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Trade and Development Board
Intergovernmental Group of Experts
on E-commerce and the Digital Economy
Eighth session
Geneva, 12–14 May 2025
Item 3 of the provisional agenda

Making digitalization work for inclusive and sustainable development

Note by the UNCTAD secretariat

Summary

As the world is facing more substantial and interconnected global challenges, it becomes increasingly critical to enhance understanding of the complexities in order to inform policy debates at all levels. The relationship between rapid digitalization, environmental sustainability and inclusive development is explored in this note. The major environmental impacts of digitalization over its life cycle are depicted, as well as corresponding implications from the trade and development perspective. Ensuring inclusive and environmentally sustainable digitalization requires policy measures at the national, regional and international levels, as well as actions by all stakeholders towards sustainable consumption and production.

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Making digitalization work for inclusive and sustainable development

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Corrigendum

1. Page 5, box

For the existing text *substitute*

Increasing environmental impacts from the artificial intelligence boom

The acceleration of artificial intelligence development and deployment following the emergence of Chat GPT [generative pre-trained transformer] in 2022 is leading to rapidly increasing environmental costs in terms of the demand for materials, water and energy use, air pollution and carbon emissions and electronic waste generation. Competition, particularly among large technology companies, to develop more powerful and sophisticated artificial intelligence models requires escalating data processing and computing capacity for training and inference, which mostly translates to a significant increase in data centre demand. One study by a consulting firm shows that global demand for data centre capacity could more than triple by 2030, with artificial intelligence as the key driver. Data centre investment is expanding worldwide; one estimate by a research and advisory firm shows that spending on data centre systems grew by 39.4 per cent in 2024, with a 23.2 per cent growth forecasted for 2025.

Evidence of the environmental impacts of artificial intelligence is limited, as technology companies often do not disclose such information and assessment methodologies vary. However, the recent proliferation of analyses is leading to agreement that the impacts are significant and are increasing rapidly with developments in generative artificial intelligence. For example, greenhouse gas emissions from the use of artificial intelligence are significant; emissions by Google rose by 48 per cent in 2019–2024 and emissions by Microsoft were almost 31 per cent higher in 2024 than in 2020. One media study shows that emissions from large technology companies could be many times higher than officially reported, due to varying accounting methods. Another study by a financial services firm shows that data centre emissions could more than double in 2020–2030. The increase in data centre and graphic processing unit chips, for the deployment of artificial intelligence, also leads to significant increases in demand for minerals, metals and other materials.

The high level and increasing intensity of energy consumption in the deployment of artificial intelligence is becoming increasingly evident. It is estimated that an artificial intelligence search requires 10 times the electricity used during a conventional online search. One study by a financial services firm shows that data centre power demand will grow by 160 per cent by 2030 and that in 2024, data centres worldwide consumed 1–2 per cent of overall power, which could rise to 3-4 per cent by the end of the 2020s. By 2028, artificial intelligence is expected to represent about 19 per cent of data centre power demand. This raises concerns about negative effects on the electricity grid, with potential disruptions and shortages that may in turn limit the deployment of artificial intelligence. As a result, there is a return to fossil fuel energy sources and the revival of nuclear energy plans, as renewable energy sources are not enough to meet demand. Ideally, renewable energy sources should not be additional but should replace the use of fossil fuels.

Increasing energy demand for data centres is threatening progress towards climate-related goals by both large technology companies and in some economies. For example, in Ireland, electricity use by data centres rose from 5 to 21 per cent of national consumption in 2015–2023 and projections indicate that this could reach 28 per cent by 2031. Chip production is also challenging the achievement of climate goals, for example in Taiwan, Province of China. Artificial intelligence technology and related chip production also has a significant impact on water consumption. One study, a research collaboration between media and academia, shows that generating a 100-word email message with the use of Chat GPT-4 requires over half a litre of water. It is estimated that global demand for water resulting from the use of artificial intelligence may reach 4.2 billion–6.6 billion cubic metres in 2027, which would exceed half of the annual use in the United Kingdom of Great Britain and Northern Ireland in 2023. Since 95 per cent of the water consumed by data centres is potable, and most of it evaporates, competition with more essential water uses raises concerns, particularly where water is scarce. Moreover, air pollution from manufacturing, electricity generation and the use of diesel back-up generators is another environmental effect and can significantly impact public health.

At the end-of-life phase, artificial intelligence technology leads to the greater generation of electronic waste, since it requires new devices and more frequent equipment replacement. One study in a peer-reviewed journal shows that electronic waste from generative artificial intelligence could potentially reach a total accumulation of 1.2 million–5 million tons in 2020–2030. The estimated compound annual growth rate of electronic waste from large language artificial intelligence models ranges from 129 to 167 per cent in 2023–2030, compared with 3.6 per cent for global conventional electronic waste.

The escalating environmental impacts of artificial intelligence technology over its life cycle, although uncertain, are raising concerns among relevant stakeholders, including affected communities in many countries. There are emerging policy initiatives to address the impacts at the national, regional and international levels. Awareness is increasing, but significant efforts are needed by all stakeholders to move towards the environmental sustainability of artificial intelligence technology. Much remains to be done in terms of measurement, transparency and research, to increase understanding of the environmental impacts. Discussions should also focus on the need to integrate environmental dimensions in the cost-benefit analysis of the design and deployment of artificial intelligence; critical questions include whether some tasks are worth the environmental cost and whether competition for larger models that affect environmental sustainability goals is required to meet societal needs or whether smaller models can do some of the work. Moreover, it is critical to consider the equity aspects of such impacts. Limited energy access and water stress situations in many developing countries challenge the possibility of developing artificial intelligence capacities and thereby hinder potential benefits.

Source: UNCTAD, based on the following: https://news.ucr.edu/articles/2024/12/09/ais-deadly-air-pollution-toll; https://qz.com/ai-google-microsoft-climate-change-data-center-energy-1851589453; https://www.aljazeera.com/economy/2024/12/25/taiwan-struggles-to-reconcile-climate-ambitions-and-chip-manufacturing; https://www.bbvaresearch.com/en/publicaciones/global-ai-and-climate-disruptive-potential-amid-growing-resource-strain/; https://www.capgemini.com/news/press-releases/organizations-are-increasingly-aware-of-the-environmental-footprint-of-gen-ai-but-most-arent-able-to-address-it-alone/; https://www.gartner.com/en/newsroom/press-releases/2025-01-21-gartner-forecasts-worldwide-it-spending-to-grow-9-point-8-percent-in-2025; https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand; https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand; https://www.nature.com/articles/s43588-024-00712-6; https://www.reuters.com/technology/artificial-intelligence/how-ai-cloud-computing-may-delay-transition-clean-energy-2024-11-21/; https://www.theguardian.com/technology/2024/sep/15/data-center-gas-emissions-tech; https://www.theguardian.com/world/2024/dec/10/ai-fuelled-cloud-storage-boom-threatens-irish-climate-targets-report-warns; https://www.unep.org/resources/report/artificial-intelligence-ai-end-end-environmental-impact-full-ai-lifecycle-needs-be; and https://www.washingtonpost.com/technology/2024/09/18/energy-ai-use-electricity-water-data-centers/.

