Building a Sustainable ICT Ecosystem

Strategies and Best Practices for Reducing Environmental Harms in a Digital World

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Research by

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Preface:

The Information and Communications Technology Council (ICTC) is a not-for-profit, national centre of expertise for strengthening Canada's digital advantage in a global economy. Through trusted research, practical policy advice, and creative capacity-building programs, ICTC fosters globally competitive Canadian industries enabled by innovative and diverse digital talent. In partnership with an expansive network of industry leaders, academic partners, and policymakers from across Canada, ICTC has empowered a robust and inclusive digital economy for over 25 years.

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Foreword

Over the past two years, the Information and Communications Technology Council (ICTC) has been working to advance environmental sustainability in Canada's information and communications technology (ICT) sector:

In February 2022, ICTC and the Digital Governance Council (DGC) forged a partnership to advance the objectives of DGC's Sustainable IT Pledge, the first-ever commitment by Canadian organizations to cut rapidly rising emissions from digital technologies.

In 2022 and 2023, ICTC conducted three knowledge syntheses about sustainable ICT: one about the environmental impacts of ICT, another about global policy responses to these impacts, and still another about international standards for sustainable ICT. ICTC also conducted a series of key informant interviews with global ICT sustainability experts to identify best practices for advancing sustainable ICT and Canadian ICT businesses to learn more about the state of environmental sustainability in the Canadian ICT sector.

In April 2023, ICTC partnered with the Digital Governance Council to hold a policy roundtable on advancing sustainable ICT in Canada. Roundtable participants discussed how they measure the environmental impacts of ICT, the current state of ICT sustainability in Canada's ICT sector and progress to date, ongoing challenges to accomplishing sustainable ICT, and potential responses to these challenges, such as standards and best practices for sustainable ICT development and procurement.

In May 2023, ICTC conducted a survey of 500 professionals from across Canada who, in their current role, are responsible for ICT procurement, ICT operations management, or ICT product and service development. The first of its kind in Canada, the survey benchmarked the state of sustainability in Canada's ICT ecosystem, including whether organizations are thinking about sustainability from an ICT perspective, how organizations are approaching sustainable ICT, and what challenges organizations face in advancing sustainable ICT.

In November 2023, ICTC and the Digital Governance Council worked together to publish a policy brief outlining what steps need to be taken to advance environmentally sustainable ICT in Canada.[1] The policy brief details the current state of ICT sustainability in Canada, drawing on findings from ICTC's sustainable ICT survey. It also discusses what challenges organizations face in accomplishing sustainable ICT and considers what industry and policy solutions may be needed from industry and government to advance sustainable ICT in Canada.

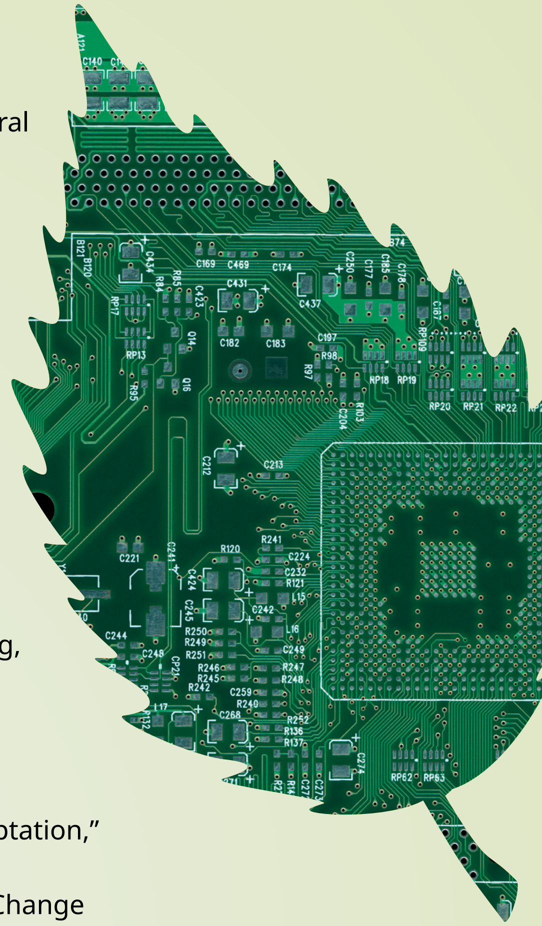
[1] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

This report builds on ICTC's aforementioned work by providing industry stakeholders with a succinct summary of the environmental impacts that occur across the ICT supply chain and guidance about what ICT designers, developers, and adopters can do to reduce the environmental impact of ICT.

Section I provides an overview of what environmental impacts occur across the global ICT supply chain, including during raw material extraction, manufacturing and production, transportation, use, software and web design, and disposal and recycling. This section is based on a robust knowledge synthesis that reviewed 116 publications about the environmental impacts of ICT products and services.

Section II provides guidance about what ICT industry stakeholders can do to improve the environmental impact of the ICT sector. Drawing from the literature and consultations with industry experts, it focuses on the three main areas where ICT designers, developers, and adopters have the greatest ability to influence the environmental impact of ICT products and services: namely, adopting environmental strategies at the organizational level, incorporating eco-design into product and service design, and engaging in sustainable technology procurement.

Introduction



Since the onset of the industrial revolution, humans have transformed natural ecosystems to enable goods and services production—converting forests to agricultural and industrial land, processing natural resources to develop innovative infrastructure and products, and engaging in the widespread use of fossil fuels for energy. Despite improving quality of life, particularly for the Western world,[2] these practices have pushed the Earth beyond the boundaries that define a safe environment for humanity.[3] At present, the global economy emits excessive greenhouse gas (GHG) emissions, consumes too much water, alters the use of too much natural land, produces excessive novel entities, and compromises biosphere integrity.[4] Excessive GHG emissions and changes in the use of natural land are also contributing to climate change at an unprecedented rate.[5] Between 2011 and 2020, global surface temperatures increased 1.1°C above pre-industrial levels.[6] This rise in temperature has triggered a chain reaction of adverse environmental effects, including rising sea levels, increased flooding, droughts, and forest fires.[7]

In response to a 2023 survey by the World Economic Forum, world leaders identified “failure to mitigate climate change” as the number one risk facing humanity over the next 10 years, followed by “failure of climate-change adaptation,” “natural disasters and extreme weather events,” and “biodiversity loss and ecosystem collapse.”[8] Worryingly, the Intergovernmental Panel on Climate Change predicts that surface temperatures will continue to rise during the next century.[9]

Environmental considerations aside, the urgent need to address climate change and other environmental harms is putting environmental criteria at the forefront of government policy and regulations, corporate social responsibility strategies, financial reporting frameworks, and more. Further, it is creating new criteria for future success and growth for many industries around the world. In 2016, nearly 200 parties signed the first legally binding international treaty on climate change, spurring a vast number of governments and organizations to adopt net-zero strategies, increase their use of clean energy, divest from fossil fuels, and engage in things like sustainable procurement, sustainable resource management, and eco-

2 Lucas, Robert, “The Industrial Revolution: Past and Future,” 2004, *American Institute for Economic Research,* https://www.aier.org/wp-content/uploads/2013/11/EEB-8.04-IndustRev.pdf; “Planetary Boundaries,” 2021, Stockholm Resilience Centre, https://www.stockholmresilience.org/research/planetary-boundaries.html
3 “Planetary Boundaries,” 2021, Stockholm Resilience Centre, https://www.stockholmresilience.org/research/planetary-boundaries.html
4 “Planetary Boundaries,” 2021, Stockholm Resilience Centre, https://www.stockholmresilience.org/research/planetary-boundaries.html
5 “Climate Change 2023 Synthesis Report,” 2023, *Intergovernmental Panel on Climate Change,* https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
6 “Climate Change 2023 Synthesis Report,” 2023, *Intergovernmental Panel on Climate Change,* https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
7 “Climate Change 2023 Synthesis Report,” 2023, *Intergovernmental Panel on Climate Change,* https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
8 “The Global Risks Report 2023,” 2023, *World Economic Forum,* https://www3.weforum.org/docs/WEF_Global_Risks_Report_2023.pdf
9 https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

design. At present, 120 countries and subnational governments representing nearly 88% of global GHG emissions, 92% of global GDP, and 89% of the global population have committed to achieving net-zero emissions by 2050.[10]

Turning to the private sector, as of 2023, 132 banks representing 40% of all global banking assets and all of Canada's largest banks had signed onto the Net-Zero Banking Alliance, which embodies a commitment to align all lending and investment portfolios with pathways to net-zero by 2050 or sooner.[11] Additionally, 929 companies from the Forbes 2000 list, representing $26.4 trillion in annual revenue, have set net-zero targets.[12]

Beyond net-zero commitments, regulatory bodies are increasingly requiring companies to engage in climate-related financial disclosure or the disclosure of financial risks that they might face as a result of climate change and economic and policy responses to climate change. For example, the European Union is now requiring approximately 50,000 large companies and subsidiaries of large companies to disclose standardized information about their climate-related risks to investors, consumers, and civil society organizations.[13]

In order to meet net-zero targets and appease investors, consumers, and civil society organizations, all of the above entities will need to begin incorporating environmental criteria into their legal, economic, and financial decisions. Governments will need to consider environmental criteria when drafting legislation, designing tax credits and tax rebate schemes, and providing funding to the private sector in the form of loans and grants. Banks will need to consider environmental criteria when deciding which companies to invest in and lend to. Finally, large-scale and public companies will need to consider environmental criteria when deciding which vendors to procure products and services from and which types of products and services to procure. Together, these trends will reshape the global economy, creating an economy that favours organizations, products, and services that prioritize sustainability and minimize harmful environmental impacts.

While high-emitting and material-intensive sectors will be at the forefront of sustainability gains, all sectors will have a role to play.[14] Importantly, this also includes ICT, which, despite being perceived as having minimal impacts on the environment, contributes to GHG emissions, the depletion of natural resources, land use change, energy consumption, water consumption, and air, soil, and water pollution.[15] For example, the sector currently contributes 1.8% to 3.9% of global GHG emissions, which is comparable to that of the global aviation sector, including

10 Net-Zero Emissions by 2050," November 27, 2023, *Government of Canada,* https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html
11 "Our Members," 2023, *UN Environmental Programme,* https://www.unepfi.org/net-zero-banking/members/
12 "Net zero targets among world's largest companies double, but credibility gaps undermine progress," June 2023, *Net Zero Tracker,* https://zerotracker.net/insights/net-zero-targets-among-worlds-largest-companies-double-but-credibility-gaps-undermine-progress
13 "Corporate sustainability reporting," 2023, *European Commission*, https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en
14 E.g., Mining, oil and gas, transport, agriculture, and buildings and infrastructure. See: "Greenhouse gas emissions: drivers and impacts," 2023, *Environment and Climate Change Canada,* https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions-drivers-impacts.html
15 Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

both domestic and international flights).[16] As is explored in Section I of this report, the ICT sector has a broad range of environmental impacts across its supply chain, from raw material extraction to manufacturing and production to transportation, use, and end-of-life disposal.

As the adoption of ICT grows, so will its associated environmental impacts. In 2023, 65.7% of the global population was connected to the internet,[17] and ICT devices already outnumber the global population.[18] By 2025, the number of devices is expected to reach 55.9 billion, generating further growth in the use of ICT services.[19] Emerging technologies like internet of things, artificial intelligence, digital twins, and immersive technology are expected to see widespread adoption, generating increased demand for energy and ICT hardware, devices, and components. Amid this growth, it will be important for ICT designers, developers, and adopters to align their operations, products, and services with environmental best practices for sustainable ICT. If not, technological innovation will likely come at the cost of the earth's natural environment and our societal well-being.

Unfortunately, research shows that ICT designers, developers, and adopters are not consistently considering environmental impacts or environmental sustainability in their technology decisions. For example, in response to a 2023 survey by ICTC, approximately 46% of Canadian organizations indicated they do not factor environmental impact or environmental sustainability into how they design, develop, buy, or manage ICT; 26% indicated that they do factor environmental impact or sustainability into their technology decisions, but only minimally; and 27% indicated that they do outright. Similarly, a 2021 survey by Capgemini found that less than half (43%) of global organizations were aware of the environmental impact of their IT, while just 18% had a sustainable IT strategy with well-defined goals and target timelines.[20]

A policy brief that ICTC published in 2023 discussed the main reasons why organizations are not considering environmental impacts or environmental sustainability in their technology decisions.[21] These include limited awareness among ICT professionals about the environmental impacts of ICT, a lack of organizational capacity, knowledge, and skills needed to implement sustainable ICT, and a lack of data and reporting standards for sustainable ICT. While the brief

[16] These estimates vary due to the fact that ICT emissions are challenging to measure: in part due to a lack of consistent data for CO2 emissions accounting, and in part due to the fact that ICTs transcend traditional sectoral boundaries, making it challenging to capture their total share of emissions. See: Freitag, C. Et al., "The real climate and transformative impact of ICT" A critique of estimates, trends, and regulations," 2021, ScienceDirect, https://www.sciencedirect.com/science/article/pii/S2666389921001884#; Ritchie, Hannah, "Climate change and flying: what share of global CO2 emissions come from aviation?" 2020, *Our World in Data,* https://ourworldindata.org/co2-emissions-from-aviation; Schwarzer, Stefan and Peduzzi, Pascal, "Foresight Brief," 2021, *UNEP,* https://wedocs.unep.org/bitstream/handle/20.500.11822/37439/FB027.pdf

[17] Petrosyan, Ani, "Global Internet User Penetration 2014 to 2023," November 2023, *Statista,* https://www.statista.com/statistics/325706/global-internet-user-penetration/

[18] Taylor, Petroc, "Global number of devices and connections per capita 2018 to 2023," January 2023, *Statista,* https://www.statista.com/statistics/1190270/number-of-devices-and-connections-per-person-worldwide/

[19] "How you contribute to today's growing datasphere and its enterprise impact," November 2019, *International Data Corporation,* https://blogs.idc.com/2019/11/04/how-you-contribute-to-todays-growing-datasphere-and-its-enterprise-impact/

[20] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf

[21] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

highlighted what governments and industry can do to enable sector-wide change, such as standardizing environmental data and reporting across the ICT sector, this report addresses the first two of the above challenges: that is, increasing awareness of the environmental impacts of ICT among ICT professionals and expanding the ability of Canadian organizations to implement strategies for sustainable ICT.

