boards and backplanes that have, on average, a higher precious metal content than the typical circuit boards from individual consumer or small IT devices (ITU, 2021a).

The growth in the electronics market and the subsequent rise in waste generation has also led to increased demand in the second-hand market for electronic products, as well as markets for repairing, remanufacturing, refurbishing and recycling. Considering the projections for continued growth, the value of these markets is likely to increase further, as shown by various market research studies:[48]

- The global market for electronics *recycling* is estimated to grow from $37.2 billion in 2022 to $108.3 billion by 2030, led by the United States and China (Research and Markets, 2024);
- The value of *refurbished* electronics is estimated to increase from $85.9 billion in 2022 to $262.2 billion in 2032. In 2022, the largest shares were seen in North America, Europe and Asia and the Pacific, with the latter expected to overtake Europe by 2032. The share of the rest of the world is small in comparison (Market Research Future, 2024);
- The global consumer electronics *repair* and maintenance industry generated $15.3 billion in 2021 and is expected to generate $21.6 billion by 2031 (Allied Market Research, 2023); and
- The *second-hand* electronics product market in Europe, which was valued at $78.9 billion in 2022, is estimated to reach $225.5 billion by 2031 (Transparency Market Research, 2023).

[45] For more discussions on the circular economy in the ICT sector, see https://www.itu.int/en/mediacentre/backgrounders/Pages/e-waste.aspx, Ellen MacArthur Foundation (2018), PACE and WEF (2019), APC (2024), Roura et al. (2021), GSMA (2022a, 2022b), CEP (2022), PACE (2021) and United Kingdom, House of Commons Environmental Audit Committee (2020).

[46] See https://www.consilium.europa.eu/en/policies/circular-economy/.

[47] See https://www.europarl.europa.eu/news/en/press-room/20220930IPR41928/long-awaited-common-charger-for-mobile-devices-will-be-a-reality-in-2024.

[48] Multiple market research studies look at the evolution of the market for activities related to circular electronic products, with significant variety in terms of coverage, time period and methodology. However, there seems to be agreement on a positive outlook.

Overall, the markets for recycling, refurbished electronics and second-hand electronics are all estimated to approximately triple their value in the coming decade.

There is a strong business case for such circular economy activities, which generate economic value and job opportunities. This also creates environmental benefits by reducing the resources extracted and emissions linked to extraction, manufacturing and waste treatment processes. Circularity allows for resource recovery and an increase in the secondary supply of minerals. It can also lead to the reduced consumption of electronic devices and equipment, and in turn reduce the demand for materials used in their manufacturing. This alleviates some of the pressure on the mining supply and the associated environmental and social impacts from extractive activities.

The circular digital economy should not necessarily be associated with less digitalization, but with better, more environmentally sustainable digitalization. Overall, as materials are kept in use as products or components, waste and pollution can be significantly reduced, and the potential value of products and materials and minerals better captured.

The market for **recycling, refurbished electronics and second-hand** electronics is **estimated to triple** in the coming decade

G. International trade in digitalization-related waste

International flows of digitalization-related waste are a critical issue, representing both opportunities and risks for developing countries. A common belief is that this trade is characterized by substantial dumping of such waste from developed to developing countries (Abalansa et al., 2021). While flows from developed to developing countries may have been more significant in the past, when digitalization was primarily taking place in developed countries, this is no longer the case. As developing countries have been rapidly digitalizing, they have been generating increasing volumes of digitalization-related waste. Accordingly, an increase in intraregional flows of this waste can also be observed. Assessing the implications of these international flows of waste is complicated by the limited availability of statistics.

The transboundary movement of all e-waste is regulated by the Basel Convention (see section B), which now applies to both hazardous and non-hazardous electrical and electronic waste. The objective of the Convention is to protect human health and the environment against the adverse effects of hazardous waste. By mid-2024, 191 countries were Parties to the Basel Convention; the United States had not yet ratified it.

The implementation of the Basel Convention in the context of e-waste may be challenging, given the magnitude of informal shipments and illegal trade of such waste.[49] Thus, the correct implementation of the Convention requires ongoing improvement and adjustment, to include clear definitions related to e-waste fractions, better waste statistics and practical solutions (Meidl, 2023; Mihai et al., 2022; Baldé et al., 2023). For this reason, Parties to the Basel Convention adopted e-waste amendments which extend the scope of the Convention to all e-waste, effective 1 January 2025.