2. Page 8, chapter II, section B header

For the existing text *substitute*

Impacts of data centres in developing countries

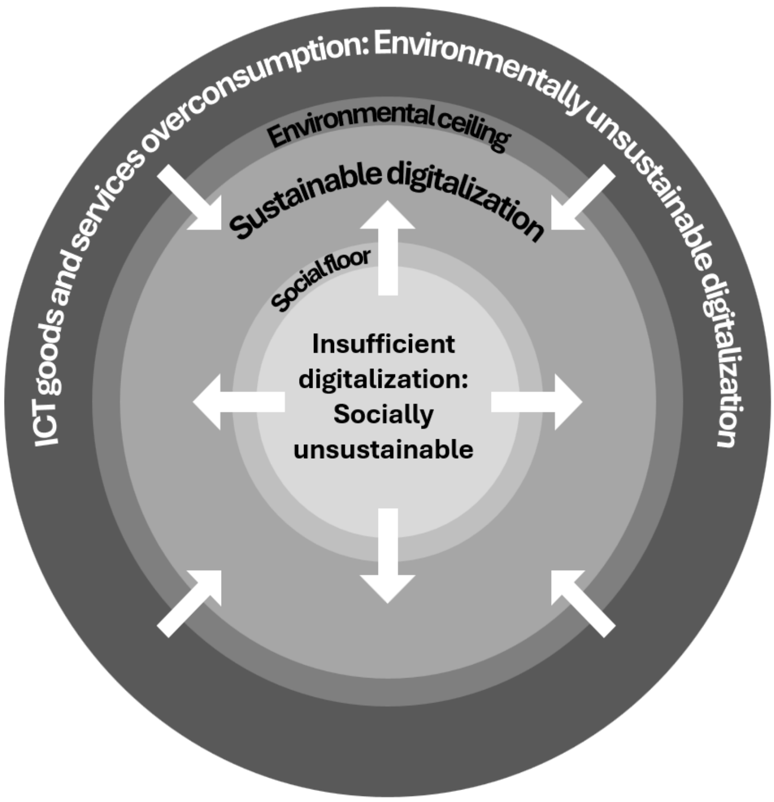
3. Page 9, chapter II, section C header

For the existing text *substitute*

Divides related to digitalization-related waste; and unequal ecological exchanges

4. Page 9, figure

Replace the figure with the figure below



5. Page 10, paragraph 28, third sentence

For the existing text *substitute*

In contrast, the higher value components of the waste chain are exported from developing to developed countries.

6. Page 11, paragraph 33, last sentence

For the existing text *substitute*

The risk of subsidies and trade-related tensions is increasing, which may lead to significant losses globally, particularly among developing countries, which have a comparatively much lower fiscal space.

7. Page 11, paragraph 34, first sentence

For the existing text *substitute*

Beyond increasing domestic production, many countries are looking abroad to secure access to transition minerals from alternative sources through alliances or partnerships. Examples include the Minerals Security Partnership between the United States, the European Union and various countries; and the bilateral strategic partnerships between the European Union and some countries.

8. Page 12, paragraph 35, first sentence

For the existing text *substitute*

Digitalization-related waste is complex and involves both hazardous substances and valuable materials.

9. Page 13, paragraph 39, fourth sentence

For the existing text *substitute*

While formalization should be the long-term objective in areas where a large part of waste is handled informally, in the short and medium terms, ensuring effective ways of involving the informal sector may also be important in an overall sound waste management strategy.

10. Page 14, paragraph 41, last two sentences

For the existing text *substitute*

At present, an inclusive global governance framework is not in place for collective action and knowledge-sharing among countries, building consensus, setting global standards and encouraging the transparent reporting and monitoring of progress towards shared goals at the interface of digitalization and environmental sustainability. However, the issue is being recognized at international discussions, such as with regard to the Global Digital Compact and on the digitalization day held during the twenty-ninth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change.

Introduction

1. The Trade and Development Board, at its seventy-sixth executive session, decided that the focus of the eighth session of the Intergovernmental Group of Experts on E-commerce and the Digital Economy should be on the topic "Making digitalization work for inclusive and sustainable development".

2. A global digital transformation is taking place in parallel with growing concerns about raw material depletion, water use, air quality, pollution and waste generation, which are linked to planetary boundaries, including in the context of climate change. How this transformation is managed will greatly influence the future of humanity and the health of the planet. With growing global inequality and vulnerabilities, including with regard to increasing socioeconomic disparities, environmental degradation and geopolitical tensions, rapid digitalization and the urgent need to foster environmental sustainability are becoming increasingly interconnected. Digitalization continues to evolve at a high speed and, from an environmental perspective, offers new solutions but also presents sustainability obstacles. To date, shifts towards low-carbon and digital technologies have been considered parallel processes; however, they are closely intertwined within the broader global economic transition. Developing countries, particularly the least developed countries, face a double bind amid digitalization and environmental challenges, namely, they are often the most vulnerable to potential negative environmental and social effects and are also less equipped to harness digital technologies in order to mitigate risks from environmental crises. They therefore experience limited benefits from digitalization while also experiencing a high level of exposure to negative impacts. Divides in development, environmental responsibility and impacts and digitalization are interrelated and need to be addressed holistically. More attention should be given to the interlinkages between rapidly evolving digitalization and environmental sustainability and how they relate to trade and development. This includes improving the understanding of how countries at different levels of development are affected by the environmental impacts of digitalization and how these affect global trade. Doing so can inform policymaking on digitalization, trade and environmentally sustainable and inclusive development, to maximize potential gains from digitalization while mitigating environmental harms.

3. Against this backdrop, in chapter I of this note, major environmental impacts over the digitalization life cycle are detailed; in chapter II, corresponding trade and development implications are highlighted; in chapter III, ways to ensure sustainable development gains are explored; and in chapter IV, policy options at different levels for inclusive and environmentally sustainable digitalization are presented.

4. This note is based on the following guiding questions, as decided by the Trade and Development Board:[1]

(a) What are the main environmental impacts of digitalization over its life cycle and how can they be addressed, and what are the implications from the trade and development perspective, particularly for developing countries?

(b) How can sustainable development gains from digitalization be ensured over its life cycle, looking particularly, among others, at critical minerals linked to the digital transformation process and waste management?

(c) How can national, regional and international policymaking and cooperation contribute to digitalization that is sustainable and inclusive and addresses environmental impacts, in particular for those furthest behind?

[1] This note draws on UNCTAD, 2024, *Digital Economy Report 2024: Shaping an Environmentally Sustainable and Inclusive Digital Future* (United Nations publication, sales No. E.24.II.D.12, Geneva), which includes the corresponding sources of data and references, unless otherwise indicated.
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All websites referred to in footnotes were accessed in February 2025.