Section I of this report provides an in-depth summary of the environmental impacts that occur from ICT products and services across the ICT supply chain. To convey the full breadth and depth of environmental impacts from ICT, this section adopts a supply chain perspective, homing in on raw material extraction, manufacturing and production, transportation, use, and recycling and end-of-life disposal. Section II turns its focus to the strategies that can be implemented by organizations to reduce the environmental impact of their ICT infrastructure, products, services, and purchases. It covers four broad strategies that organizations can use, including (1) developing an organization-wide environmental sustainability strategy, (2) adopting best practices for sustainable ICT infrastructure, (3) building environmentally sustainable products and services, and (4) sourcing and procuring sustainable ICT. Each subsection includes an in-depth description of the strategy at hand, as well as a list of useful resources, tools, and standards that organizations can use while implementing the strategy.

Environmental Impacts Across the Global ICT Supply Chain

The ICT sector relies on a complex and highly globalized supply chain involving numerous steps from design to fulfillment.[22] Many of the brand name companies that ICT professionals are familiar with are directly responsible for the design, selecting preferred suppliers, and interacting with customers, but the majority of manufacturing and procurement activities are outsourced to other companies.[23] Due to the complexity of the ICT supply chain, a large portion of the environmental impacts of ICT are "hidden" from ICT professionals and consumers. Indeed, during the research interviews for this study, many ICT professionals reported limited knowledge of ICT's environmental impact, as well as a lack of understanding about how to address the environmental impacts of ICT.

Despite this lack of awareness, the ICT sector has a broad range of environmental impacts, from raw material extraction, processing, and manufacture to transportation, use, and end-of-life disposal. Problematically, many of the most harmful environmental impacts occur during the earliest and latest stages of the ICT supply chain—raw material extraction and disposal—far from the eyes of ICT designers, developers and consumers. Raw material extraction and electronic waste disposal release a long list of toxic byproducts into the environment.[24] Manufacturing and production, meanwhile, account for the vast majority of GHG emissions emitted by end-user devices across their lifecycles.

22 "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf

23 "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf

24 Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Santarius, Tilman et al., "Digital sufficiency: conceptual considerations for ICTs on a finite planet," 2022, *Annals of Telecommunications,* https://doi.org/10.1007/s12243-022-00914-x; Santarius, Tilman et al., "Digitalization and the decoupling debate," 2022, *Sustainability,* https://doi.org/10.1007/s12243-022-00914-x; Tansel, Berrin, "From electronic consumer products to ewastes: global outlook, waste quantities, recycling challenges," 2017, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412016305414; Wäger, Patrick et al., "The material basis of ICT," 2015, *ICT Innovations for Sustainability,* https://link.springer.com/chapter/10.1007/978-3-319-09228-7_12;

For example, manufacturing and producing a mobile phone emits nearly 18 times more greenhouse gas emissions than are emitted during its use.[25] Similarly, manufacturing and production account for about 83% of the GHG emissions released over the lifecycle of a laptop, while use and end-of-life disposal account for about 16% and 1%, respectively.[26]

Despite this reality, when ICT professionals introduce measures to improve their products and services, they focus primarily on environmental impacts that occur during the use stage of the ICT supply chain, such as energy consumption. Meanwhile, environmental impacts at the very beginning and tail end of the ICT supply chain tend to be neglected. According to a survey of 92 government programs and industry initiatives across the OECD and European Commission, two-thirds of sustainable ICT initiatives focus on the use phase of the ICT lifecycle.[27] Similarly, a recent survey by ICTC found that the majority of Canadian organizations' sustainable ICT initiatives focused on energy consumption and waste creation versus non-renewable resource exploitation and air, water, and soil pollution.[28] While any effort to make the ICT supply chain more sustainable is positive, the high proportion of initiatives that focus on the use stage—versus raw material extraction, production, and disposal—suggest that ICT sustainability initiatives are not aligned with the larger environmental impacts of the ICT supply chain.

To help address this challenge, this section of the report sheds light on the environmental impacts that occur across the ICT supply chain, including during raw material extraction, manufacturing and production, transportation, use, and disposal. It relies on a knowledge synthesis of existing publications about the environmental impacts of ICT.

The ICT Supply Chain

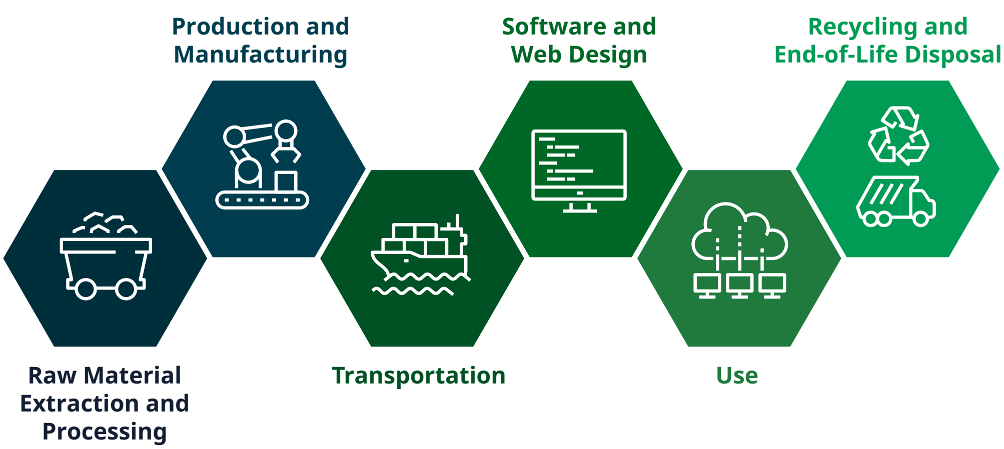


Figure 1. *The ICT Supply Chain*

[25] Andrae, Anders, "Life-Cycle Assessment of Consumer Electronics: A review of methodological approaches," 2016, *IEEE Consumer Electronics Magazine,* https://doi.org/10.1109/MCE.2015.2484639
[26] "Sustainable IT: 3 Steps to Mitigate Asset GHG Emissions Throughout the Product Life Cycle," May 2023, *Gartner,* https://www.gartner.com/en/documents/4392999
[27] Reimsbach Kounatze, "Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment," 2009, *OECD Digital Economy Papers,* http://dx.doi.org/10.1787/222431651031
[28] Clark, A. and Matthews, M., "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

RAW MATERIAL EXTRACTION

Raw material extraction refers to the extraction and processing of raw materials used in ICT hardware and devices. ICT hardware and devices, such as computers, smartphones, and networking equipment, are built using a long list of raw materials, including indium, lithium, tantalum, gallium, copper, silver, gold, and rare earth elements (REEs).[29] Because stockpiles of these materials are located all over the world, mining for the materials used in ICT hardware occurs on a global scale. Currently, a large proportion of these mining activities take place in regions that are geographically very distant from Canada, for example, in China and the Democratic Republic of Congo.[30] While Canada only accounts for a small percentage of this activity at present, several provincial governments and the federal government of Canada have announced plans to expand mining activities in the years to come.

Most of the materials that are used to manufacture ICT products come from primary sources, which means they are extracted directly from the Earth. Only a small portion is extracted from secondary sources, such as post-consumer hardware or mine tailings (a liquid slurry of fine particles and water generated during the process of ore crushing for mineral extraction).[31] Extracting materials from primary sources is usually more environmentally harmful than extracting materials from secondary sources: according to some estimates, extracting materials from primary sources is more than 5.5 times more harmful than extracting materials from secondary material sources.[32]

Research shows that the extraction and processing of raw materials for the ICT sector has negative implications for both the environment and human health.[33] For one, raw material extraction is very energy intensive. The most energy-intensive mining processes are land clearing, drilling, blasting, crushing, and hauling.[34] When these processes use fossil fuels instead of clean energy sources, which they typically do, they also generate high volumes of GHG emissions, in turn contributing to global climate change. Besides energy consumption, activities like land clearing also contribute to GHG emissions in the mining sector.[35] Overall, raw material extraction accounts for a significant portion of the ICT sector's total GHG emissions,[36] however, a lack of GHG emissions reporting by industry makes it challenging for scientists to accurately estimate.[37]

[29] "Digital Economy Growth and Mineral Resources: Implications for Developing Countries," December 2020, *UNCTAD,* https://unctad.org/system/files/official-document/tn_unctad_ict4d16_en.pdf

[30] "Digital Economy Growth and Mineral Resources: Implications for Developing Countries," December 2020, *UNCTAD,* https://unctad.org/system/files/official-document/tn_unctad_ict4d16_en.pdf

[31] Bascompta et al., "Corporate Social Responsibility Index for Mine Sites," 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Jha et al., "Review on hydrometallurgical recovy of rare earth metals," 2016, *Hydrometallurgy,* https://www.sciencedirect.com/science/article/abs/pii/S0304386X16300603; Jouini et al., "Sustainable production of rare earth elements from mine waste and geoethics," 2022, *Minerals,* https://www.mdpi.com/2075-163X/12/7/809

[32] Jouini et al., "Sustainable production of rare earth elements from mine waste and geoethics," 2022, Minerals, https://www.mdpi.com/2075-163X/12/7/809

[33] Manhart, Andreas et al., "Resource Efficiency in the ICT Sector," 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf

[34] Azadi, Mehdi et al., "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," 2020, *Nature Geoscience,* https://www.nature.com/articles/s41561-020-0531-3

[35] Azadi, Mehdi et al., "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," 2020, *Nature Geoscience,* https://www.nature.com/articles/s41561-020-0531-3

[36] Belkhir, Lotfi and Elemeligi, Ahmed, "Assessing ICT global emissions footprint: Trends to 2040 & recommendations," 2018, *Journal of Cleaner Production,* https://doi.org/10.1016/j.jclepro.2017.12.239; Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf

[37] Azadi, Mehdi et al., "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," 2020, *Nature Geoscience,* https://www.nature.com/articles/s41561-020-0531-3; Costa, Carlos M. et al., "Recycling and environmental issues of lithium-ion batteries: Advances, challenges and opportunities," 2021, *Energy Storage Materials,* https://www.sciencedirect.com/science/article/abs/pii/S2405829721000829

Raw material extraction also has a major impact on land use, soil pollution, and overall ecosystem health. Raw materials are usually located in natural areas, far from cities and infrastructure. In order to carry out mining projects, mining companies need to build new infrastructure, including roads, processing facilities, and waste containment areas.[38] Because this infrastructure needs to be located in natural areas, the surrounding habitats experience fragmentation (the breaking up of large natural areas into fragmented, smaller parts) and land use change (a change in the way land is used), leading to ecosystem disruption (the disruption of natural ecosystems) and biodiversity loss (a decline in biodiversity, which is an important attribute of healthy ecosystems).[39] The soil surrounding mining sites often experiences increased erosion and pollution, leading to poor soil health, which impacts local plant populations.[40] Mining operations also cause soil acidification and eutrophication (an unnatural increase in the concentration of nutrients), leading to terrestrial toxicity.[41]

Finally, raw material extraction contributes to the production of waste and hazardous materials, which are a concern for both natural environments and human health.[42] Specifically, raw material extraction generates high volumes of waste gases, wastewater, radioactive waste, mine tailings (the materials left over

38 Bascompta et al., “Corporate Social Responsibility Index for Mine Sites,” 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Duporte, Alexandre, “Environmental impacts of digitalization,” 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Dutta, Tanushree et al., “Global demand for rare earth resources and strategies for green mining,” 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/; Ganguli, Rajive and Cook, Douglas,” Rare earths: A review of the landscape,” 2018, *MRS Energy and Sustainability,* https://www.semanticscholar.org/paper/Rare-earths%3A-A-review-of-the-landscape-Ganguli-Cook/b87c058f428f69e15399d6700d0f67219d4e9bc9; Golev, Artem et al., “Rare earths supply chains: Current status, constraints, and opportunities,” 2014, *Resources Policy,* https://www.uvm.edu/giee/pubpdfs/Golev_2014_Resources_Policy.pdf; Lennerfors, Thomas Taro et al, “Sustainable ICT: A Critique from the Perspective of World Systems Theory,” 2014, *ICT and Society*, https://doi.org/10.1007/978-3-662-44208-1_6; Liu, Ran et al., “Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Ojala, Tuuli et al., “The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland,” 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473