Some of the trade flow scenarios for digitalization-related waste are legal, while others are illegal. Trade is legal if the waste is to be recycled in an environmentally sound manner and the trade follows national regulations, as well as international and regional agreements. Problems emerge

Assessing the implications of international flows of digitalization-related waste is complicated by the **limited availability of statistics**

[49] For example, implementation issues in Latin America are discussed in Hernandez et al. (2023).

with illegal trade, in the form of smuggling or trafficking, when waste is disguised as second-hand electronic equipment or other goods. Mixing legal and illegal items is one of the main strategies used by criminal actors; in instances of illegally shipped waste, criminals frequently use tactics such as misclassification, misdeclaration and fraud to mix the items (Baldé et al., 2024).

Informal activities in a developing country that is importing digitalization-related waste can provide economic opportunities and livelihoods for people in need. Even if the electronic equipment does not work, if it can be repaired, it can help generate business and job opportunities. Refurbished or repaired devices can also increase access to and affordability of equipment. If components could be easily disassembled, there could be trade in components that may be reintegrated into the production cycle for remanufacturing or refurbishing. Such trade could also contribute to economic activity in the receiving country. However, the process carries significant environmental, health-related and other social costs, while it is less efficient in terms of value and resources recovery.

The most recent comprehensive global analysis of international flows of e-waste is the Global Transboundary E-waste Flows Monitor 2022 by UNITAR (Baldé et al., 2022). It notes that the quantification of such shipments is difficult, and that their true magnitude remains unclear. Accurately estimating international e-waste flows is challenging for various reasons, including limited global data and lack of harmonization. Data stemming from national reporting in the context of the Basel Convention show incomplete reporting, ambiguous definitions, incorrect categorizations, discrepancies in reporting and inaccuracies. Moreover, there is no obligation to report on international trade of used electronic equipment. All of these problems are also connected to the illicit nature of illegal trade in e-waste.

The transboundary movement of e-waste has, to date, been divided into controlled and uncontrolled flows.[50] Controlled transboundary movements include international flows of e-waste that are reported as hazardous waste, in compliance with the Basel Convention control regime. Under the Basel Convention reporting, it is not possible to distinguish between categories 2 and 6 of the statistical definition of e-waste, so records of these movements refer to overall e-waste. Controlled flows also include trade in waste of printed circuit boards (PCBs) to the countries where the specialized processing facilities are located. Such trade is highly relevant because PCBs are among the most valuable parts of electronic products. Uncontrolled flows may include used ICT equipment and digitalization-related waste, including cases where parties introduce exceptions into national legislation regarding used equipment that has been sent for failure analysis or repair. Although the respective shares of functioning equipment and waste are not known, it is normally understood that the uncontrolled nature of this trade, and limited inspection capacities, make this a significant channel for illegal e-waste trade.

Against this background, Baldé et al. (2022) find that controlled shipments under the Basel Convention mostly occur either between high-income regions or into high-income regions (figure IV.5). Only 9 per cent of this trade is between continents.