I. Main environmental impacts over the life cycle of digitalization

5. The overall environmental footprint of digitalization is difficult to assess and remains largely unknown. Identifying the opportunities and risks is hindered by the lack of agreement on the constituent parts of the information and communications technology (ICT) sector and the criteria to include; the lack of timely, comparable and accessible data; insufficient harmonized reporting standards; and differing methodologies. Consequently, available results vary significantly; for example, estimates of the life cycle greenhouse gas emissions of the ICT sector in 2020 range from 0.69 to 1.6 gigatons of carbon dioxide equivalent emissions, corresponding to 1.5–3.2 per cent of global greenhouse gas emissions. There are indications that the environmental impact of digitalization is significant and growing. The need to improve the availability of quality data and common measurement methodologies should not be a reason for policy inaction.

6. Life cycle assessments allow for evaluations of the environmental impact of a product throughout its entire lifespan. Direct impacts from digital devices and ICT infrastructure occur along the life cycle, taking place during the production phase (raw material extraction and processing, manufacturing, distribution), the use phase and the end-of-life phase. Direct effects on natural resources, including on transition minerals, energy and water, as well as carbon emissions and waste-related pollution, constitute the environmental footprint of the ICT sector. There are also indirect effects from the use of digital technologies in other sectors, which can be positive or negative. Digitalization has significant potential for environmental good, as it can drive technology efficiency, optimize resource use and enable innovative solutions for climate change mitigation and adaptation. However, potential gains may be overcompensated by rebound effects, since efficiency gains may lead to greater consumption.

7. Digital technologies can be used to address environmental concerns, yet growing numbers of devices, investments in data transmission networks and data centres and more computationally intensive digital applications, such as artificial intelligence and blockchain technologies, notably cryptocurrencies, translate into a growing environmental footprint. In the current highly linear digital economy production model, based on take and extract–make–use–waste, this implies more demand for raw materials, water and energy; greater greenhouse gas emissions; and increased waste. Direct impacts are the focus of the present note; however, the underlying policy objective is to maximize the benefits of digitalization, including positive indirect environmental impacts, while reducing negative effects over the entire life cycle. This entails making digitalization more environmentally sustainable while contributing to inclusive development.

A. Production phase

8. The first phase of the digitalization life cycle is the production of digital devices and ICT infrastructure, covering raw material extraction, including minerals and metals, and processing; the manufacturing of different components and the final assembly of digital products; and subsequent transportation for global distribution.

9. Digitalization is often considered virtual, intangible or in the cloud, yet relies heavily on the physical world. Digital devices, hardware and infrastructure are composed of plastics, glass and ceramics, as well as dozens of minerals and metals, which cannot be easily substituted. The expectation of the dematerialization of the world economy through digitalization has not been met. The amount of minerals and metals used in a device may be small, particularly in view of the general miniaturization trend, yet this complicates the recycling of materials once they become waste. Moreover, as digitalization evolves, larger volumes of minerals and metals are needed to meet global demand and are accompanied by a greater variety of elements required at high degrees of purity, to allow for greater complexity and the continuously improved performance of devices. With regard to the manufacture of telephones, for example, 10 elements were used in 1960, increasing to 27 elements in 1990 and to as many as 63 elements in 2021 in order to manufacture a

smartphone. Minerals and metals are also mixed in alloys, making separation for recycling and recovery purposes difficult. Moreover, high levels of purity require energy-intensive processing. Declining or low-ore mineral concentration also requires significant amounts of ore in order for final mineral content to be derived. For example, manufacturing a 2 kg computer involves extracting 800 kg of raw materials. Overall, the more efficient a product is in terms of performance, the less efficient it becomes in terms of material use.

10. Available evidence suggests that the production phase has the greatest combined negative impact on the environment. This is due to mineral and metal production, the volume of greenhouse gas emissions generated and water-related impacts. For example, with regard to smartphones, around 80 per cent of emissions are attributed to this phase. Key minerals and metals used in digitalization, the basis for essential digital, electronic and electric functionalities, are almost identical to those required for the transformation towards a low-carbon economy. There is much discussion of critical and strategic minerals related to the energy transition, but less attention is given to their role in digitalization. Increasing demand for these materials is driven by the shift to low-carbon and digital technologies; digitalization cannot be achieved without these materials. According to estimates by the World Bank, to meet the growing demand, the production of minerals such as graphite, lithium and cobalt could increase by 500 per cent by 2050. Similarly, the International Energy Agency projects that the level of consumption of platinum group minerals could be 120 times higher in 2050 than in 2022. The expected surge in demand raises concerns that it will collide with the limits of finite resources. Increasing costs, as discoveries of deposits and mineral ores decline, result in increasing interest in exploring mineral resources in uncharted areas such as the ocean bed and outer space, which are global commons in which regulation for mining remains unclear and undeveloped. A critical question, from both an economic and an environmental and geological perspective, is whether there will be sufficient minerals to meet the significant needs for low-carbon and digital technologies. Paradoxically, this could eventually become an obstacle to the development of such technologies.

11. The production phase of digitalization creates ecological costs in developing countries that are rich in relevant minerals. Mining activities frequently have negative impacts on the environment, which vary by type of mineral and geographical location. However, some general impacts may be observed, as follows:

(a) Greenhouse gas emissions and energy use: Mining activities are energy intensive at both the extraction and processing stages, mostly relying on fossil fuel energy.

(b) Water use: Extraction and processing operations, as well as component manufacturing for final devices, such as semiconductors, require large amounts of water, and such activities may take place in areas experiencing water stress.

(c) Soil, air and water pollution: Mining generates waste and toxic chemicals; if such mine tailings are not properly managed, they can lead to soil and water pollution as a result of leakages, as well as land erosion, and separation and processing also require the use of chemicals that generate toxic externalities.

(d) Ecosystems and biodiversity: Negative impacts can be particularly severe when mining activities take place in areas that are protected or that have a high biodiversity value, threatening vulnerable ecosystems.

(e) Deforestation: Mining is considered to be the fourth largest driver of deforestation.

12. Environmental implications from mining are often linked to social impacts and may have effects on human rights, including with regard to impacts on people’s health and safety; impacts on communities, particularly Indigenous Peoples, resulting from displacements due to land use changes; poor working conditions, notably for women; impacts on artisanal and small-scale informal workers; child labour; and related imbalances, injustices and possible violations of human rights. Moreover, mining often takes place in areas facing conflict situations. These issues are exacerbated in developing countries, particularly the least developed countries, with limited capabilities for addressing negative externalities from mining.

B. Use phase

13. The use phase relates to the operation and utilization of end-user devices, transmission networks and data centres. The latter exert a significant environmental impact. Expanding digitalization increasingly relies on significant and growing levels of data storage and computing capacity in data centres, consuming large amounts of energy and water, with associated greenhouse gas emissions. Water and electricity use by data centres should be considered holistically. An additional significant impact of data centres, of a local nature, is noise generation.