39 Bascompta et al., “Corporate Social Responsibility Index for Mine Sites,” 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Duporte, Alexandre, “Environmental impacts of digitalization,” 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Dutta, Tanushree et al., “Global demand for rare earth resources and strategies for green mining,” 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/; Ganguli, Rajive and Cook, Douglas,” Rare earths: A review of the landscape,” 2018, *MRS Energy and Sustainability,* https://www.semanticscholar.org/paper/Rare-earths%3A-A-review-of-the-landscape-Ganguli-Cook/b87c058f428f69e15399d6700d0f67219d4e9bc9; Golev, Artem et al., “Rare earths supply chains: Current status, constraints, and opportunities,” 2014, *Resources Policy,* https://www.uvm.edu/giee/pubpdfs/Golev_2014_Resources_Policy.pdf; Lennerfors, Thomas Taro et al, “Sustainable ICT: A Critique from the Perspective of World Systems Theory,” 2014, *ICT and Society,* https://doi.org/10.1007/978-3-662-44208-1_6; Santarius, Tilman et al., “Digital sufficiency: conceptual considerations for ICTs on a finite planet,” 2022, *Annals of Telecommunications,* https://doi.org/10.1007/s12243-022-00914-x; Liu, Ran et al., “Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Ojala, Tuuli et al., “The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland,” 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473; Duporte, Alexandre, “Environmental impacts of digitalization,” 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Dutta, Tanushree et al., “Global demand for rare earth resources and strategies for green mining,” 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/; Ojala, Tuuli et al., “The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland,” 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473

40 Duporte, Alexandre, “Environmental impacts of digitalization,” 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Dutta, Tanushree et al., “Global demand for rare earth resources and strategies for green mining,” 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/; Gwenzi, Willis et al., “Sources, behaviour, and environmental and human health risks of high-technology rare earth elements as emerging contaminants,” 2018, *The Science of the Total Environment,* https://pubmed.ncbi.nlm.nih.gov/29709849/

41 Jouini et al., “Sustainable production of rare earth elements from mine waste and geoethics,” 2022, *Minerals,* https://www.mdpi.com/2075-163X/12/7/809; Liu, Ran et al., “Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

42 Hilty, LM and Bieser, JCT, “Opportunities and risks of digitalization for climate protection in Switzerland,” 2017, *University of Zurich,* https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A14982; Duporte, Alexandre, “Environmental impacts of digitalization,” 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Liu, Ran et al., “Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Krumay, Barbara and Brandtwiner, Roman, ”Measuring The Environmental Impact Of Ict Hardware,” 2016, *International Journal of Sustainable Development and Planning,* https://research.wu.ac.at/en/publications/measuring-the-environmental-impact-of-ict-hardware-5

after target resources, such as rare earth elements, have been removed), and toxic fumes.[43] In China, for example, processing just one ton of rare earth elements can result in up to 20,000 tons of mine tailings and 1,000 tons of waste water.[44] Waste gases, water, and mine tailings contain heavy metals, hazardous materials, and environmentally degrading elements, including lead, arsenic, cadmium, and radioactive materials like thorium.[45] These pollute local water sources, soils, and the atmosphere, and adversely impact the surrounding plants and animals.[46] They also increase the prevalence of disease among mine workers and in the local communities surrounding mines.[47]

Looking forward, demand for ICT hardware and devices is expected to grow, in turn increasing demand for raw material extraction.[48] For example, demand for dysprosium and neodymium, which are used in the production of sensors, fibre optics, and magnets, is projected to grow by 2,500% and 700% over the next 15 years.[49] As raw material extraction for the ICT sector grows, so too will the resultant environmental impacts, including energy consumption, GHG emissions, land use change, soil, water, and air pollution, biodiversity loss, and more.

43 Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Haque, Nawshad et al., "Rare earth elements: Overview of mining, mineralogy, uses, sustainability and environmental impact," 2014, *Resources,* https://www.mdpi.com/2079-9276/3/4/614; Hurst, Cindy, "China's rare earth elements industry: What can the West learn?" 2010, *Institute for the Analysis of Global Security,* http://www.iags.org/rareearth0310hurst.pdf; Lennerfors, Thomas Taro et al, "Sustainable ICT: A Critique from the Perspective of World Systems Theory," 2014, *ICT and Society,* https://doi.org/10.1007/978-3-662-44208-1_6

44 Bascompta et al., "Corporate Social Responsibility Index for Mine Sites," 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Azadi, Mehdi et al., "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," 2014, Nature Geoscience, https://www.nature.com/articles/s41561-020-0531-3; Hurst, Cindy, "China's rare earth elements industry: What can the West learn?" 2010, *Institute for the Analysis of Global Security,* http://www.iags.org/rareearth0310hurst.pdf; Dutta, Tanushree et al., "Global demand for rare earth resources and strategies for green mining," 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/

45 Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Manhart, Andreas et al., "Resource Efficiency in the ICT Sector," 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf

46 Bascompta et al., "Corporate Social Responsibility Index for Mine Sites," 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Azadi, Mehdi et al., "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," 2014, Nature Geoscience, https://www.nature.com/articles/s41561-020-0531-3; Hurst, Cindy, "China's rare earth elements industry: What can the West learn?" 2010, *Institute for the Analysis of Global Security,* http://www.iags.org/rareearth0310hurst.pdf; Dutta, Tanushree et al., "Global demand for rare earth resources and strategies for green mining," 2016, *Environmental Research,* https://pubmed.ncbi.nlm.nih.gov/27295408/; Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Haque, Nawshad et al., "Rare earth elements: Overview of mining, mineralogy, uses, sustainability and environmental impact," 2014, *Resources,* https://www.mdpi.com/2079-9276/3/4/614; Lennerfors, Thomas Taro et al, "Sustainable ICT: A Critique from the Perspective of World Systems Theory," 2014, *ICT and Society,* https://doi.org/10.1007/978-3-662-44208-1_6; Ajwang and Nambiro, "Climate change adaptation and mitigation using information and communication technology," 2022, *International Journal of Computer Science Res. 6, 6, 1046-1063,* https://www.researchgate.net/publication/362732924_Climate_Change_Adaptation_and_Mitigation_using_Information_and_Communication_Technology; Bascompta et al., "Corporate Social Responsibility Index for Mine Sites," 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/20/13570; Gwenzi, Willis et al., "Sources, behaviour, and environmental and human health risks of high-technology rare earth elements as emerging contaminants," 2018, *The Science of the Total Environment,* https://pubmed.ncbi.nlm.nih.gov/29709849/; Hurst, Cindy, "China's rare earth elements industry: What can the West learn?" 2010, *Institute for the Analysis of Global Security,* http://www.iags.org/rareearth0310hurst.pdf; Jha et al., "Review on hydrometallurgical recovery of rare earth metals," 2016, *Hydrometallurgy,* https://www.sciencedirect.com/science/article/abs/pii/S0304386X16300603; Jouini et al., "Sustainable production of rare earth elements from mine waste and geoethics," 2022, *Minerals,* https://www.mdpi.com/2075-163X/12/7/809; Krumay, Barbara and Brandtwiner, Roman, "Measuring The Environmental Impact Of Ict Hardware," 2016, *International Journal of Sustainable Development and Planning,* https://research.wu.ac.at/en/publications/measuring-the-environmental-impact-of-ict-hardware-5; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Weng et al., 2015

47 Chakhmouradian, Anton and Wall, Frances, "Rare Earth Elements: Minerals, Mines, Magnets (and More)," 2012, *Elements,* https://pubs.geoscienceworld.org/msa/elements/article-abstract/8/5/333/137928/Rare-Earth-Elements-Minerals-Mines-Magnets-and; Hurst, Cindy, "China's rare earth elements industry: What can the West learn?" 2010, *Institute for the Analysis of Global Security,* http://www.iags.org/rareearth0310hurst.pdf; Weng, Zhehan et al., "A detailed assessment of global rare earth element resources: opportunities and challenges," 2015, *Economic Geology,* https://research.monash.edu/en/publications/a-detailed-assessment-of-global-rare-earth-element-resources-oppo

48 Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf

49 Ganguli, Rajive and Cook, Douglas," Rare earths: A review of the landscape," 2018, *MRS Energy and Sustainability,* https://www.semanticscholar.org/paper/Rare-earths%3A-A-review-of-the-landscape-Ganguli-Cook/b87c058f428f69e15399d6700d0f67219d4e9bc9; Jha et al., "Review on hydrometallurgical recovy of rare earth metals," 2016, *Hydrometallurgy,* https://www.sciencedirect.com/science/article/abs/pii/S0304386X16300603

MANUFACTURING AND PRODUCTION

The manufacturing and production of ICT hardware and devices are incredibly complex. ICT hardware and devices require the use of many individual components, including printed circuit boards, backplanes, enclosures, cables, precision machine components, and optical modules.[50] Often, the manufacturers of these individual components are not the designers or manufacturers of the final, assembled device. Indeed, as was noted in the introduction to this section, many brand name companies that ICT consumers would be familiar with are only directly responsible for overall product design, selecting preferred suppliers of individual components and engaging with customers once the assembled product is complete; the manufacturing activities that take place in between are meanwhile outsourced.[51] For the purposes of this paper, manufacturing and production refers to all of the activities that take place between raw material extraction and final product sales, including the processing of raw materials for inclusion in individual components, the manufacturing and production of individual components, and the final assembly of ICT hardware and devices.

Like raw material extraction, the manufacturing and production of ICT hardware is very energy intensive. Manufacturing complex ICT hardware, such as memory chips, displays, semiconductors, RAM bars, and integrated circuits, involves the use of clean rooms, air compression, and soldering, all of which are energy intensive.[52] Because of this, manufacturing and production account for most of the energy consumed over the lifecycle of many ICT devices. As an illustrative example, a two-gram memory chip consumes 73% of its lifetime energy during the manufacturing process.[53]

Manufacturing and production also account for a high percentage of the GHG emissions that are emitted by ICT devices over their lifecycles.[54] As mentioned in introduction to this paper, manufacturing and producing a mobile phone emits nearly 18 times more GHG emissions than are emitted during its use.[55] Similarly, manufacturing and producing a laptop generates about 83% of the

[50] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf

[51] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf

[52] Kern, Eva et al., "Processes for green and sustainable software engineering," 2015, *Green in Software Engineering,* https://link.springer.com/chapter/10.1007/978-3-319-08581-4_3; Koomey, Jonathan et al., "Smart Everything: Will Intelligent Systems Reduce Resource Use?" 2013, *Annual Review of Environment and Resources,* https://www.annualreviews.org/doi/10.1146/annurev-environ-021512-110549; Manhart, Andreas et al., "Resource Efficiency in the ICT Sector," 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf; Schischke, Karsten et al., "Lifecycle energy analysis of PCs—Environmental consequences of lifetime extension through reuse," 2003, *Research Gate,* https://www.researchgate.net/publication/268435652_Life_cycle_energy_analysis_of_PCs-Environmental_consequences_of_lifetime_extension_through_reuse

[53] Williams, Eric, "Environmental effects of information and communications technologies," 2011, *Nature,* https://www.nature.com/articles/nature10682

[54] Belkhir, Lotfi and Elmeligi, Ahmed, "Assessing ICT global emissions footprint: Trends to 2040 & recommendations," 2018, *Journal of Cleaner Production,* https://www.sciencedirect.com/science/article/abs/pii/S095965261733233X?via%3Dihub; Bomhof, Freek et al., "Systematic Analysis of Rebound Effects for 'Greening by ICT' Initiatives," 2009, *Communication and Strategies,* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1659725; Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Hilty, LM and Bieser, JCT, "Opportunities and risks of digitalization for climate protection in Switzerland," 2017, *University of Zurich,* https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A14982; Kern, Eva et al., "Processes for green and sustainable software engineering," 2015, *Green in Software Engineering,* https://link.springer.com/chapter/10.1007/978-3-319-08581-4_3; Khan, Farzana Naheed et al., "Information and communication technology (ICT) and environmental sustainability: a panel data analysis," 2020, *Environmental Science and Pollution Research,* https://link.springer.com/article/10.1007/s11356-020-09704-1; Viana, Luciano Rodrigues et al., "Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users," 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025

[55] Andrae, Anders, "Life-Cycle Assessment of Consumer Electronics: A review of methodological approaches," 2016, *IEEE Consumer Electronics Magazine,* https://doi.org/10.1109/MCE.2015.2484639

GHG emissions that are released over its lifecycle.[56] Still, the exact volume of GHG emissions emitted during manufacturing and production versus use depends on where and how manufacturing takes place, where and to what extent the device is used, and what type of energy sources are employed during manufacturing, production, and use.[57] For example, research suggests that for energy-intensive devices like servers, manufacturing and production may account for a lower percentage of total lifecycle emissions.[58]