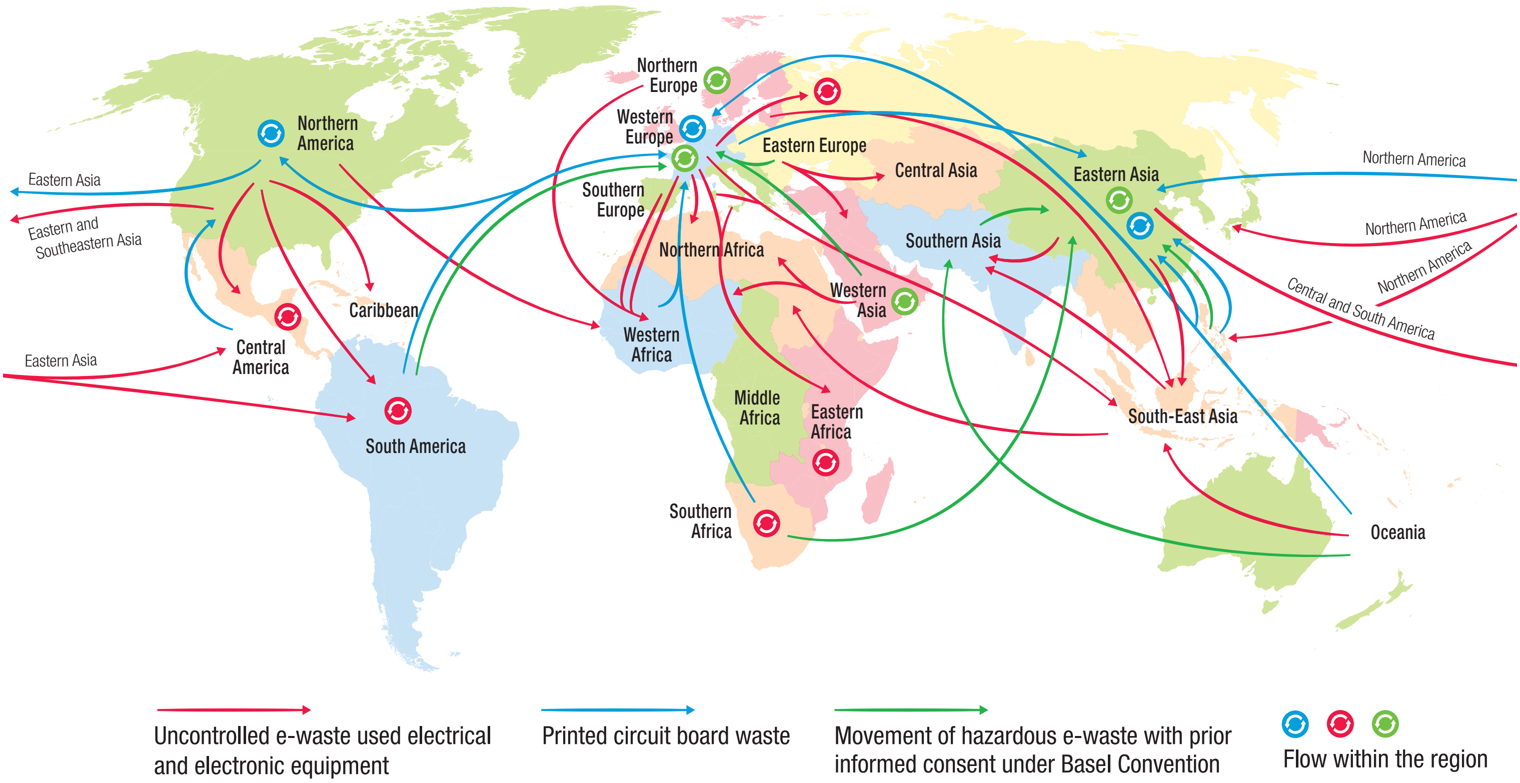
In the case of PCB waste, it is mainly imported into East Asia, North America and Northern and Western Europe. Globally there are less than ten specialized facilities that can handle such waste, and these are located in developed countries. Due to its higher value, this type of waste has a higher collection rate (34 per cent in 2019) than e-waste in general (17 per cent) and

[50] The recent decisions by the Basel Convention can help address uncontrolled trade in the future.

SCSIT waste (25 per cent).[51] More than half of international trade in PCB waste is intercontinental, while much of it is from developing to developed countries.

Uncontrolled international trade of used electrical and electronic equipment or e-waste flows mainly from developed to developing economies, and in most cases constitutes illegal traffic. Intraregional movements also take place towards the poorest economies in a given region. As shown in figure IV.5 Northern and Western Europe are sources of exports to Western Africa. Western Europe also exports such waste to Southeast Asia and, at the regional level, to Eastern Europe. North America exports to Western Africa, Asia and Latin America and the Caribbean. East Asia exports mostly at the regional level to Southeast Asia and Southern Asia. Developed countries in Oceania export used equipment and e-waste to Southeastern Asia.[52]

Figure IV.5
International trade in controlled e-waste and uncontrolled used equipment and e-waste



Disclaimer: the boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: UNCTAD, based on Baldé et al. (2022).

[51] Although the most recent Global E-Waste Monitor provides data for 2022, the information provided here is for 2019 because the last available international trade data are only for the latter year.

[52] Figure IV.5 and the analysis provided in Baldé et al. (2022) refer to e-waste, i.e., electrical and electronic waste. While it is not possible to obtain data from Basel Convention reporting for categories 2 and 6, statistics for categories 2 and 6 (SCSIT waste) on uncontrolled flows point to the same conclusions. More detailed analyses on transboundary flows of e-waste are available at https://ewastemonitor.info/regional-e-waste-monitors/. For a recent account in the case of Asia and the Pacific, see United Nations Office on Drugs and Crime and UNITAR (2022).