14. The estimated electricity consumption by 13 of the largest data centre operators more than doubled in 2018–2022, led by Amazon, Alphabet, Microsoft and Meta. According to the International Energy Agency, worldwide, electricity use by data centres was about 460 TWh in 2022 and could more than double by 2026, to 1,000 TWh. As a comparison, total electricity consumption in France was about 459 TWh in 2022.

15. Digital technologies have a significant water-use footprint. However, information on water consumption is limited. Data centres not only have considerable electricity needs but also require water for cooling. The impact of water usage on local water resources needs to be assessed in a location-specific context, since the choice of cooling technology and the water or energy intensity is influenced by the local climate and resource availability; comparisons between regions with plentiful water supplies and those facing severe water shortages require different considerations.

16. The environmental impacts of the use phase of digitalization are accentuated by progress in compute-intensive technologies, such as blockchain technology and, notably, generative artificial intelligence. In the 2010s, efficiency gains kept up with data centre demand growth, resulting in a stable share of global electricity use, at around 1 per cent; this has changed significantly with the expanded use of artificial intelligence (see box).

Increasing environmental impacts from the artificial intelligence boom

The acceleration of artificial intelligence development and deployment following the emergence of Chat GPT [generative pre-trained transformer] in 2022 is leading to rapidly increasing environmental costs in terms of the demand for materials, water and energy use, air pollution and carbon emissions and electronic waste generation. Competition, particularly among large technology companies, to develop more powerful and sophisticated artificial intelligence models requires escalating data processing and computing capacity for training and inference, which mostly translates to a significant increase in data centre demand. One study shows that global demand for data centre capacity could more than triple by 2030, with artificial intelligence as the key driver. Data centre investment is expanding worldwide; one estimate shows that spending on data centre systems grew by 39.4 per cent in 2024, with a 23.2 per cent growth forecasted for 2025.

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The high level and increasing intensity of energy consumption in the use of artificial intelligence is becoming increasingly evident. It is estimated that an artificial intelligence search requires 10 times the electricity used during a conventional online search. One study shows that data centre power demand will grow by 160 per cent by 2030 and that in 2024, data centres worldwide consumed 1–2 per cent of overall power, which could rise to 3-4 per cent by the end of the 2020s. By 2028, artificial intelligence is expected to represent about 19 per cent of data centre power demand. This raises concerns about negative effects on the electricity grid, with potential disruptions and shortages that may in turn limit the deployment of artificial intelligence. As a result, there is a return to fossil fuel energy sources and the revival of nuclear energy plans, as renewable energy sources are not enough to meet demand. Ideally, renewable energy sources should not be additional but should replace the use of fossil fuels.

Increasing energy demand for data centres is threatening progress towards climate-related goals by both large technology companies and in some economies. For example, in Ireland, electricity use by data centres rose from 5 to 21 per cent of national consumption in 2015–2023 and projections indicate that this could reach 28 per cent by 2031. Chip production is also challenging the achievement of climate goals, for example in Taiwan, Province of China. Artificial intelligence technology and related chip production also has a significant impact on water consumption. One study shows that generating a 100-word email message with the use of Chat GPT-4 requires over half a litre of water. It is estimated that global demand for water resulting from the use of artificial intelligence may reach 4.2 billion–6.6 billion cubic metres in 2027, which would exceed half of the annual use in the United Kingdom of Great Britain and Northern Ireland in 2023. Since 95 per cent of the water consumed by data centres is potable, and most of it evaporates, competition with more essential water uses raises concerns, particularly where water is scarce. Moreover, air pollution from manufacturing, electricity generation and the use of diesel back-up generators is another environmental effect and can significantly impact public health.

At the end-of-life phase, artificial intelligence technology leads to the greater generation of electronic waste, since it requires new devices and more frequent equipment replacement. One study shows that electronic waste from generative artificial intelligence could potentially reach a total accumulation of 1.2 million–5 million tons in 2020–2030. The estimated compound annual growth rate of electronic waste from large language artificial intelligence models ranges from 129 to 167 per cent in 2023–2030, compared with 3.6 per cent for global conventional electronic waste.

The escalating environmental impacts of artificial intelligence technology over its life cycle, although uncertain, are raising concerns among relevant stakeholders, including affected communities in many countries. There are emerging policy initiatives to address the impacts at the national, regional and international levels. Awareness is increasing, but significant efforts are needed by all stakeholders to move towards the environmental sustainability of artificial intelligence technology. Much remains to be done in terms of measurement, transparency and research, to increase understanding of the environmental impacts. Discussions should also focus on the need to integrate environmental dimensions in the cost-benefit analysis of the design and deployment of artificial intelligence; critical questions include whether some tasks are worth the environmental cost and whether competition for larger models that affect environmental sustainability goals is required to meet societal needs or whether smaller models can do some of the work. Moreover, it is critical to consider the equity aspects of such impacts. Limited energy access and water stress situations in many developing countries challenge the possibility of developing artificial intelligence capacities and thereby hinder potential benefits.

Source: UNCTAD, based on the following: https://news.ucr.edu/articles/2024/12/09/ais-deadly-air-pollution-toll; https://qz.com/ai-google-microsoft-climate-change-data-center-energy-1851589453; https://www.aljazeera.com/economy/2024/12/25/taiwan-struggles-to-reconcile-climate-ambitions-and-chip-manufacturing; https://www.bbvaresearch.com/en/publicaciones/global-ai-and-climate-disruptive-potential-amid-growing-resource-strain/; https://www.capgemini.com/news/press-releases/organizations-are-increasingly-aware-of-the-environmental-footprint-of-gen-ai-but-most-arent-able-to-address-it-alone/; https://www.gartner.com/en/newsroom/press-releases/2025-01-21-gartner-forecasts-worldwide-it-spending-to-grow-9-point-8-percent-in-2025; https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand; https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand; https://www.nature.com/articles/s43588-024-00712-6; https://www.reuters.com/technology/artificial-intelligence/how-ai-cloud-computing-may-delay-transition-clean-energy-2024-11-21/; https://www.theguardian.com/technology/2024/sep/15/data-center-gas-emissions-tech; https://www.theguardian.com/world/2024/dec/10/ai-fuelled-cloud-storage-boom-threatens-irish-climate-targets-report-warns; https://www.unep.org/resources/report/artificial-intelligence-ai-end-end-environmental-impact-full-ai-lifecycle-needs-be; and https://www.washingtonpost.com/technology/2024/09/18/energy-ai-use-electricity-water-data-centers/.