In addition to being energy intensive, the manufacturing and production of ICT hardware are very resource intensive.[59] When manufacturers use electricity derived from fossil fuels, they contribute to fossil fuel resource depletion. Manufacturing ICT hardware also requires large volumes of water; because of this, manufacturing and production often account for most of the water footprint of ICT devices.[60] In addition to fossil fuel and water consumption, approximately 98% of the materials used in the manufacturing and production of ICT hardware ultimately become waste, meaning just 2% are utilized in the final product.[61]

Like resource extraction, the manufacturing and production of ICT devices result in high volumes of soil, water, and air pollution. Manufacturing processes for ICT hardware often emit hazardous gases, which can build up in the atmosphere and soil, causing acidification and ecotoxicity.[62] They can also release acids, metals, solvents, cleaning solutions, and other pollutants into local water sources, in turn harming aquatic ecosystems and human health.[63] Despite the perception of ICT as a "clean industry," toxic chemical spills and leaks have contaminated surface and groundwater sources for decades.[64]

[56] "Sustainable IT: 3 Steps to Mitigate Asset GHG Emissions Throughout the Product Life Cycle," May 2023, *Gartner,* https://www.gartner.com/en/documents/4392999

[57] Arunshanyan, Yevgenia et al., "Lessons learned – Review of LCAs for ICT products and services," 2014, *Computers in Industry,* https://doi.org/10.1016/j.compind.2013.10.003

[58] "Sustainable IT: 3 Steps to Mitigate Asset GHG Emissions Throughout the Product Life Cycle," May 2023, *Gartner,* https://www.gartner.com/en/documents/4392999

[59] Arunshanyan, Yevgenia et al., "Lessons learned – Review of LCAs for ICT products and services," 2014, *Computers in Industry,* https://doi.org/10.1016/j.compind.2013.10.003; Chen, Sibo, "The Materialist Circuits and the Quest for Environmental Justice in ICT's Global Expansion," 2016, *TripleC,* https://doi.org/10.31269/triplec.v14i1.695; Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Granit, Ian, "The Digital Divide: Effects on Distribution of Wealth and Resources and Climate Change," 2020, *Undergraduate Journal of Politics, Policy, and Society,* https://ujpps.com/index.php/ujpps/article/download/79/35; Hilty, LM and Bieser, JCT, "Opportunities and risks of digitalization for climate protection in Switzerland," 2017, *University of Zurich,* https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A14982; International Telecommunication Union, "Toolkit on environmental sustainability in the ICT sector," 2012, *ITU,* https://www.itu.int/ITU-T/climatechange/ess/index.html; Kopp, Thomas and Lange, Steffen, "The climate effect of digitalization in production and consumption of OECD countries," 2019, *The University of Grottingen and the Institute for Ecological Economy Research,* https://ceur-ws.org/Vol-2382/ICT4S2019_paper_3.pdf; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

[60] Berkhout, Frans and Hertin, Julia, "De-materialising and re-materialising: digital technologies and the environment," 2004, *Futures,* https://doi.org/10.1016/j.futures.2004.01.003; Bomhof, Freek et al., "Systematic Analysis of Rebound Effects for 'Greening by ICT' Initiatives," 2009, *Communication and Strategies,* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1659725; Chen, Sibo, "The Materialist Circuits and the Quest for Environmental Justice in ICT's Global Expansion," 2016, *TripleC,* https://doi.org/10.31269/triplec.v14i1.695; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

[61] Chowdhury, Adib Kabir and Veeramani, Shanmugam, "Information technology: Impacts on environment and sustainable development," 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development

[62] Chowdhury, Adib Kabir and Veeramani, Shanmugam, "Information technology: Impacts on environment and sustainable development," 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10

[63] Berkhout, Frans and Hertin, Julia, "De-materialising and re-materialising: digital technologies and the environment," 2004, *Futures,* https://doi.org/10.1016/j.futures.2004.01.003; Bomhof, Freek et al., "Systematic Analysis of Rebound Effects for 'Greening by ICT' Initiatives," 2009, *Communication and Strategies,* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1659725; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Smith, Lucy et al., "Lifecycle assessment and environmental profile evaluations of high volumetric efficiency capacitors," 2018, *Applied Energy,* https://www.sciencedirect.com/science/article/abs/pii/S0306261918304057?via%3Dihub

[64] Gwenzi, Willis et al., "Sources, behaviour, and environmental and human health risks of high-technology rare earth elements as emerging contaminants," 2018, *The Science of the Total Environment,* https://pubmed.ncbi.nlm.nih.gov/29709849/; Yi, Lan and Thomas, Hywel, "A review of research on the environmental impact of e-business and ICT," 2007, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412007000736?via%3Dihub

TRANSPORTATION

As discussed, the ICT supply chain is highly globalized, with multiple steps located in different regions of the world.[65] Spanning vast distances, transportation is required at multiple stages of the ICT supply chain, including the following:

1. To transport raw materials from their natural environments to where they are processed
2. To transport processed materials from processing plants to manufacturing facilities
3. To transport individual components to assembly centres
4. To transport assembled products from assembly facilities to warehouses, sales centres, and eventually to consumers
5. To transport end-of-life products to facilities for recycling and disposal.[66]

While transportation occurs repeatedly throughout the ICT supply chain, the environmental impacts of transportation are poorly researched. GHG emissions from motive energy use and air pollution are the primary environmental impacts of transportation.[67] While further research is needed, localizing ICT supply chains and increasing clean transportation could help reduce the environmental impacts associated with this stage of the supply chain.

[65] Berkhout, Frans and Hertin, Julia, “De-materialising and re-materialising: digital technologies and the environment,” 2004, *Futures,* https://doi.org/10.1016/j.futures.2004.01.003; Gossart, Cedric, “Rebound Effects and ICT: A Review of the Literature,” 2014, *ICT Innovations for Sustainability,* https://link.springer.com/chapter/10.1007/978-3-319-09228-7_26; Røpke, Inge, “The unsustainable directionality of innovation – The example of the broadband transition 2012,” November 2012, *Research Policy*, https://linkinghub.elsevier.com/retrieve/pii/S0048733312001011

[66] Chowdhury, Adib Kabir and Veeramani, Shanmugam, “Information technology: Impacts on environment and sustainable development,” 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development; Schischke, Karsten et al., “Lifecycle energy analysis of PCs—Environmental consequences of lifetime extension through reuse,” 2003, *Research Gate,* https://www.researchgate.net/publication/268435652_Life_cycle_energy_analysis_of_PCs-Environmental_consequences_of_lifetime_extension_through_reuse; Viana, Luciano Rodrigues et al., “Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users,” 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025

[67] Chowdhury, Adib Kabir and Veeramani, Shanmugam, “Information technology: Impacts on environment and sustainable development,” 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development; Schischke et al., 2003; Viana, Luciano Rodrigues et al., “Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users,” 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025; Ojala, Tuuli et al., “The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland,” 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473; Manhart, Andreas et al., “Resource Efficiency in the ICT Sector,” 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf

USE

This stage involves the use of a long list of ICT hardware and devices, including desktop computers, laptops, servers, data centres, networks, and other ICT hardware components. The main environmental impacts that are generated during this stage are energy consumption (and, by virtue, GHG emissions), water consumption, and land use change.[68]

ICT hardware and devices require energy in the form of electricity to be used. According to the Centre on Regulation in Europe, end-user devices account for approximately 42% of energy use in the ICT sector, data centres account for about 30%, and telecommunications infrastructure accounts for about 27%.[69] Depending on the source of energy and electricity, energy consumption can also result in GHG emissions and other environmental impacts, such as water consumption. For instance, electricity generated from coal exhibits a higher carbon, water, and land footprint than nuclear and renewable energy sources.[70] According to ICT firm Ericsson, 80% of the ICT sector's GHG emissions could be reduced if all of the electricity that is consumed in the sector was sourced from renewable energy sources.[71] Ericsson also reports that about half of ICT's carbon footprint is accounted for by user devices, while networks and data centres each account for the remaining quarter.[72] While energy consumption may be reduced by energy efficiency, device maintenance, product design, and user behaviour, rapid increases in the consumption of digital products and services[73] are increasing

[68] Appiah-Otoo, Isaac et al., "The impact of information and communication technology (ICT) on carbon dioxide emissions: Evidence from heterogeneous ICT countries," 2022, *Energy and Environment,* https://journals.sagepub.com/doi/10.1177/0958305X221118877; Belkhir, Lotfi and Elmeligi, Ahmed, "Assessing ICT global emissions footprint: Trends to 2040 & recommendations," 2018, *Journal of Cleaner Production,* https://www.sciencedirect.com/science/article/abs/pii/S095965261733233X?via%3Dihub; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10; Viana, Luciano Rodrigues et al., "Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users," 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025; Dandres et al., 2016; Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Monserrate, Steven Gonzalez., "MIT Case Studies in Social and Ethical Responsibilities of Computing," 2022, *MIT Case Studies in Social and Ethical Responsibilities of Computing,* https://doi.org/10.21428/2c646de5.031d4553; Viana, Luciano Rodrigues et al., "Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users," 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025

[69] Banet, Catherine et al., 2021, *Centre on Regulation in Europe,* https://cerre.eu/wp-content/uploads/2021/10/211013_CERRE_Report_Data-Centres-Greening-ICT_FINAL.pdf

[70] Viana, Luciano Rodrigues et al., "Sending fewer emails will not save the planet! An approach to make environmental impacts of ICT tangible for Canadian end users," 2022, *Sustainable Production and Consumption,* https://doi.org/10.1016/j.spc.2022.09.025

[71] "ICT and the climate," Ericsson, https://www.ericsson.com/en/reports-and-papers/industrylab/reports/a-quick-guide-to-your-digital-carbon-footprint#decarbonizingict

[72] "ICT and the climate," Ericsson, https://www.ericsson.com/en/reports-and-papers/industrylab/reports/a-quick-guide-to-your-digital-carbon-footprint#decarbonizingict

[73] E.g., Appiah-Otoo, Isaac et al., "The impact of information and communication technology (ICT) on carbon dioxide emissions: Evidence from heterogeneous ICT countries," 2022, *Energy and Environment,* https://journals.sagepub.com/doi/10.1177/0958305X221118877; Chen, Xiaoxia et al., "Environmental Sustainability of Digitalization in Manufacturing: A Review," 2020, *Sustainability,* https://www.mdpi.com/2071-1050/12/24/10298; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10; Santarius, Tilman et al., "Digital sufficiency: conceptual considerations for ICTs on a finite planet," 2022, *Annals of Telecommunications,* https://doi.org/10.1007/s12243-022-00914-x; Jora, Octavian-Dragomir, "Cyberspace Ecologism," 2021, *Amfiteatru Economic,* https://doi.org/10.24818/EA/2022/59/9; Chowdhury, Adib Kabir and Veeramani, Shanmugam, "Information technology: Impacts on environment and sustainable development," 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development; Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Luciervo, Frederica, "Big Data, Big Waste? A Reflection on the Environmental Sustainability of Big Data Initiatives," 2020, *Science and Engineering Ethics,* https://doi.org/10.1007/s11948-019-00171-7; Ozpolat, Asli, "How does internet use affect ecological footprint?: An empirical analysis for G7 countries," 2021, *Environment, Development, and Sustainability,* https://link.springer.com/article/10.1007/s10668-021-01967-z; Jora, Octavian-Dragomir, "Cyberspace Ecologism," 2021, *Amfiteatru Economic,* https://doi.org/10.24818/EA/2022/59/9

energy consumption in the ICT sector[74] and are projected to continue increasing energy consumption in the ICT sector for years to come.[75]

The use of ICT hardware and devices also contributes to water consumption and land use change. This is most evident in the case of data centres, which consume exorbitant volumes of water to remove heat waste from ICT equipment energy use to prevent overheating. This exacerbates water stress, impacts local aquatic ecosystems, and subjects nearby communities to competition over water sources.[76] A study from 2019 estimates that data centres with 15MW of IT capacity consume between 0.8 and 1.3 million litres of water per day.[77] Another study estimated that in 2014, in the United States alone, data centres consumed a collective 165 billion gallons of water.[78]