Uncontrolled trade in used electrical and electronic equipment and digitalization-related waste flows from developed to developing economies…

These estimations suggest a pattern of unequal ecological exchange, where uncontrolled trade in used electrical and electronic equipment and most likely digitalization-related waste flows from developed to developing economies, and within regions from the most developed to the less developed economies. This implies the transfer of responsibilities and risks, with the burden of environmental and social costs placed on those that are receiving the waste streams. In contrast, the higher value parts of the waste chain are exported from developing to developed countries. Thus, as in many international trade dynamics, developing countries remain locked in at the low-value part of the digitalization-related waste value chain, while developed economies capture the highest value.

...developing countries remain locked in at the low-value part of the digitalization-related waste value chain, while developed economies capture the highest value

There are some well-known digitalization-related waste dumping sites in developing countries. WHO (2021b) maps locations of informal e-waste dismantling and recycling sites reported in research literature, including Bangladesh, Cameroon, Chile, China, Egypt, Ghana, India, Mexico, Pakistan, the Philippines, Thailand, Uruguay, Viet Nam and the State of Palestine.

These results are also shown in other analyses, including case studies.[53] For instance, the Basel Action Network is a non-governmental organization that works to combat against illegal hazardous waste trade. By using GPS trackers, the network has highlighted holes in the circular economy through e-waste leaking in Europe and illegal exports of e-waste from Australia (Basel Action Network, 2018a, 2018b). These findings are complemented by anecdotal evidence of crime related to e-waste trade. For example, in January 2023, authorities in Spain dismantled a criminal network that was using forged documents to ship hazardous e-waste from the Canary Islands to Western Africa. This included 14 containers with 300 tons of material ready for shipment.[54]

A major challenge in preventing digitalization-related waste imports is limited capacity to enforce legislation, or to carry out the necessary monitoring and controlling of imports. This is mostly due to insufficient financial and human resources. Exporting countries also face challenges with regards to controlling exports. For example, through the “person in the port” project, a two-year study into used EEE sent to Nigeria, mostly from European ports, severe problems were highlighted with regard to non-compliance with international and national rules governing such shipments; the equipment often arrived mixed with other goods such as bicycles, kitchenware, sports equipment or furniture (Odeyingbo et al., 2017).

Wider access and use of the UNCTAD Automated System for Customs Data (ASYCUDA) could reduce the efforts needed to assess and evaluate import documentation in relation to digitalization-related waste. However, this would still need to be combined with inspections to identify incorrect declarations of imports of used electronic equipment. Cooperation between major stakeholders, including customs and port authorities, as well as enforcement agencies, is essential (Forti et al., 2018).

It is important to ensure that digitalization-related waste is not dumped into developing countries. In light of the experience of illegal trade and the limitations in implementing the Basel Convention, amendments to the Convention were adopted at the fifteenth session of the Conference of the Parties in 2022. All transboundary movements of e-waste, whether hazardous or not, will be subject to the procedure known as “prior informed consent”. Previously, this was only required for hazardous e-waste. These amendments will become effective on 1 January 2025. However, this has raised concerns within the e-waste management industry as it may negatively affect recycling. Procedures that are too strict may become overly cumbersome and discourage

[53] See Favarin et al. (2023), Meidl (2023), Mihai et al. (2022) and Tong et al. (2022). Moreover, the European Court of Auditors (2021) highlights the challenge of illegal e-waste trade and the urgent need to address it.

[54] See https://www.occrp.org/en/daily/17220-spain-nabs-europe-africa-electronic-waste-smugglers.

exports for legitimate recycling purposes. Moreover, in an effort to address illegal imports of such waste, some countries, including Ghana, Kenya and Uganda, have reportedly imposed bans on such imports, including for second-hand items.[55]

Although there is a clear need to ban imports of digitalization-related waste that do not meet legitimate purposes, the case for a wholesale ban on imports of used functional digital equipment may not be as straightforward. If the equipment can be reused, is truly second-hand and can be repaired or refurbished, it can contribute to value addition, job creation and affordability, alleviating digital divides, therefore advancing developmental objectives. However, some countries may ban imports of second-hand equipment to stimulate the growth of domestic electronics manufacturing.