C. End-of-life phase: Environmental impacts of digitalization-related waste

17. The last phase of the digitalization life cycle takes place when users no longer want or cannot use digital devices or ICT infrastructure; this phase includes the treatment of equipment after use. Waste from digitalization is a growing environmental concern. In 2010–2022, waste volumes from screens and monitors, as well as small information technology and telecommunications equipment, rose by 30 per cent globally, from 8.1 million to 10.5 million tons. This results from several factors, including the increased consumption of electronic devices and the shorter lifespans of ICT equipment; insufficient consumer awareness of the waste implications of devices; a linear model of production; and limited options for repairing or upgrading existing devices. New higher performance models quickly replace existing models or make them redundant. Programmed obsolescence, for example by making smartphones work more slowly over time or phasing out support for older versions of software, adds to the growing waste problem.

18. Digitalization-related waste contains hazardous materials that, if not properly handled, 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. Moreover, several unsafe and environmentally unsound practices are observed in the management of digitalization-related waste in informal settings, including scavenging, dumping waste on land or water, landfilling along with regular waste, open burning or heating, using acid baths or leaching, stripping and shredding plastic coatings and disassembling manual equipment without proper security measures. Such activities also release pollutants that contaminate air, soil, dust, water and food, at both 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.

19. In a linear model of production, waste is the last stage of the life cycle. However, in the alternative digital circular economy model, which is a more sustainable approach, the end of one cycle becomes the beginning of another.

II. Trade and development implications

20. The environmental impact of digitalization is a global issue, but countries at different levels of development are unevenly affected. Many developing countries continue to face obstacles in accessing digital technologies for development-related needs, while experiencing many of the negative impacts of material extraction and depletion, waste management and the effects of climate change. Moreover, they tend to be more affected by climate change, which can limit options for socioeconomic development, and lack the resources and capacity to use digital technologies in mitigating negative environmental impacts. Most of the value added in the digital economy is captured in developed countries and some digitally advanced developing countries, while many of the costs are more significantly borne in other developing countries. Many developing countries are providers of key raw materials and some are destinations for significant digitalization-related waste; and developing regions are often at the end of global trade chains, with limited opportunities for value addition and economic development, highlighting patterns of unequal ecological exchange.

A. Unequal ecological exchanges in minerals and metals trade

21. Developing countries are pivotal in the global supply chain of transition minerals and metals, with reserves, extraction and processing highly concentrated in a few regions. For example, about 60 per cent of global lithium reserves are in Argentina, the Plurinational State of Bolivia and Chile, known as the lithium triangle. With regard to extraction, in 2022, in Africa, the Democratic Republic of the Congo produced 68 per cent of global cobalt and in Asia, Indonesia produced about half of global nickel. The share of China in

global production was 65 per cent for natural graphite, 78 per cent for silicon metal and 70 per cent for rare earth elements. China also plays a major role in mineral processing, representing over half of global mineral processing for aluminium, cobalt and lithium, about 90 per cent for manganese and rare earth elements and nearly 100 per cent for natural graphite.

22. Many developing countries, often rich in the minerals needed for digital technologies, bear a disproportionate share of the negative environmental effects of mining, while earning limited benefits. Geographical concentration implies that most of the environmental and social impacts are concentrated in producing areas. In mineral-dependent developing countries, overall economic growth, foreign exchange earnings and government revenues are highly dependent on the evolution of the mining sector. As a result, they are vulnerable to external conditions and shocks affecting demand for transition minerals, as well as the high volatility of prices, impacting economic stability.

23. International trade in transition minerals largely mirrors the geographical distribution of reserves and extraction. Many developing countries in Africa, Asia and the Pacific and Latin America are major exporters of mostly unprocessed minerals and metals for further processing, mainly to developed countries and China. China, the United States of America and the European Union cannot meet total mineral demand through domestic mining. This results in an "unequal ecological exchange" dynamic whereby high value addition activities, mainly services and intangibles, are concentrated in developed economies that import raw materials yet outsource material- and energy-intensive production stages to other countries and also externalize production-related environmental impacts to middle- and low-income countries. Developing countries therefore export mainly unprocessed and low-value minerals and metals, bear the environmental and social costs and import higher-value final products. It is estimated that in the ICT sector, 82 per cent of carbon emissions are attributable to emerging regions, while developed regions benefit from 58 per cent of value added.

B. Environmental impacts of data centres in developing countries

24. Most data centres are in digitally advanced economies, yet the digital transformation in developing countries is driving increased demand for data centres in these countries, despite challenging climate-related conditions, limited energy availability, water scarcity and connectivity constraints and power outages. For latency reasons, the Internet of things and fifth-generation mobile network growth also favour establishing data centres closer to users. Moreover, with regard to various policy objectives, such as protecting privacy and other human rights, national security and economic development, countries may prefer to build data centres within their borders. This situation is likely to persist until there is a global approach to data governance, which allows for the equitable harnessing of the value of data for development independent of where data are stored. Further growth in data centre investments in developing countries is anticipated, with implications for local energy and water consumption. In regions with significant water stress, data centres often compete with local communities for potable water access. In warm regions, such as in Africa and Southeast Asia, reducing water consumption for cooling may be a challenge.

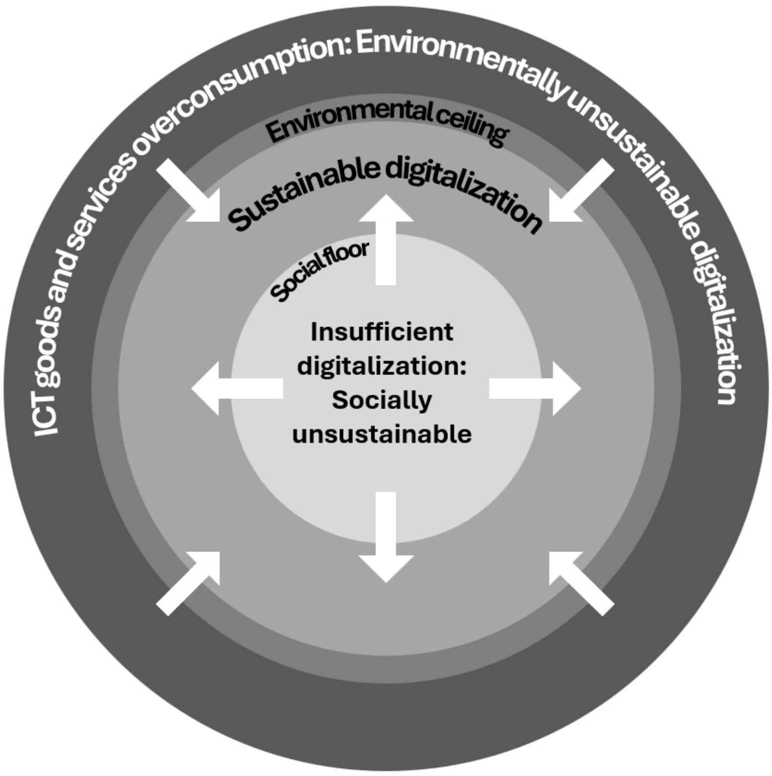
25. Concerns have been raised about the environmental impacts of data centres in both developed countries and developing countries, including Nigeria in Africa, Malaysia in Asia and Chile, Mexico and Uruguay in Latin America. It is imperative to integrate sustainability concerns into early stages of the planning of new data centres, in a holistic manner, including all environmental effects. To enable a global distribution of data centres that respects environmental sustainability, measures also need to be taken to achieve better data governance. In developing countries, policymakers and utilities could consider opportunities to co-develop local electricity and water infrastructure with new data centre and network projects, to expand electricity and water access in communities, with digital infrastructures serving as important anchor customers of electricity and water.