[74] E.g., Appiah-Otoo, Isaac et al., "The impact of information and communication technology (ICT) on carbon dioxide emissions: Evidence from heterogeneous ICT countries," 2022, *Energy and Environment,* https://journals.sagepub.com/doi/10.1177/0958305X221118877; Chen, Xiaoxia et al., "Environmental Sustainability of Digitalization in Manufacturing: A Review," 2020, *Sustainability,* https://www.mdpi.com/2071-1050/12/24/10298; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10; Santarius, Tilman et al., "Digital sufficiency: conceptual considerations for ICTs on a finite planet," 2022, *Annals of Telecommunications,* https://doi.org/10.1007/s12243-022-00914-x; Jora, Octavian-Dragomir, "Cyberspace Ecologism," 2021, *Amfiteatru Economic,* https://doi.org/10.24818/EA/2022/59/9; Chowdhury, Adib Kabir and Veeramani, Shanmugam, "Information technology: Impacts on environment and sustainable development," 2015, *Pertanika Journal of Science and Technology,* https://www.researchgate.net/publication/273130988_Information_Technology_Impacts_on_Environment_and_Sustainable_Development; Duporte, Alexandre, "Environmental impacts of digitalization," 2022, *AEIDL,* https://www.aeidl.eu/wp-content/uploads/2022/10/AEIDL-PolicyUnit-Environmental-impacts-of-digitalisation-AD-v4.pdf; Luciervo, Frederica, "Big Data, Big Waste? A Reflection on the Environmental Sustainability of Big Data Initiatives," 2020, *Science and Engineering Ethics,* https://doi.org/10.1007/s11948-019-00171-7; Ozpolat, Asli, "How does internet use affect ecological footprint?: An empirical analysis for G7 countries," 2021, *Environment, Development, and Sustainability,* https://link.springer.com/article/10.1007/s10668-021-01967-z; Jora, Octavian-Dragomir, "Cyberspace Ecologism," 2021, *Amfiteatru Economic,* https://doi.org/10.24818/EA/2022/59/9

[75] Guillaume, Bourgeois et al., "Review of the Impact of IT on the Environment and Solution with a Detailed Assessment of the Associated Gray Literature," 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/4/2457; Hilty, LM and Bieser, JCT, "Opportunities and risks of digitalization for climate protection in Switzerland," 2017, *University of Zurich,* https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A14982; Lago, Patricia et al., "The service greenery-integrating sustainability in service-oriented software," 2010, *International Workshop on Software Research and Climate Change,* https://research.vu.nl/en/publications/the-service-greenery-integrating-sustainability-in-service-orient; Belkhir, Lotfi and Elmeligi, Ahmed, "Assessing ICT global emissions footprint: Trends to 2040 & recommendations," 2018, *Journal of Cleaner Production,* https://www.sciencedirect.com/science/article/abs/pii/S095965261733233X?via%3Dihub; Plepys, Andrius, "The grey side of ICT," 2002, *Environmental Impact Assessment Review,* https://www.sciencedirect.com/science/article/abs/pii/S0195925502000252?via%3Dihub

[76] "Data Centres and the Grid—Greening ICT in Europe," 2023, *CERRE,* https://cerre.eu/wp-content/uploads/2021/10/211013_CERRE_Report_Data-Centres-Greening-ICT_FINAL.pdf; International Telecommunication Union, "Toolkit on environmental sustainability in the ICT sector," 2012, *ITU,* https://www.itu.int/ITU-T/climatechange/ess/index.html; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Brevini, Bendetta, "Black boxes, not green: Mythologizing artificial intelligence and omitting the environment," 2020, *Big Data & Society,* https://doi.org/10.1177/2053951720935141; Monserrate, Steven Gonzalez., "MIT Case Studies in Social and Ethical Responsibilities of Computing," 2022, *MIT Case Studies in Social and Ethical Responsibilities of Computing,* https://doi.org/10.21428/2c646de5.031d4553

[77] Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

[78] Shehabi, Arman et al., "United States Data Center Energy Usage Report," 2016, *Berkeley Lab,* https://eta.lbl.gov/publications/united-states-data-center-energy

RECYCLING AND END-OF-LIFE DISPOSAL

When ICT hardware and devices reach the end of their life, they become electronic waste, or "e-waste." Research shows that e-waste has become a major contributor to global solid waste. According to the Global E-Waste Monitor, approximately 53.6 metric tons (Mt) of e-waste were produced in 2019, which is equal to approximately 7.3kg per capita.[79] E-waste is challenging because the vast majority of it goes undocumented. Some estimates suggest that only 17.4% of e-waste is collected and properly disposed of.[80] E-waste also differs chemically and physically from regular waste, containing hazardous materials like lead, mercury, nickel, and cobalt, which require specialized methods of dismantling, recycling, and disposal.

Globally, it is estimated that 70% to 80% of e-waste is disposed of by landfilling or incineration.[81] Landfilling involves e-waste compacted and buried underground, often using liner systems to minimize the amount of toxins that leach into the surrounding environment.[82] Still, toxic elements and pollutants leach from landfilling facilities, leading to terrestrial and aquatic pollution. Alternatively, incineration is used both to dispose of e-waste and to extract valuable components from e-waste for recycling: it creates hazardous fumes, dust, and ashes that contain pollutants and can contaminate nearby air, water, and soil.[83]

The degree to which landfill or incineration is used differs by region and formality of waste management programs. In many developing areas, incineration is the primary disposal method, even though it causes long-lasting and harmful impacts on surrounding ecosystems and communities.[84] Exporting e-waste to developing countries increases the environmental impacts associated with end-of-life processing and disposal because these countries are more likely to rely on

[79] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

[80] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, United Nations University, *United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

[81] Balaram, V., "Rare earth elements: A review of applications, occurrence, exploration, analysis, recycling, and environmental impact," 2019, *Geoscience Frontiers,* https://www.sciencedirect.com/science/article/pii/S1674987119300258; Tanskanen, Pia, "Management and recycling of electronic waste," 2013, *Acta Materialia,* https://www.sciencedirect.com/science/article/abs/pii/S1359645412007999; Kaya, Muammer, "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes," 2020, https://www.sciencedirect.com/science/article/abs/pii/S0956053X16304299

[82] Tanskanen, Pia, "Management and recycling of electronic waste," 2013, *Acta Materialia,* https://www.sciencedirect.com/science/article/abs/pii/S1359645412007999; Kaya, Muammer, "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes," 2020, https://www.sciencedirect.com/science/article/abs/pii/S0956053X16304299; Robinson, Brett, "E-waste: An assessment of global production and environmental impacts," 2009, *Science of the Total Environment,* https://www.sciencedirect.com/science/article/abs/pii/S0048969709009073; Tansel, Berrin, "From electronic consumer products to ewastes: global outlook, waste quantities, recycling challenges," 2017, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412016305414

[83] Ilankoon, IMSK et al., "E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery," 2018, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X18306366?via%3Dihub; Kaya, Muammer, "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes," 2020, https://www.sciencedirect.com/science/article/abs/pii/S0956053X16304299; Tansel, Berrin, "From electronic consumer products to ewastes: global outlook, waste quantities, recycling challenges," 2017, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412016305414; Tsydenova, Oyuna and Bengtsson, Magnus, "Chemical hazards associated with treatment of waste electrical and electronic equipment," 2011, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X10004393; Williams, Eric, "Environmental effects of information and communications technologies," 2011, *Nature,* https://www.nature.com/articles/nature10682

[84] Ilankoon, IMSK et al., "E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery," 2018, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X18306366?via%3Dihub; International Telecommunication Union, "Toolkit on environmental sustainability in the ICT sector," 2012, *ITU,* https://www.itu.int/ITU-T/climatechange/ess/index.html; Purchase, Diane et al., "Global occurrence, chemical properties, and ecological impacts of e-wastes (IUPAC Technical Report)," 2020, *Pure and Applied Chemistry,* https://www.degruyter.com/document/doi/10.1515/pac-2019-0502/html?lang=en

informal landfilling and incineration, which tend to be less regulated and involve less safety and environmental best practices.[85] Despite ongoing efforts to curb e-waste exportation, a significant proportion of global e-waste is sent to developing regions, either illegally or disguised as functional ICT devices.[86] While pollution is generally worse near informal versus formal processing sites, even well-regulated methods for e-waste recycling and disposal release contaminants into the natural environment.

Aside from landfilling and incineration, a portion of global e-waste is recycled. While recycling may be a more environmentally friendly alternative, it too has environmental impacts. Recycling involves e-waste collection and sorting, pre-processing and separation, and metallurgical processing to obtain valuable components.[87] These steps not only require substantial energy and resources to complete; they also produce toxic byproducts, wastewater, and hazardous emissions.[88] In particular, pyrometallurgical processes like incineration and smelting used in the recycling process result in harmful pollution, which leads to acidification, eutrophication, and ozone depletion and contributes to climate change.[89] Informal recycling typically involves self-employed individuals disassembling e-waste using unregulated processes and limited safety procedures.[90] For example, informal recycling often takes place in open,

[85] Robinson, Brett, "E-waste: An assessment of global production and environmental impacts," 2009, *Science of the Total Environment,* https://www.sciencedirect.com/science/article/abs/pii/S0048969709009073

[86] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Purchase, Diane et al., "Global occurrence, chemical properties, and ecological impacts of e-wastes (IUPAC Technical Report)," 2020, *Pure and Applied Chemistry,* https://www.degruyter.com/document/doi/10.1515/pac-2019-0502/html?lang=en; Robinson, Brett, "E-waste: An assessment of global production and environmental impacts," 2009, *Science of the Total Environment,* https://www.sciencedirect.com/science/article/abs/pii/S0048969709009073; Tsydenova, Oyuna and Bengtsson, Magnus, "Chemical hazards associated with treatment of waste electrical and electronic equipment," 2011, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X10004393

[87] Ojala, Tuuli et al., "The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland," 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473; Weber, RJ et al., "Rare earth elements: A review of production, processing, recycling, and associated environmental issues," 2012, *U.S. Environmental Protection Agency* https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=251706&Lab=NRMRL

[88] Ghodrat, Maryam et al., "Thermodynamic-Based Exergy Analysis of Precious Metal Recovery out of Waste Printed Circuit Board through Black Copper Smelting Process," 2019, *Energies,* https://www.mdpi.com/1996-1073/12/7/1313; Ghosh, Bablu et al., "A Review on Global Emissions by E-Products Based Waste: Technical Management for Reduced Effects and Achieving Sustainable Development Goals" 2022, *Sustainability,* https://www.mdpi.com/2071-1050/14/7/4036; Golev, Artem et al., "Rare earths supply chains: Current status, constraints, and opportunities," 2014, *Resources Policy,* https://www.uvm.edu/giee/pubpdfs/Golev_2014_Resources_Policy.pdf; Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_10; Ojala et al., 2020

[89] Hischier, Roland et al., "Grey Energy and Environmental Impacts of ICT Hardware, 2015, *ICT Innovations for Sustainability,* https://doi.org/10.1007/978-3-319-09228-7_105; Jha et al., "Review on hydrometallurgical recovy of rare earth metals," 2016, *Hydrometallurgy,* https://www.sciencedirect.com/science/article/abs/pii/S0304386X16300603; Kaya, Muammer, "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes," 2020, https://www.sciencedirect.com/science/article/abs/pii/S0956053X16304299; Smith, Lucy et al., "Lifecycle assessment and environmental profile evaluations of high volumetric efficiency capacitors," 2018, *Applied Energy,* https://www.sciencedirect.com/science/article/abs/pii/S0306261918304057?via%3Dihub; Tansel, Berrin, "From electronic consumer products to ewastes: global outlook, waste quantities, recycling challenges," 2017, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412016305414; Tsydenova, Oyuna and Bengtsson, Magnus, "Chemical hazards associated with treatment of waste electrical and electronic equipment," 2011, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X10004393

[90] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf; Ilankoon, IMSK et al., "E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery," 2018, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X18306366?via%3Dihub; Smith, Lucy et al., "Lifecycle assessment and environmental profile evaluations of high volumetric efficiency capacitors," 2018, *Applied Energy,* https://www.sciencedirect.com/science/article/abs/pii/S0306261918304057?via%3Dihub; Williams, Eric, "Environmental effects of information and communications technologies," 2011, *Nature,* https://www.nature.com/articles/nature10682

unfortified land, where hazardous chemicals can easily seep into the surrounding land, harming natural ecosystems and impacting the health of local human populations.[91]

E-waste is now recognized as the fastest-growing waste stream.[92] By 2030, the global generation of e-waste is projected to reach 74.7 Mt per year.[93] Several factors are contributing to the growth of e-waste globally. The number of users and the number of devices per user are both increasing constantly.[94] Many devices also have short lifespans due to the rapid cycle of innovation and a lack of hardware and software compatibility between old and new devices.[95] Finally, repairing ICT devices is complex and repair options are often limited and expensive.[96]

The rate at which e-waste is growing highlights the importance of developing robust recycling programs for ICT hardware and devices globally. Post-consumer devices contain valuable resources that, if harvested successfully and correctly, can reduce e-waste and raw material extraction.[97] Unfortunately, formal recycling

[91] Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Majeed, Muhammad Tariq, "Information and Communication Technology (ICT) and Environmental Sustainability in Developed and Developing Countries," 2018, *Pakistan Journal of Commerce and Social Sciences,* https://www.jespk.net/publications/4314.pdf; Williams, Eric, "Environmental effects of information and communications technologies," 2011, *Nature,* https://www.nature.com/articles/nature10682; Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf; Ilankoon, IMSK et al., "E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery," 2018, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X18306366?via%3Dihub

[92] "Electronic waste (e-waste)," 2023, *World Health Organization,* https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste)