Thus, there is a need to balance out the requirement to refrain from dumping digitalization-related waste in developing countries with the ability to harness circularity and development opportunities from international trade in used EEE.

All of this shows that digitalization-related waste is a worldwide challenge that requires a globally coordinated approach. When factoring in trade flows, the circular economy can become global and contribute to a just transition that is environmentally sustainable. However, one additional factor to consider is transportation, which may have an influence on the environmental and economic efficiency of the circular economy.

Using the example of illegal trade between the European Union and Nigeria, Thapa et al. (2023) highlight that current EPR schemes do not focus on the entire global value chain of digitalization-related waste. When this waste is exported to another country, financial support for proper waste management is not transferred with it. Thus, the receiving country, normally with little waste management capacity, bears the environmental and social costs of the waste, without the corresponding financial compensation to help improve waste management efforts. Implementation of EPR on a global scale is fragmented and is not aligned with international waste flows. Thus, these authors note the need for “ultimate producer responsibility”, making producers responsible for managing waste globally.[56]

> There is a need to refrain from dumping digitalization-related waste in developing countries, while harnessing circularity and development opportunities from international trade in used electronic equipment

[55] See https://www.graphic.com.gh/news/general-news/ghana-bans-importation-of-some-substandard-used-appliances-list.html, https://peopledaily.digital/news/state-bans-secondhand-electronics-importation-9643/; https://www.itnewsafrica.com/2010/04/uganda-effects-ban-on-used-electronics-imports-controversy-continues/, and Denmark, Ministry of Environment and Food, Environmental Protection Agency (2015).

[56] For a discussion of EPR in the global context, see ITU et al. (2022).

H. Circular digital economy opportunities for developing countries

The circular digital economy provides **opportunities for new players** and contributes to inclusive and sustainable development

Beyond the potential benefits for the environment in terms of sustainable consumption and production, the circular digital economy can also bring substantial economic benefits. With proper management of waste, including with regard to possible health risks, the process of extracting valuable materials by recycling and recovering digitalization-related waste can represent an opportunity for value addition and job creation along the waste value chain. The value of activities related to the circular economy in the digital equipment sector, such as repairing, refurbishing and the second-hand electronics market, is expected to continue its upward trajectory. There is a business case for many activities in the circular economy for digital equipment, with innovative business models that can extend the lifetime of electronic products, such as through reuse, or by offering electronics as a service (UNEP, 2021b).

Opportunities to create economic value in the circular economy of digital equipment arise in both developing and developed countries (Lee et al., 2023; Rizos et al., 2019). These go beyond the focus on end-of-life activities, such as recycling and material recovery. This is particularly the case in a circular digital economy, in which products and processes are designed for easy repair and disassembly from the outset, with the objective of minimizing digitalization-related waste.

According to the Circularity Gap Report 2024, the global economy is still only 7.2 per cent circular, with declining trend driven by rising material extraction and use (Circle Economy Foundation, 2024). This indicates significant potential for economic gains from related activities, as well as for reducing resource use and recovering resources. There may, however, be vested interests to keep the linear economy model, as it is led by large corporations focused on profits. The circular digital economy provides opportunities for new players and contributes to inclusive and sustainable development.

At present, the pattern of international trade in digitalization-related waste is one in which developing countries are mostly involved at the lower value-added parts of the digital equipment value chain. Nevertheless, global flows of second-hand electronics can provide economic opportunities in the importing developing countries, as long as it is not related to illegal trade.

Furthermore, the management of digitalization-related waste in developing countries is mostly handled in the informal sector. While informal activities are thriving in some developing countries, they tend to carry significant environmental, health-related and other social costs. Moreover, the methods used for recycling and recovering materials are typically less efficient, resulting in fewer opportunities for economic value. It is important to ensure that the potential value from circular economy activities can be properly captured without exposing people involved to health risks. The distribution of benefits of the global digitalization-related waste value chain should be equitable between and within countries, to enable a just and environmentally sustainable digital transformation (Ghisellini et al., 2022; Ogunseitan, 2023; Thapa et al., 2023).