C. Divides related to digitalization-related waste and unequal ecological exchanges

26. Growth in digitalization-related waste has uneven regional implications. Unequal waste-related trends between developed and developing countries are expected to continue, driven by asymmetries in the demand for devices. The largest contributors of such waste in 2024 were China, the United States and the European Union. In per capita terms, there are significant divides in waste generation; developed countries generated on average 3.25kg of waste, compared with less than 1kg in developing countries and 0.21kg in the least developed countries. In the United States, one citizen generated on average 25 times more waste than one citizen in the least developed countries. This reflects digital divides in terms of access, affordability and use of devices and equipment, shown in the device consumption divide; the average number of devices and connections per capita is around 13 in North America, 9 in Western Europe, 4 in Central and Eastern Europe, about 3.5 in Asia and the Pacific and Latin America and less than 2 in Africa and the Middle East.

27. It is important to address overconsumption in high-income countries and be mindful of the associated waste generated, and many developing countries need to digitalize further, to participate effectively in the global economy. This will inevitably involve increasing consumption, highlighting the complex balance between sustainability and economic development. Achieving sustainable digitalization requires the moderation of overconsumption, leaving more scope for those not sufficiently connected to digitalize as part of development. From a social perspective, the aim is to move out of the circle of insufficient digitalization, while from an environmental perspective, there is a need to move below the environmental ceiling marking unsustainable digitalization (see figure). Much of the suboptimal waste management processes often used in this context, due to informality, lead to the inefficient and insufficient recovery of valuable resources. Workers often lack the necessary skills and knowledge about how to effectively manage waste, to recover the maximum potential value. They also experience poor working conditions, a lack of social protection schemes and limited opportunities to organize and improve livelihoods.

Sustainable digitalization



Source: UNCTAD.

28. Available evidence indicates a pattern of unequal ecological exchange in the international trade of digitalization-related waste, with uncontrolled trade in used electrical and electronic equipment and digitalization-related waste flows from developed to developing economies, and within regions from the most developed to less developed regions. This implies the transfer of responsibilities and risks, with the burden of environmental and social costs placed on receiving countries. In contrast, the higher value stages of the waste chain are exported from developing to developed countries. Developing countries therefore remain locked in at the low-value stage of the chain, while developed economies capture the highest value. Moreover, in destination countries, formal collection and recycling systems are often inadequate. The movement of such waste is regulated by the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, yet implementation is challenging, given the magnitude of informal shipments and illegal trade and limited enforcement capacities. There is a need to refrain from sending waste to developing countries, while harnessing circularity and development opportunities from international trade in used electronic equipment.

III. Ensuring sustainable development gains from digitalization

29. Achieving environmentally sustainable digitalization that fosters inclusive development requires reversing unequal ecological exchange dynamics and addressing the vulnerabilities faced in developing countries. Doing so should involve enabling a more circular digital economy and reducing the environmental footprint of digitalization, including through the better management of waste, while ensuring inclusive and equitable development outcomes.

A. Harnessing of critical minerals for inclusive and sustainable development

30. Transition minerals have become a major issue on the international development agenda, strongly interconnected with global challenges related to digitalization and environmental sustainability. Increased demand raises major geopolitical and developmental concerns. It can be leveraged as an opportunity for development if resource-rich developing countries can add more value to the minerals extracted, ensuring a fair share of the mineral rents, making effective use of related proceeds and diversifying into other parts of the value chain and sectors. Developing countries, notably the least developed countries, have long been concerned by a high level of reliance on a few primary commodities. Shifting away from this dependence requires diversification of the production and export structure as a development path, moving from low productivity and value added products to higher productivity and value added production and exports. The aim is to capture, manage and use the proceeds from exported minerals as part of achieving structural transformation. To reverse trade imbalances, developing countries should seek to maximize development opportunities through domestic processing and manufacturing. The international trade and investment context should be supportive for developing countries to be better equipped to benefit from mineral resources in order to help them secure a larger share of the global digital economy, increase government and export revenues, finance development, overcome commodity dependence, create jobs and raise living standards. Africa and Latin America hold significant untapped minerals potential that could be used in achieving inclusive and sustainable development.

31. Lessons from past "extractivist" experiences, during which developing countries rarely benefited from mineral resources, are relevant in the emerging transition mineral boom. Avoiding a new scramble for resources requires moving away from extractive dynamics in order for mining to function more as an engine for structural transformation and development. Mineral resources can be used to stimulate a process of dynamic interaction, or a virtuous circle, between production and export, through economic diversification, including by increased manufacturing. Doing so could help to alter traditional global trade patterns, improving the position of developing countries as exporters of higher value mineral-based products. Some developing countries exporting

transition minerals are already exploring the potential of, and moving into, the production of higher value added products, for example, seeking to add value by processing minerals, manufacturing intermediate goods such as precursors and batteries and, in the longer term, creating a regional value chain for manufacturing final products such as electric vehicles and smartphones. This is particularly evident in Africa, for example in the Democratic Republic of the Congo with regard to cobalt and other minerals, and in Latin America in the lithium triangle. Moreover, in Indonesia, the export restrictions on raw nickel may have led to significant foreign investment inflows and increased downstream activities.

32. Beyond national policies, regional and international cooperation and support are needed to ensure the necessary fiscal and policy space for structural transformation and development. Minerals-based development should ensure that the environmental and social costs of extraction, processing and manufacturing activities are minimized. In this context, the Secretary-General of the United Nations established the Panel on Critical Energy Transition Minerals; in its report, *Resourcing the Energy Transition: Principles to Guide Critical Energy Transition Minerals towards Equity and Justice*, the Panel identifies ways to ground the renewables revolution in justice and equity in order for it to spur sustainable development, respect people, protect the environment and power prosperity in resource-rich developing countries.[2] Recommendations are made on fairness, transparency, investment, sustainability and human rights, not only where minerals are mined, but along the entire mineral value chain, from refining and manufacturing to transport and end-of-life recycling. These recommendations are equally applicable to minerals used for digital equipment.