[93] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

[94] Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Monserrate, Steven Gonzalez., "MIT Case Studies in Social and Ethical Responsibilities of Computing," 2022, *MIT Case Studies in Social and Ethical Responsibilities of Computing,* https://doi.org/10.21428/2c646de5.031d4553; Røpke, Inge, "The unsustainable directionality of innovation – The example of the broadband transition 2012," November 2012, *Research Policy,* https://linkinghub.elsevier.com/retrieve/pii/S0048733312001011

[95] Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Monserrate, Steven Gonzalez., "MIT Case Studies in Social and Ethical Responsibilities of Computing," 2022, *MIT Case Studies in Social and Ethical Responsibilities of Computing,* https://doi.org/10.21428/2c646de5.031d4553; Røpke, Inge, "The unsustainable directionality of innovation – The example of the broadband transition 2012," November 2012, *Research Policy,* https://linkinghub.elsevier.com/retrieve/pii/S0048733312001011

[96] Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, Oko-Institute EV, https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Monserrate, Steven Gonzalez., "MIT Case Studies in Social and Ethical Responsibilities of Computing," 2022, *MIT Case Studies in Social and Ethical Responsibilities of Computing,* https://doi.org/10.21428/2c646de5.031d4553; Røpke, Inge, "The unsustainable directionality of innovation – The example of the broadband transition 2012," November 2012, *Research Policy,* https://linkinghub.elsevier.com/retrieve/pii/S0048733312001011

[97] Forge, Simon, "Powering down: remedies for unsustainable ICT," 2007, *Foresight,* https://www.proquest.com/docview/224194572; Haque, Nawshad et al., "Rare earth elements: Overview of mining, mineralogy, uses, sustainability and environmental impact," 2014, *Resources,* https://www.mdpi.com/2079-9276/3/4/614; Kaya, Muammer, "Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes," 2020, https://www.sciencedirect.com/science/article/abs/pii/S0956053X16304299; Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability; Martinuzzi, Andre et al., "CSR Activities and Impacts of the ICT Sector," 2011, *Vienna University of Economics and Business,* https://research.wu.ac.at/en/publications/csr-activities-and-impacts-of-the-ict-sector-rimas-working-papers-4; Ojala, Tuuli et al., "The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland," 2020, *Finland Ministry of Transportation,* https://julkaisut.valtioneuvosto.fi/handle/10024/162473; Wäger, PA et al., "Environmental impacts of the Swiss collection and recovery systems for Waste Electrical and Electronic Equipment (WEEE): A follow-up," 2011, *Science of the Total Environment,* https://www.sciencedirect.com/science/article/abs/pii/S0048969711001094?via%3Dihub

programs remain limited at the global level. At present, Europe has the highest rate of e-waste recycling, at 42.5%, while many other regions' rates are much lower.[98] One of the reasons why e-waste recycling remains limited at the global level is that users regularly stockpile old devices, either because they perceive old devices as valuable or because they are unaware of how to dispose of them correctly.[99] While stockpiling does not directly impact the environment, it does reduce the reuse of valuable components, which in turn drives raw material extraction.[100] For example, it is estimated that approximately 700 million devices are being stockpiled in Europe, accounting for over 15,000 tons of important materials like gold, copper, palladium, and lithium.[101]

CASE STUDY: E-WASTE PRODUCTION, DISPOSAL, AND RECYCLING IN CANADA

While it is difficult to determine exactly how much e-waste is produced in Canada per year, or how much of that e-waste is recycled, versus disposed of, some estimates are available. According to the United Nations, Canada produced 757 kilotons of e-waste in 2019, which is equal to approximately 20kg per capita.[102] Researchers from the University of Waterloo meanwhile estimate that Canada produced approximately 945 kilotons of e-waste in 2020, equal to 25.3kg per capita, and project that this number will reach approximately 1.2 million tonnes per year and 31.5kg per capita by 2030.[103] While limited data is available for Canada, the United Nations estimates that approximately 15% of e-waste in North America is recycled,[104] while a report from 2016 places this number at approximately 20%.[105]

In addition to the above estimates, Statistics Canada asks a subset of Canadians about their e-waste as part of its Household and the Environment Survey.[106] In 2021, approximately 15% of surveyed households reported having unwanted computers to dispose of, 14% reported having unwanted televisions to dispose of and cell

98 Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf; Ilankoon, IMSK et al., "E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery," 2018, *Waste Management,* https://www.sciencedirect.com/science/article/abs/pii/S0956053X18306366?via%3Dihub; Tansel, Berrin, "From electronic consumer products to ewastes: global outlook, waste quantities, recycling challenges," 2017, *Environment International,* https://www.sciencedirect.com/science/article/abs/pii/S0160412016305414

99 Manhart, Andreas et al., "Resource Efficiency in the ICT Sector," 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf

100 Manhart, Andreas et al., "Resource Efficiency in the ICT Sector," 2016, *Green Peace,* https://www.greenpeace.de/sites/default/files/publications/20161109_oeko_resource_efficency_final_full-report.pdf; Smith, Lucy et al., "Lifecycle assessment and environmental profile evaluations of high volumetric efficiency capacitors," 2018, *Applied Energy,* https://www.sciencedirect.com/science/article/abs/pii/S0306261918304057?via%3Dihub

101 Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

102 Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

103 Habib, Komal et al., "A first comprehensive estimate of electronic waste in Canada," 2023, *Journal of Hazardous Materials,* https://www.sciencedirect.com/science/article/abs/pii/S0304389423001474

104 Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

105 Habib, Komal et al., "A first comprehensive estimate of electronic waste in Canada," 2023, *Journal of Hazardous Materials,* https://www.sciencedirect.com/science/article/abs/pii/S0304389423001474

106 "Electronic Waste: Table: 38-10-0154-01," 2022, *Statistics Canada,* https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810015401

phones to dispose of, 11% reported having unwanted printers to dispose of, 10% reported having unwanted audio visual equipment to dispose of, 6% reported having unwanted landline telephones to dispose of, and 3% reported having unwanted electronic gaming equipment to dispose of.

Households that had e-waste to dispose of were also asked how they disposed of their e-waste. While the results varied significantly by device (e.g., computer versus cell phone, versus audio visual equipment, etc.), 40% to 69% of surveyed households indicated that they took or sent their unwanted devices to a depot or drop-off centre; 12% to 24% indicated that they donated or gave away their unwanted devices; 3% to 12% indicated that they returned their unwanted devices to a supplier or retailer, and 2% to 11% indicated that they repaired or sold their unwanted devices. Meanwhile, 12% to 38% indicated that they still had their e-waste at the time of the survey and 3% to 7% indicated that they disposed of their devices in the garbage.

To date, 12 Canadian provinces and territories have enacted regulations to govern e-waste management within their jurisdictions. While the specific regulations vary by province and territory, most jurisdictions place a responsibility on industry to help collect, recover, recycle, and dispose of electronic waste. Additionally, in jurisdictions with extended producer responsibility legislation, the manufacturers, retailers, distributors, and suppliers of electronics products are specifically required to partake in an approved product stewardship program.[107]

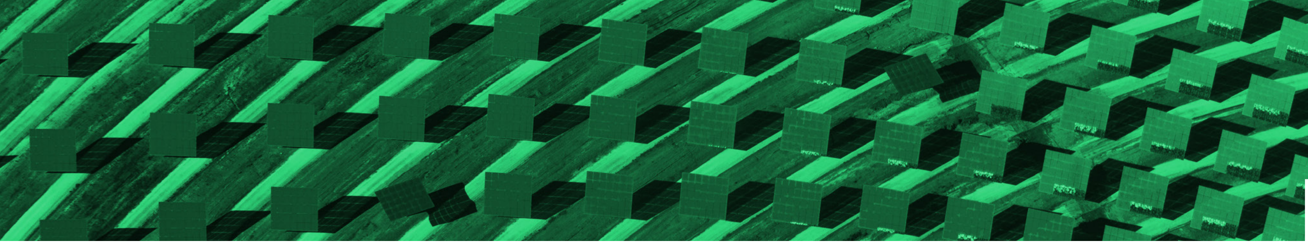
The Electronic Products Recycling Association (EPRA) is an industry-led, not-for-profit organization that helps industry meet their extended producer responsibility obligations by managing government-approved programs for the collection and recycling of electronics products in nine Canadian provinces.[108] The EPRA has more than 2,500 collection sites across Canada and claims to have collected more than 1.2 million tonnes of electronics products since 2011.[109] Importantly, the EPRA only works with recyclers who have been verified to comply with Electronics Product Stewardship Canada's electronics recycling standard.[110] The EPRA independently audits and verifies recyclers under their Recycler Qualification Program.[111]

While significant progress has been in Canada with respect to the recycling of end-of-life electronics products, it is important to note that stockpiling, improper disposal, and the illegal collection and export of end-of-life electronics products limit the success of formal collection programs.

[107] "What is a Steward," 2023, *EPRA,* https://epra.ca/what-is-a-steward
[108] "What is a Steward," 2023, *EPRA,* https://epra.ca/what-is-a-steward
[109] No citation. Information provided directly to ICTC.
[110] "Electronics Recycling Standard," 2016, *RQP,* https://rqp.ca/wp-content/uploads/2018/09/ERS-2015-V3-16.12.29-EPSC.pdf
[111] "The Recycler Qualification Office," 2023, *RQP,* https://rqp.ca/

CONCLUSION

Despite the extensive impact of ICT products and services on the environment, many of ICT's environmental impacts remain hidden from ICT professionals and consumers. Problematically, some of the most harmful environmental impacts occur at the beginning and tail end of the ICT supply chain, far from the eyes of technology designers and buyers. To help address this challenge, this section of the report provided a detailed overview of the environmental impacts of ICT, shedding light on how different stages of the ICT supply chain impact and interact with the environment. Building on this, the next section of the report discusses strategies and best practices that can be used by organizations and technology designers, developers, and adopters to reduce the environmental impacts of ICT.



Strategies and Best Practices for Reducing Environmental Harms in a Digital World

Despite ICT's broad range of environmental impacts, many technology-enabled organizations do not factor environmental impact into their technology decisions in a robust enough way. For example, in response to a recent survey by ICTC, approximately 46% of Canadian organizations indicated that they do not factor environmental impact or environmental sustainability into how they design, develop, buy, or manage ICT.[112] While 53% indicated that they do factor environmental impact or environmental sustainability into their technology decisions, half of these respondents only do so minimally. Additionally, a large proportion only focuses on a very narrow set of environmental impacts (e.g., energy consumption or physical waste generation, as opposed to GHG emissions, non-renewable resource exploitation, water consumption, or air, water, and soil pollution), while two-thirds only began considering environmental impact within the last five years.[113]

[112] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada
[113] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

When asked what barriers prevent their organization from considering environmental impact in their technology decisions, 37% indicated that they do not have enough time, capacity, or other resources to do so, 27% indicated that they lack the required knowledge and skills, and 27% indicated that they have more important priorities to focus on.[114] Notably, other surveys have found similar trends at the global level. In 2021, research institute Capgemini surveyed 1,000 organizations from 14 countries around the world and found that despite the growing impact of IT on the environment, "sustainable IT is not a priority for most organizations."[115] Less than half (43%) of the surveyed organizations understood the environmental impact of their IT footprint, while just 18% had a sustainable IT strategy with well-defined goals and target timelines.[116] When asked what challenges were preventing their organization from implementing sustainable IT, more than half (53%) of respondents indicated that they lacked the domain expertise to implement sustainable ICT initiatives.[117]

This section responds to the above challenges by reviewing four high-impact strategies that organizations can use to improve the environmental impact of their ICT infrastructure, products, and services. These include (1) designing and implementing an organization-wide environmental sustainability strategy, (2) adopting best practices for sustainable IT infrastructure, (3) using eco-design to inform ICT product and service design, and (4) using sustainable procurement to make environmentally sustainable technology purchases. For each strategy, information, resources, and tools are provided to help organizations develop the required knowledge and expertise to implement sustainable ICT.