The economies of developing countries tend to be more circular than those of developed countries.[57] This arises from necessity, as lower levels of income compel people to engage in circular economy activities; users tend to buy more affordable second-hand devices or try to keep the devices for longer by repairing them. For example, enterprises focusing on repair and refurbishment are widespread across Africa. In particular, Ghana and Nigeria have a well-organized repair and refurbishment sector, representing an important economic activity for many households (ILO, 2023b). Such businesses play a key role in bridging the digital divide between wealthy consumers and those whose access to electronic devices is limited due to prohibitive costs. Thus, used and repairable equipment can have significant economic and social benefits in developing countries (Maes and Preston-Whyte, 2022).[58] Reusing electronic equipment for social good can support the transformation towards a more sustainable and equitable society by providing it a new life among disconnected people (Good Things Foundation et al., 2023).

Businesses, particularly local MSMEs, including in the informal sector, can create value from digitalization-related waste and contribute to keeping products and materials in use through upcycling. Small enterprises focused on repairing, remanufacturing, updating and recycling benefit the environment by extending the life of products and recovering materials, thereby reducing the need for raw materials and diminishing harmful waste and pollutants. Collaboration between businesses and other stakeholders is key in moving towards the circular digital economy in a coordinated manner (UNEP, 2021b).

Such small businesses also provide benefits for the local population by providing income and job opportunities. However, challenges remain in terms of scalability. Among circular economy activities, repairing has a high level of labour intensity, holding significant potential for domestic job creation in developing countries (ILO, 2023b; Meysner and Urios, 2022). According to ILO et al. (2023), the transition to a circular economy (in all sectors) could generate 7 to 8 million new jobs. However, this study highlights a lack of research in developing countries. Moreover, the link between circularity and achieving social and economic progress remains significantly overlooked. Research also tends to focus disproportionately on job creation, while largely disregarding job quality, including working conditions and wages.

Working conditions and value creation in the informal digitalization-related waste management sector can be improved by integrating it with formal sector infrastructures. One way to do this would be to create cooperatives and associations. This can help informal workers to organize and reap greater benefits in terms of claiming enhanced value from the recovery of resources and other economic activities (Awasthi et al., 2023; United Nations, 2021b). By contrast, banning informal waste-related activities without having a formal structure in place can be counterproductive. It may leave a significant part of the poorest population without much-needed livelihoods. For example, when the Agbogbloshie, Ghana, e-waste dumping site was dismantled in 2021, it had significant negative impacts on poor and vulnerable communities, who were deprived of this income source.[59] It may be more advisable to build on existing collection networks already developed by the informal sector, to make concerted efforts to formalize them, and to continue to raise awareness of the negative environmental and health-related effects arising from improper e-waste disposal and handling.

57 For regional analyses of the circular economy in the electronics sector, see, for instance, UNEP (2021c) for Africa; SAICM and GEF (2023), and Clerc et al. (2021) for Latin America; and SAICM Secretariat (2022) for Central and Eastern Europe.

58 For a discussion of opportunities from responsible e-waste value chains in Africa, see Avis (2022).

59 See Akese et al. (2022) and https://electronicajusta.net/crisis-in-agbogbloshie-ghana-caused-by-forced-dismantlement-of-the-landfill/?lang=en.

A regional approach to managing digitalization-related waste can offer opportunities for **value addition**

Promoting skills development and sustainable enterprises, formalization, and the establishment of employer and worker organizations and social dialogue are all part of a just transition in e-waste management (ILO, 2022). While formalization should be the ultimate long-term objective, in countries where a large part of waste is handled informally, it may also be important to ensure effective ways of involving the informal sector as part of the overall strategy for sound e-waste management.

Moreover, persistent illegal exports of digitalization-related waste into developing countries transfer the responsibility for the management of such waste to them, while their capacities for doing it are limited. There is a need for developing countries to build capacities for the management of e-waste and proper oversight and to strengthen circular economy activities in the digital economy. This requires increased financial resources, stakeholder skills and infrastructure to collect and recycle digitalization-related waste in a way that mitigates health-related and environmental risks. Also needed are the institutional capacities to monitor and enforce legislation.

Given the limited resources available domestically in many countries, international support in this context is essential. There are already some ongoing capacity-building programmes. UNIDO offers an e-waste management programme in Latin America and a UNEP programme in Nigeria is focusing on circular economy approaches for the electronics sector.[60] At the individual donor level, the German Development Agency has provided capacity-building on environmentally and socially responsible handling of e-waste in different countries; it has, for example designed an e-waste training manual (GIZ, 2019).