33. As transition minerals have become key inputs for both low-carbon and digital technologies, the importance of geopolitical factors associated with their production, trade and access has intensified. Developed countries and China account for most of the global consumption of transition minerals. Securing access to supply, reducing import dependence and diversifying sources have become strategic priorities, particularly in countries that are major low-carbon and digital technology producers. There is a race to increase mining worldwide, which is part of a broader economic, trade-related and technological leadership race, and may result in less efficient processes and an unnecessarily large environmental footprint, encouraging hoarding and leading to production overcapacity, while hindering development prospects. Policymaking changes have been triggered. Asia, particularly China, has emerged as a global electronics manufacturing hub, and the proximity to markets of intermediary products and components has bolstered burgeoning mineral processing activities. The aim to improve performance in strategic technology sectors, such as artificial intelligence and low-carbon technology, has resulted in an increased demand for minerals. More recently, due to supply shortages in moving from economic efficiency objectives towards more economic security, the focus in some global supply chains has shifted from "just in time" to "just in case" approaches, resulting in the revival of industrial policies related to transition minerals and associated industries, including electronics, in some developed countries, for example under the 2022 Inflation Reduction Act of the United States and the 2023 Critical Raw Materials Act of the European Union. The risk of subsidies and trade -related conflicts is increasing, which may lead to significant losses globally, particularly among developing countries, which have a comparatively much lower fiscal space.

34. Beyond increasing domestic production, many countries are looking abroad to secure access to transition minerals from alternative sources through alliances or partnerships, such as the Minerals Security Partnership between the European Union and various countries. Such alliances, often among developed countries importing minerals, should not result in even more asymmetrical negotiating power, against the interests of developing countries that export minerals, which should not be compelled to choose among sources of foreign direct investment; rather, developing countries should leverage competition to negotiate the most favourable conditions for their development. Resource diplomacy efforts to secure access to transition minerals by developed countries should be based on equity, ensuring mutual benefits and allowing for domestic value addition in developing countries. Moreover, international support is needed, particularly in the least

[2] See https://www.unep.org/resources/report/resourcing-energy-transition.

developed countries, in the form of financial and technical assistance, to overcome structural constraints and build capacity for structural transformation. Approaches that may be perceived to be strategic from a national economic security perspective may negatively affect global economic efficiency and environmental sustainability. A more balanced, comprehensive, global approach may be preferable, considering supply and demand and combining the interests of developing and developed countries, exporters and importers, while aiming for more responsible and sustainable consumption and production. Overall, the global response to increasing demand for transition minerals seems to mainly centre on increasing extraction. There is a need to balance the expansion of mining for development with the rights of local populations and environmental protection. More needs to be done in terms of waste management and moving towards a circular digital economy.

B. Digitalization-related waste management

35. The management of digitalization-related waste is a complex stream with a dual character, involving both hazardous substances and valuable materials. Such waste needs to be managed in an environmentally sound manner to ensure that dangerous materials are treated safely and dealt with separately. If not properly managed, waste can result in significant negative environmental and health-related and other social impacts, often affecting the most vulnerable. When digitalization-related waste is managed effectively, valuable materials can be recovered, which can create economic and environmental benefits, by increasing the supply of secondary raw materials and substituting for the primary supply of minerals and metals for the manufacturing of new equipment. Having statistics that properly reflect the digitalization-related waste situation is essential in waste management. Current formal collection rates of digitalization-related waste remain low, particularly in developing countries. The global average amounted to 24 per cent of all waste in 2022 yet was 7.5 per cent in developing countries. Even in developed countries, despite generally better formal collection systems, the average collection rate of 47 per cent is not sufficient.

36. Waste management involves significant challenges. In developing countries, formal collection systems to manage digitalization-related waste in an environmentally sound manner are often lacking, with much handling taking place in the informal sector. Moreover, only one in four developing countries has adopted relevant legislation on managing such waste. Other challenges in managing, collecting and recycling such waste are the complexity of electronic products, the limited availability of recycling and recovering technologies, the high cost of recycling, limited collection and treatment infrastructure and the lack of worker awareness and training and of consumer awareness of the impact of improper disposal. Moreover, there are significant investment needs, for enhancing capacities to manage digitalization-related waste. At informal sites, workers and microenterprises and small and medium-sized enterprises typically use rudimentary techniques to refurbish equipment for secondary sale or dismantle and process parts to extract valuable materials. Such activities contribute to the reduction of poverty and digital divides as devices and equipment become more affordable. However, suboptimal processes and limited skills lead to the inefficient and insufficient recovery of valuable resources. Workers also experience poor working conditions linked to weak labour rights. When women participate, they often occupy positions at the lower levels of the working hierarchy. Moreover, there may be tensions in developing countries arising from the urgent need in the short term to ensure that informal sector waste pickers have a living income and in the long term to address health-related and environmental risks that arise from inadequate waste processing

C. Development opportunities from the circular digital economy

37. Addressing environmental challenges related to digitalization involves adopting sustainable practices throughout the entire life cycle, from design and production to usage and disposal, while ensuring equitable benefits. Discussions on responsible consumption and production (Sustainable Development Goal 12) have increasingly focused on the

desirability of a more circular economy. The digital economy remains highly linear; a more circular digital economy would seek to reduce, reuse and recycle digital devices and infrastructure, including by extending lifespans. This can be achieved through sharing, rental or donation; maintenance and repair; resale and redistribution; and remanufacturing and refurbishing. Waste can thereby be turned into resources and gain economic value.

38. Circular economy activities should be based on the critical overarching principle of designing products with circularity in mind, for longer durability and easy repair and recycling. They offer an opportunity to recover valuable resources and enable economically beneficial activities and job creation. Consumers also need to reconsider digitalization-related behaviours, allowing for longer lifespans and making conscious decisions to consume more sustainable equipment. Preventing waste is the priority in a circular digital economy. Pressure over primary minerals supply can be alleviated to an extent by increasing secondary supply through the recycling of waste, allowing for the recovery of some materials through urban mining. Yet recycling alone is not enough to fill potential material gaps or reduce major environmental impacts arising from the production and disposal of electronic equipment; other circular digital economy actions can reduce supply pressure by moderating demand for new digital equipment. Technological progress can also help, with new processes leading to increased efficiency in the use of resources; emerging substitute materials that may be more environmentally friendly; and better technologies for proper waste management.

39. Beyond environmental benefits, circularity can bring substantial economic benefits, as waste contains valuable parts and materials that can be recycled and recovered. With proper management, including of possible health risks, the process of extracting valuable materials can represent an opportunity for value addition and job creation along the waste value chain. Such activities can provide livelihoods to workers and incomes to related enterprises. Formalization should be the long-term objective in areas where a large part of waste is handled informally; ensuring effective ways of involving the informal sector may also be important in an overall sound waste management strategy. Skills development and sustainable enterprises, better working conditions and worker organizations and social dialogue are part of a just transition. There is a business case for activities in the circular economy, with innovative business models that can extend the lifetime of electronic products, such as through reuse or by offering electronics as a service. For example, the markets for recycling, refurbished and second-hand electronics are forecast to triple in the coming decade.