[114] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada
[115] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf
[116] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf
[117] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf

DEFINING SUSTAINABLE ICT

The term "sustainability" was first introduced in 1987 to describe "meeting the needs of the present generation without compromising the needs of future generations."[118] This early definition acknowledged that pollution and overconsumption of natural resources would impact the ability of future generations to meet their basic needs. Modern definitions build on this by expanding "the needs of present and future generations" into three interconnected "pillars," namely, the environment, the economy, and society.[119] Accordingly, for something to be truly sustainable, it must:

1. Prioritize ecological stewardship and conservation, and ensure that natural resources are replenished faster than they are consumed.[120]
2. Ensure global populations can access the resources they need to meet their financial and economic needs.[121]
3. Ensure global populations can fulfill their basic needs, including food, water, and shelter, and their social and cultural needs, including freedom, education, employment, and recreation.[122]

Sustainable ICT, therefore, refers to ICT infrastructure, products, and services that are designed, manufactured, managed, used, and disposed of in a way that reduces the associated environmental impacts while also optimizing for societal well-being and economic prosperity.[123] This differs from ICT for sustainability, which refers to ICT infrastructure, products, and services that harness the power of technology to reduce environmental impacts in other areas of the economy, such as by reducing inefficiencies or waste, automating activities that pose safety risks to humans, or enabling organizations to engage in more robust environmental monitoring.[124]

Though ICT for sustainability has the potential to reduce environmental impacts, it is important to note that ICT solutions are not inherently sustainable and can sometimes increase the total environmental impact of a process, product, service, or organization. For example, ICT solutions that drive efficiencies or reduce cost can sometimes result in rebound effects that increase consumption

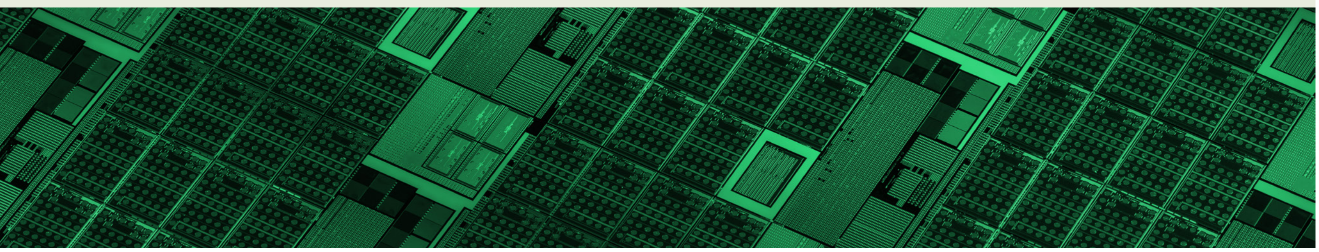
[118] Our common future, Chapter 2, Towards Sustainable Development
[119] Brown, Becky et al., " Global sustainability: Toward definition," 1987, *Environmental Management,* https://link.springer.com/article/10.1007/BF01867238; Pearce, David and Barbier, Edward, "Blueprint for a sustainable economy," 2000, *Business Strategy and the Environment,* https://onlinelibrary.wiley.com/doi/10.1002/bse.299
[120] Ekins, Paul, "Environment Sustainability: From environmental valuation to the sustainability gap," 2011, *Progress in Physical Geography Earth and Environment,* https://journals.sagepub.com/doi/10.1177/0309133311423186
[121] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344
[122] "1987: Brundtland Report," 1987, *Federal Office for Spatial Development,* https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html
[123] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344.
[124] Ayub, Tayba, "Information and Communication Technology and Environmental Degradation Global Perspective: A Panel Data Analysis," 2022, *Journal of Energy and Environment,* https://journals.internationalrasd.org/index.php/jee/article/view/794; Gonel, Feride and Akinci, Atakan, "How does ICT-use improve the environment? The case of Turkey," 2018, *World Journal of Science Technology and Sustainable Development,* https://www.emerald.com/insight/content/doi/10.1108/WJSTSD-03-2017-0007/full/html; "Accelerating sustainability with AI," 2023, *Microsoft,* https://blogs.microsoft.com/on-the-issues/2023/11/16/accelerating-sustainability-ai-playbook/

or pollution overall.[125] ICT solutions may also be more resource intensive or use more environmentally harmful resources: for example, e-readers have greater environmental impacts than paper books, depending on the number of books they replace.[126] Because of this, it is important for the designers and developers of ICT *for sustainability* to also consider the environmental impact of their ICT infrastructure, products, and services when designing solutions.[127] In sum, this report adopts the perspective that sustainable ICT is an important precursor to ICT for sustainability: once the ICT sector becomes sustainable, ICT solutions will also become more sustainable and unforeseen impacts from ICT for sustainability will, in turn, be reduced.

[125] Ayub, Tayba, "Information and Communication Technology and Environmental Degradation Global Perspective: A Panel Data Analysis," 2022, *Journal of Energy and Environment,* https://journals.internationalrasd.org/index.php/jee/article/view/794
Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

[126] Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability

[127] Steffen Lange, Johanna Pohl, and Tilman Santarius, "Digitalization and energy consumption. Does ICT reduce energy demand?" 2020, *Ecological Economics,* http://www.santarius.de/wp-content/uploads/2020/08/Digitalization-and-energy-consumption-Ecological-Economics-LangePohlSantarius-2020.pdf; Simpson, Joseph et al., "The Treadmill of Information: Development of the Information Society and Carbon Dioxide Emissions," 2019, *Science of Development,* https://online.ucpress.edu/socdev/article-abstract/5/4/381/109353/The-Treadmill-of-InformationDevelopment-of-the?redirectedFrom=fulltext



DEVELOP AN ORGANIZATION-WIDE ENIVIRONMENTAL SUSTAINABILITY STRATEGY

Environmental sustainability strategies are an effective way for organizations to begin their sustainable ICT journey. According to a survey conducted by ICTC in 2023, organizations with an environmental, social, and governance (ESG) or environmental sustainability strategy are twice as likely as those without to consider environmental impacts in their technology decisions. This is because environmental sustainability strategies help organizations factor environmental impact into various types of organizational activities, including those related to technology. Among other outcomes, environmental sustainability strategies help organizations:

- Set, track, and report on goals related to the environment
- Rate environmental sustainability performance
- Comply with environmental regulations
- Integrate environmental sustainability into organizational strategy, policies, decision-making infrastructure, goals, and performance metrics

Unfortunately, many organizations that design, develop, and adopt technology do not have a formal environmental sustainability strategy, or if they do, it does not incorporate ICT in a robust or comprehensive way. In response to a survey that ICTC conducted in 2023, just one-fifth (21%) of technology-focused organizations reported having an ESG or environmental sustainability strategy. A separate survey conducted by Capgemini in 2021 found that while 50% of surveyed technology firms had an enterprise-wide sustainability strategy, only 18% had a sustainable IT strategy with well-defined goals and timelines.[128]

In order to increase environmental sustainability in the ICT sector, more technology-focused organizations will need to adopt an organization-wide ESG or environmental sustainability strategy and ensure these strategies sufficiently account for ICT. In this section, we review what steps organizations can take to adopt an ESG or environmental sustainability strategy, including performing an initial assessment, developing an ESG or environmental sustainability strategy, and ensuring their strategy is complete with goals and metrics that are relevant to ICT.

[128] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf

Perform an Initial Assessment

A natural starting point for organizations that do not yet have an environmental sustainability strategy is to perform an initial assessment of their organization's approach to environmental sustainability or ESG. Assessments not only help organizations understand where they need to improve but can also provide a soft introduction to environmental sustainability terminology, concepts, and data. Indeed, many of the organizations that ICTC interviewed in preparation for this report had first grappled with environmental sustainability terminology and concepts while undergoing an initial assessment.

In part due to the benefits of performing an assessment, a variety of assessment tools are available for organizations to use.[129] Some focus solely on environmental sustainability, while others extend beyond environmental sustainability to include the "social" and "governance" aspects of ESG. Some are self-assessments, while others are performed by third-party organizations. Finally, some exist only for assessment purposes, while others can lead to third-party certifications. The table below provides an overview of some of the tools that are available to organizations when performing an initial assessment.

Type of Assessment	Providing Organization	Tool	Scope	Target Organization	Cost
Self-Assessment	Sustainability Advantage	Basic Sustainability Assessment Tool	Sustainability; Impact on People and Planet; Sustainable Development Goals	Any-Size Organization	Free
	Sustainability Advantage	Advanced Sustainability Assessment Tool	Sustainability; Impact on People and Planet; Sustainable Development Goals	Large, Multinational Organizations with Sustainability Professionals on Staff	Free
	B Corp	B Impact Assessment	Governance, Workers, Community, Environment	Any-Size Organization	Free
	Responsible Business Alliance	RBA Self-Assessment Questionnaire	Environmental, Social, and Governance Criteria	Any-Size Organization	Paid
Third-Party Assessment	S&P Global	Corporate Sustainability Assessment	Environmental, Social, and Governance Criteria	Select Public Corporations	Free
	S&P Global	Private Benchmarking Service	Environmental, Social, and Governance Criteria	Private Equity Companies and Small and Medium-Sized Organizations	Paid
	EcoVadis	EcoVadis Sustainability Assessment	Environment, Labour and Human Rights, Ethics, Sustainable Procurement	Any-Size Organization	Paid

Table 1. *List of self- and third-party- assessment options.*

[129] For example, Sustainability Advantage's open-source spreadsheet of self-assessment tools references 17 self-assessment and third-party assessment frameworks. See: "Sustainability Advantage," 2023, *Sustainability Advantage,* https://sustainabilityadvantage.com/assessments/bsat/

Whether conducting a self-assessment or contracting a third-party organization to conduct an assessment on their behalf, initial assessments are an important way for organizations to begin their environmental sustainability journey. Assessments help organizations identify what steps they need to take before being able to draft and implement an effective environmental sustainability strategy. For example, several of the organizations that were interviewed for this report only realized during their initial assessment that they were not collecting robust enough environmental data to implement an environmental sustainability strategy. Likewise, initial assessments help organizations understand which areas of environmental sustainability they need to improve on the most, leading to the development of a strategy later on. Finally, initial assessments are important because they help organizations establish a "baseline," which they can use to measure their future progress on environmental sustainability goals.[130]

Develop an Organization-Wide Environmental Sustainability Strategy

After conducting an initial assessment, organizations can begin drafting an environmental sustainability strategy. Environmental sustainability strategies identify the organization's environmental sustainability goals, indicate what metrics and data will be used to measure progress and outline how the goals will be incorporated into broader organizational strategies and decision-making structures. Fortunately, as a result of the growing importance of sustainability to the global economy, there are a number of existing resources that organizations can use to learn about and draft ESG and environmental sustainability strategies:

ISO 26000 GUIDANCE ON SOCIAL RESPONSIBILITY is an international standard that introduces organizations to common ESG terms and definitions and provides guidance to organizations on how to set ESG goals (including goals related to the environment, the prevention of pollution, sustainable resource use, climate change mitigation and adaptation, and protection of the environment, biodiversity, and restoration of natural habits) and integrate responsibility for these goals throughout an organization.[131]

B IMPACT ASSESSMENT is an online assessment tool that organizations can use to measure, manage, and improve their impact on the environment. Undergoing the B Impact Assessment can help organizations identify areas for improvement, as well as environmental sustainability goals and metrics.[132]

CDP ORGANIZATIONAL GUIDE FOR ENVIRONMENTAL ACTION is a guidance document that can be used by organizations to assess where they are in their journey toward environmental action. The document provides examples of the types of actions companies take at different stages of their environmental journey.[133]

[130] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344.
[131] "ISO 26000 Social responsibility," 2023, *ISO,* https://www.iso.org/iso-26000-social-responsibility.html
[132] "B Impact Assessment," 2023, *B Impact Assessment,* https://www.bcorporation.net/en-us/programs-and-tools/b-impact-assessment/
[133] "Organizational guide for environmental action," 2023, *CDP,* https://www.cdp.net/en/guidance/guidance-for-companies/organizational-guide-for-environmental-action

SDG ACTION MANAGER is an online tool that small and medium-sized organizations can use to set, manage, and track organizational goals that are aligned with sustainable development goals.[134]

ISO 14001 AND RELATED STANDARDS FOR ENVIRONMENTAL MANAGEMENT are a set of international standards that provide guidance to organizations on how to use environmental management systems to manage and improve their environmental impact in a systematic way. The standards apply both to organizations' own established goals and statutory and regulatory requirements.[135]

SBTI SET A TARGET is an online tool that organizations can use to set an emissions reduction target in line with the Science Based Targets Initiative's (SBTi) criteria.[136] The website includes general guidance materials for all types of organizations,[137] as well as specific guidance for the ICT sector.[138]

CDP CLIMATE DISCLOSURE FRAMEWORK FOR SMES is a framework that provides guidance to small and medium-sized enterprises on how to set GHG reduction targets grounded in science and report on GHG reduction progress.[139]

Similarly, there are a number of standardized frameworks that organizations can lean on to select relevant metrics for their strategy. Metrics are important because they help break down broad sustainability goals into measurable outcomes. For example, an organization might decide that they want to reduce their impact on raw material consumption by using more recycled content in their technology devices. In order to measure progress toward this goal, the organization will need to decide how to measure their use of recycled content: one option they might consider is measuring the volume of recycled materials used in their devices as a percentage of the total volume of materials used in their devices.