A regional approach in this area can also offer development opportunities to create value. Developing countries in a region could pool resources to build processing facilities for the higher-value parts of waste. There is also room for cooperation at the regional level, by harmonizing e-waste management strategies and collecting e-waste data. For instance, the East Africa Communications Organization (EACO) has developed a regional e-waste management strategy (EACO, 2017). Moreover, in collaboration with the EACO secretariat, ITU and the UNITAR-SCYCLE programme have provided technical assistance to EACO member States through the EACO Regional E-Waste Data Harmonization project.[61]

At the international level, for example, the Basel Convention Partnership for Action on Challenges related to E-waste provides opportunities for sharing experiences in e-waste policies and regulations. It supports the development of innovative solutions and guidance on the environmentally sound management of certain e-waste streams, such as mobile phones, computing equipment, television screens, refrigerators and cooling and heating equipment. This partnership includes original equipment manufacturers, recyclers, academia, NGOs and municipalities along with government representatives and international organizations.[62]

[60] See https://www.unido.org/news/cooperacin-regional-en-gestin-de-residuos-electrnicos-en-pases-de-amrica-latina, and https://buildingcircularity.org/recycle/circular-economy-approaches-for-the-electronics-sector-in-nigeria/.

[61] See https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/E-waste-EACO.aspx.

[62] See https://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACEII/Overview/tabid/9284/Default.aspx.

I. Conclusions

Rapid digitalization globally is leading to increasing demand for digital equipment and the minerals used to manufacture it. The world's primary supply of minerals and metals face a high level of pressure from the expected surge in demand resulting from the global transition to low-carbon and digital technologies (see chapter II).

This can be alleviated to a certain extent by increasing secondary supply through recycling digitalization-related waste, allowing for recovery of some materials through urban mining activities. Recycling alone is not enough to fill potential materials gaps or reduce the major environmental impacts that arise from producing and disposing of electronic equipment. Other circular digital economy activities discussed in this chapter can reduce the pressure on supply by contributing to moderating the growth in demand for new digital equipment.

Technological progress can also help with new processes that can lead to increased efficiency in the use of resources, as well as with emerging substitute materials that may be more environmentally friendly. It can similarly lead to better technologies for the proper management of digitalization-related waste.

The circular digital economy approach can contribute to environmental benefits through the sound management of digitalization-related waste, and by reducing the demand for natural resources, as well as through potential economic opportunities, including in developing countries.

Circular digital economy activities require a change in mindset in the modes of consumption and production to make them more responsible and sustainable. These activities can help to ensure progress towards attaining the Sustainable Development Goals. E-waste is mostly addressed under Sustainable Development Goal 12 and is included in indicators 12.4.2 and 12.5.1; the proper management of digitalization-related waste can also contribute to many of the other Goals.

Moving towards a more circular approach in the context of digitalization requires joint action and responsibility from all stakeholders. Manufacturers play a major role, notably in designing digital equipment for circularity, so that it lasts longer and can easily be repaired, disassembled and recycled. Consumers also need to reconsider their behaviour towards digitalization, to allow for a longer lifespan for products and make conscious decisions to consume more sustainable digital equipment. Consumers should reduce overconsumption in those parts of the world where this phenomenon exists, while in other regions, an increase in sustainable digitalization is required in order to harness it for development.

Actions for more sustainable consumption and production need to be supported by appropriate policies at the national, regional and international levels that provide the enabling factors and that are adequately enforced. Achieving an inclusive low-carbon and digital transition requires policies to be based on the principle of common and differentiated responsibilities, considering the respective capabilities and needs of different countries and actors. The necessary policies and the possible actions by consumers and producers are explored in chapter VI.

A major prerequisite is to strengthen the measurement of digitalization-related waste and its international flows. Without better data, it is not possible to properly inform the debate and ensure that related policymaking is based on accurate evidence. This should also include greater efforts towards clarifying and standardizing the definition of digitalization-related waste. This will help ensure better understanding of the dynamics of international trade in digitalization-related waste and used equipment.

Moving towards the circular digital economy also needs to be supported by digital tools.[63] For instance, digital product passports could be key in tracking materials and products enabling more informed consumption decisions, as well as policies.

Circular digital economy activities require **a change in mindset in consumption and production** to make them more responsible and sustainable…

...and **joint action and responsibility** from all stakeholders

[63] See, for instance, ITU (2021b).