40. The circular economy also has an international dimension. If equipment that is legally traded can be reused, is truly second-hand and can be repaired or refurbished, it can contribute to value addition, job creation and affordability, thereby alleviating digital divides and advancing developmental objectives. However, a receiving country, generally with limited waste management capacity, should not bear the environmental and social costs without corresponding financial compensation to help improve waste management. One option is to make producers responsible for managing waste globally. Developing countries need to build capacities for waste management and proper oversight and to strengthen circular economy activities. This requires increased financial resources, stakeholder skills and infrastructure to collect and recycle waste in a way that mitigates health-related and environmental risks, as well as institutional capacities to monitor and enforce legislation. Given limited resources available domestically in many countries, international support is essential.

IV. Policymaking for inclusive and environmentally sustainable digitalization, at the national, regional and international levels

41. Digitalization continues to rapidly evolve, transforming lives and livelihoods. However, unregulated digitalization risks leaving people behind and exacerbating environmental challenges. Actions with regard to more sustainable consumption and production, similar to actions with regard to circularity, need to be supported by appropriate

policies at the national, regional and international levels that are adequately enforced (see table). A circular digital economy also needs to be supported by digital tools. Achieving inclusive and sustainable digitalization requires policies to be based on the principle of common but differentiated responsibilities and respective capabilities, as well as the needs of different countries and actors. Important policymaking preconditions are improving the understanding of the environmental impacts of digitalization, notably through better evidence and transparency and the awareness of such impacts. The new and complex interplay between digitalization, environmental sustainability and inclusive development requires integrated policy responses, with an integrated, holistic, interdisciplinary and multi-stakeholder approach. Civil society plays a key role in raising concerns about the need to address the environmental impacts of digitalization over the entire life cycle. It is imperative to harness the power of digitalization, to advance inclusive and sustainable development, while mitigating negative environmental impacts. Policymakers should align digital and environmental policies at all levels, thereby enhancing the ability of the global community to address such challenges. Addressing widening digital ecological inequalities requires concerted international efforts to ensure fairer practices, such as promoting sustainable mining approaches, enhancing digital infrastructure, curbing illegal digitalization-related waste exports and supporting capacity-building in developing countries. At present, an inclusive global governance framework is not yet in place for collective action and knowledge-sharing among countries, building consensus, setting global standards and encouraging the transparent reporting and monitoring of progress towards shared goals at the interface of digitalization and environmental sustainability. However, the issue is recognized at international discussions, such as with regard to the Global Digital Compact and on the digitalization day held during the twenty-ninth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change.

Policy options, by phase of digitalization life cycle

		Policy options		
Digitalization life cycle phase	*Objective*	*National level*	*Regional level*	*International level*
Production	Ensure environmentally sustainable and responsible mining and electronics manufacturing, while enabling more domestic value addition for economic development in producing countries	Improve information on mining resources for exploration Promote mining contract negotiations for equitable distribution of rents from mining of transition minerals Develop industrial policies to support value addition of raw materials extracted and move towards manufacturing Develop technology policy for research on more sustainable substitute materials Ban use of toxic materials Incentivize and promote use of recycled materials, supporting development of	Foster regional cooperation to increase negotiating power in mining contracts and regional tax regimes Develop regional industrial policies for value addition in developing countries	Develop standards for responsible and sustainable mining and electronics manufacturing Limit use of minerals that may be a source of conflict Adopt and apply global transparency standards Collaborate for improved geological and mining data Establish sustainable development licences to operate mining activities Negotiate international tax regime that works for equitable distribution of rents among producers and

Digitalization life cycle phase	Objective	Policy options: National level	Policy options: Regional level	Policy options: International level
		secondary markets Require producers to transparently report on environmental footprints		consumers Enable international cooperation among consumer and producer countries of transition minerals and metals
Use	Optimize data centre performance to minimize impacts on energy and water and on local communities Optimize software to reduce energy use Reduce overconsumption Incentivize and promote meaningful, effective and productive use of digital tools and equipment Bridge digital and data divides	Raise awareness of environmental implications of different kinds of use (e.g. artificial intelligence) Develop policies to counter and ban greenwashing Require sharing of network infrastructure Require data centres to report holistically on environmental impacts Mitigate excessive data storage Adopt technology policy to foster and meet requirements of energy and water use efficiency in data centres Require investments by hyperscale data centres in renewable energy to feed local grids Promote water conservation in data centres, minimizing use of water for cooling	Consider regional data centres as a more efficient option for the environment Undertake needs assessment and identification of locations for regional data centres based on potential environmental impacts	Develop global reporting standards on environmental impacts Foster global data governance, including environmental sustainability considerations Strengthen international cooperation on bridging digital and data divides and building digital and environmental capabilities in developing countries Strengthen international cooperation on competition policies to address abuse of market power in the digital economy
End-of-life	Prevent and minimize digitalization-related waste and increase recovery of resources and value from such waste	Adopt and enforce electronic-waste policy, legislation and regulations, to improve collection and recycling rates Improve data and information on digitalization-related waste Build waste management infrastructure	Develop regional recycling facilities, particularly in developing countries, to enable shift to higher value addition in digitalization-related waste value chain and better recovery of valuable resources Facilitate collaboration in waste management,	Improve data and information on digitalization-related waste Develop global standards for circularity Ensure compliance with rules of Basel Convention on the Control of Transboundary Movements of

Digitalization life cycle phase	Objective	Policy options: National level	Policy options: Regional level	Policy options: International level
		Apply extended producer responsibility mechanisms Improve working conditions in waste management sector, moving towards formalization	sharing technology and best practices	Hazardous Wastes and their Disposal, to prevent illegal exports of digitalization-related waste Consider transferring extended producer responsibility in transboundary flows of used equipment and/or extending geographical scope
All phases	Enable, promote and regulate sustainable consumption and production and the circular digital economy through policies for reducing, reusing and recycling	Implement circular economy policy approaches throughout digitalization life cycle Strengthen integration of environmental sustainability and digital development aspects, in a coherent manner, in national development strategies Regulate to require the following: ICT products designed for circularity and sustainability; avoidance of programmed obsolescence; extended product durability; right to repair; traceability of products, including components and raw materials (e.g. through digital product and/or material passports); and higher levels of recycling Incentivize and promote new sustainable business models (e.g. electronic products as a service) Develop collaboration and partnerships among relevant stakeholders throughout digitalization cycle Improve evidence base for policymaking	Consider developing regional approaches to circular digital economy and digital trade Develop regional approaches to tracing of digital products	Strengthen international cooperation among relevant stakeholders throughout digitalization life cycle Adapt policies to ensure that trade works for an inclusive and sustainable global digital economy and digital trade Develop global standards of design for sustainable ICT products, as well as for reusing, repairing and recycling Include ICT sector in international frameworks for assessing various environmental impacts

Digitalization life cycle phase	*Objective*	*Policy options*		
		National level	*Regional level*	*International level*
		Raise awareness through targeted campaigns on environmental impacts of digitalization Regulate advertising in the digital economy to prevent manipulation and control over consumers, including actions that encourage overconsumption		

Source: UNCTAD.