In addition to providing a list of ready-to-adopt metrics, standardized frameworks help organizations measure their environmental impact in a way that is comparable with other organizations. When organizations develop their own individual approach, it limits their ability to share and compare data with other organizations, in turn reducing supply chain transparency and limiting progress in sustainable ICT.[140] Notably, in response to a survey that ICTC conducted in 2023, approximately one-fifth (22%) of technology-focused organizations felt their suppliers' environmental data was not standardized enough, making it difficult to compare the environmental sustainability of one supplier to another.[141]

[134] "SDG ACTION MANAGER Helping all businesses take action for the Sustainable Development Goals," 2023, *B Lab,* https://www.bcorporation.net/en-us/programs-and-tools/sdg-action-manager/
[135] "ISO 14001:2015 Environmental management systems Requirements with guidance for use," 2023, *ISO,* https://www.iso.org/iso-14001-environmental-management.html
[136] "Set a Target," 2023, *Science Based Targets,* https://sciencebasedtargets.org/set-a-target
[137] "Resources," 2023, *Science Based Targets,* https://sciencebasedtargets.org/resources/
[138] "Information and Communication Technology (ICT)," 2023, *Science Based Targets,* https://sciencebasedtargets.org/sectors/ict
[139] "A CLIMATE DISCLOSURE FRAMEWORK FOR SMALL AND MEDIUM-SIZED ENTERPRISES (SMEs)," 2021, *CDP,* https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/002/852/original/SME-Climate-Framework.pdf?1637746697
[140] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada
[141] Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada

The list below provides an overview of existing frameworks that organizations can use to measure, track, and report on a broad range of environmental impacts in a standardized way:

GLOBAL REPORTING INITIATIVE (GRI) STANDARDS are a set of interconnected standards that organizations from any sector can use to measure and report on a broad range of environmental impacts and environmental sustainability initiatives (e.g., materials, energy, water and effluents, biodiversity, emissions, effluents and waste, waste, and supplier environmental assessment).[142]

SUSTAINABILITY ACCOUNTING STANDARDS BOARD (SASB) STANDARDS are a set of interconnected standards that organizations can use to measure and report on a select range of sustainability topics (e.g., a combination of water management, energy management, waste management, environmental footprint, product lifecycle management, materials sourcing, supply chain management, and product end-of-life management, depending on the industry at hand). Industry-specific standards are available for six ICT industries, including (1) electronic manufacturing services and original design manufacturing, (2) hardware, (3) internet media and services, (4) semiconductors, (5) software and IT services, and (6) telecommunications services.[143]

WORLD ECONOMIC FORUM—TOWARD COMMON METRICS AND CONSISTENT REPORTING is a guidance document that identifies 21 core and 34 expanded metrics for ESG reporting. These metrics relate specifically to environmental sustainability, including GHG emissions, land use and ecological sensitivity, water consumption, and water withdrawal.[144]

CDP REPORTING GUIDANCE DOCUMENTS are a set of guidance documents that organizations can use to explore common reporting metrics related to climate change, forests, and water security.[145]

GHG PROTOCOL STANDARDS are a set of standards that organizations can use to measure and report their GHG emissions. The GHG Protocol standards are the world's most widely used standards for GHG accounting and reporting.[146]

CDP CLIMATE DISCLOSURE FRAMEWORK FOR SMES is a framework that provides guidance to small and medium-sized enterprises on how to measure their emissions, including both energy emissions and value chain emissions, and report on GHG reductions progress.[147]

142 "GRI Standards English Language," 2023, *GRI,* https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/
143 "Download SASB Standards," 2023, *SASB,* https://sasb.org/standards/download/
144 "Measuring Stakeholder Capitalism Towards Common Metrics and Consistent Reporting of Sustainable Value Creation," 2020, *World Economic Forum,* https://www3.weforum.org/docs/WEF_IBC_Measuring_Stakeholder_Capitalism_Report_2020.pdf
145 "Guidance for companies," 2023, *CDP,* https://www.cdp.net/en/guidance/guidance-for-companies
146 "Standards," 2023, *GHG Protocol,* https://ghgprotocol.org/standards
147 "A CLIMATE DISCLOSURE FRAMEWORK FOR SMALL AND MEDIUM-SIZED ENTERPRISES (SMEs)," 2021, *CDP,* https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/002/852/original/SME-Climate-Framework.pdf?

Once organizations have identified standardized metrics to measure progress toward their sustainability goals, they can begin incorporating these goals and metrics into organizational policies and decision-making structures. For example, sustainability goals and metrics can be incorporated into the specs that guide product teams, the criteria that procurement officers use to guide purchasing decisions, or the decision-making structures that inform bonuses, salary increases, and promotions. As was noted by participants in this study, cementing broad organizational goals into the policies and decision-making structures that influence staff during their day-to-day is an important way to ensure that organizational goals are realized, not just set.

Adapt Environmental Sustainability Strategies to the Context of ICT

Designing an environmental sustainability strategy that readily applies to ICT activities is not without its challenges. Environmental sustainability is a broad topic that spans all industries, not just ICT. Accordingly, most of the tools and frameworks that help organizations draft sustainability strategies do not include specific guidance related to ICT. While some reporting frameworks have variants designed for the ICT sector, such as the SASB standards, many are designed for all sectors and do not include specific guidance for ICT. As noted by SustainableIT.org, "mainstream reporting frameworks are not refined enough to allow technology teams to easily take direct action on sustainability" and "do not offer a relevant, consistent set of topics or metrics applicable across IT functions in multiple industries, locations, and of multiple sizes."[148] Without specific guidance, it is left to individual organizations to adapt existing tools and frameworks to an ICT context, which can be both time intensive and difficult to accomplish and has resulted in a patchwork of different approaches to sustainable ICT.

Fortunately, sustainable ICT leaders have developed guidance materials that can help organizations adapt their environmental sustainability strategies to ICT:

SUSTAINABLE IT PLAYBOOK FOR TECHNOLOGY LEADERS provides guidance to chief information officers, chief digital officers, and chief technology officers on how they can build and implement a robust, sustainable IT strategy. Among other things, the book reviews the key principles of sustainable IT, highlights industry best practices, and examines real-world case studies of sustainability strategies for IT.[149]

SUSTAINABLE IT MATURITY MODEL© is a maturity assessment framework that helps organizations assess their level of maturity when it comes to sustainable IT and then guides them through the development of a sustainable IT strategy. The model helps organizations identify areas for improvement, determine priorities, and establish goals to improve the sustainability of their IT operations. It can be found in Chapter 10 of Niklas Sundberg's Sustainable IT Playbook for Technology Leaders.[150]

[148] "SustainableIT Standards Taxonomy Version V1.0," 2023, *SustainableIT.Org,* https://www.sustainableit.org/assets/SustainableIT-Standards-Taxonomy-07262023.pdf
[149] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344
[150] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344

CAPGEMINI'S ROADMAP FOR SUSTAINABLE IT IMPLEMENTATION suggests a three-stage roadmap that organizations should follow to accelerate their sustainable IT agenda. The first stage, "assess," helps organizations set a foundation for their sustainable IT initiatives; the second stage, "governance plan," helps organizations create an effective governance structure to oversee their sustainable IT initiatives; while the third stage, "implement," focuses on operationalization.[151]

SUSTAINABLE IT ESG STANDARDS are a set of ESG reporting standards that were designed specifically for the ICT sector by a group of chief information, technology, and digital officers. "They provide a consistent way of describing or "disclosing" a company's sustainability current state to regulatory bodies and shareholders," and "are tailored to IT and relevant functions to IT in any region, industry, and size of company."[152] The standards provide guidance on how to measure, track, and report on the environmental impact of ICT and include metrics related to energy consumption, GHG emissions, water consumption, waste, and sustainable sourcing.[153]

Conclusion

Environmental sustainability strategies are an effective way for organizations to begin their sustainable ICT journey. Environmental sustainability strategies help organizations factor environmental impact into all aspects of their organization, making organizations with a broad environmental sustainability strategy more likely to factor environmental impact into their technology decisions. In order to advance sustainable ICT, more organizations will need to develop and adopt an organization-wide environmental sustainability strategy that effectively addresses ICT.

[151] Sustainable IT: Why it's time for a Green revolution for your organization's IT," 2021, *Capgemini Research Institute,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf
[152] "SustainableIT Standards Taxonomy Version V1.0," 2023, *SustainableIT.Org,* https://www.sustainableit.org/assets/SustainableIT-Standards-Taxonomy-07262023.pdf
[153] "IT Standards for Environmental, Social, and Governance Sustainability," 2023, *SustainableIT.Org,* https://www.sustainableit.org/standards/it-esg-standards

ADOPT BEST PRACTICES FOR SUSTAINABLE ICT AT THE ORGANIZATIONAL LEVEL

Due to the proliferation of ICT, nearly every organization in the modern economy is responsible for some combination of ICT infrastructure components, whether that be desktop computers and laptops, servers, data centres, networking equipment, software, or data.[154] In the lead up to this report, ICTC interviewed organizations with a wide variety of ICT infrastructure setups. Some provided employees with company laptops. Others asked employees to use their own personal computers. Some had an IT team that managed IT infrastructure internally. Others outsourced this function to managed IT service providers. Some had their own data centres and servers on site. Others outsourced these functions to infrastructure and cloud services providers. Irrespective of what ICT infrastructure an organization has, adopting best practices for sustainable ICT can help reduce environmental impacts. In this section, we review three categories of best practices for sustainable ICT that can be adopted at the organizational level: sustainable ICT infrastructure design, sustainable management of technology hardware over their lifecycles, and sustainable digital resource management.

Adopt a Sustainable ICT Infrastructure Design

How organizations choose to structure their ICT infrastructure alters their environmental impact. If an organization decides to build their own data centre internally instead of opting for a cloud services provider, it will likely need to acquire the necessary hardware, which has a variety of environmental impacts across its lifecycle. On the other hand, if an organization opts for a cloud services provider that is physically located in a water-stressed region, they will likely increase their organization's impact on water scarcity. Accordingly, it is important for organizations to consider environmental impact when deciding how to structure their IT infrastructure or when considering significant changes to their IT infrastructure.

In terms of high-level guidance, sustainable ICT experts suggest organizations can reduce their environmental impact by transitioning from "on-premises" IT infrastructure to a cloud services provider.[155] Cloud services providers enable multiple organizations to dynamically share the same IT hardware, which reduces the need for duplicative hardware within each organization.[156] They also

[154] "What is IT Infrastructure?" 2021, IBM, https://www.ibm.com/topics/infrastructure; "Digital Infrastructure," 2021, *SDIA,* https://knowledge.sdialliance.org/glossary/digital-infrastructure
[155] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344; Currie, Anne et al., "Building Green Software," 2024, O'Reilly Media Inc., https://www.oreilly.com/library/view/building-green-software/9781098150617/; "Sustainable IT: Why it's time for a Green revolution for your organizations," 2021, *SustainableIT.org,* https://www.capgemini.com/be-en/wp-content/uploads/2021/07/Sustainable-IT_Report-2.pdf; "The Carbon Benefits of Cloud Computing," 2020, *Microsoft,* https://info.microsoft.com/ww-landing-Carbon-Benefits-of-Cloud-Computing.html
[156] Notably, "the more you utilize a computer, the more efficient it becomes at converting electricity to useful computing operations. Running [digital products and services] on as few servers as possible with the highest utilization rate maximizes their energy efficiency." See: Principle: Energy efficiency," *Microsoft,* https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-over-

enable organizations to dramatically increase or decrease their digital resource consumption without needing to acquire or dispose of the associated hardware internally. Additionally, because cloud services providers aggregate demand for ICT infrastructure, they create opportunities for optimization and efficiencies of scale, and can aggregate resources for investment in sustainability best practices.[157]

Nonetheless, it is important to note that the environmental sustainability of a cloud services provider can vary depending on a number of factors, including the type of services they provide, their size and scale, the local climate where they are located, whether they utilize renewable energy, whether they have access to sustainable water sources, what type of hardware they use, how they manage waste, whether they use carbon credits and which kinds, and whether they apply best management practices for green data centres.[158] Because of this, it is important for organizations to consider environmental sustainability metrics when choosing whether to outsource their IT infrastructure, deciding which infrastructure tier they will use to meet their business requirements,[159] or deciding which IT infrastructure and services providers to use. Fortunately, several organizations have published guidance on how to identify and select an environmentally sustainable infrastructure provider:

THE WEB SUSTAINABILITY GUIDELINES (WSG) 1.0 ask organizations to use the lowest possible infrastructure tier that still meets their business requirements, "avoid over-provisioning multi-datacenter, multi-zone, or distributed deployments if standalone instances meet [their] requirements," implementing autoscaling in response to things like traffic and business hours, and "avoid provisioning for peak loads."[160]

THE INTERNATIONAL TELECOMMUNICATIONS UNION asks organizations to consider where the data centre is located, whether the equipment in the data centre is aligned with environmental best practices for energy consumption and end-of-life management, whether the facility where the data centre is housed was designed to reduce environmental impact, and whether the data centre is operated and maintained in an environmentally sustainable way.[161]

SUSTAINABLE WEB DESIGN outlines key criteria that organizations should consider when choosing a hosting and infrastructure provider.[162] According to Sustainable Web Design, environmentally sustainable services providers calculate and share environmental sustainability metrics like power usage effectiveness (PUE), water

view/4-energy-efficiency

[157] "ITU Recommendation L.1300," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1300; "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304

[158] "ITU Recommendation L.1300," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1300; "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304

[159] "Use the lowest infrastructure tier meeting business requirements," 2023, *Sustainable Web Design,* https://sustainablewebdesign.org/guidelines/4-11-use-the-lowest-infrastructure-tier-meeting-business-requirements/

[160] "Use the lowest infrastructure tier meeting business requirements," 2023, *Sustainable Web Design,* https://sustainablewebdesign.org/guidelines/4-11-use-the-lowest-infrastructure-tier-meeting-business-requirements/

[161] "ITU Recommendation L.1300," 2023, *International Telecommunications Union*, https://www.itu.int/rec/T-REC-L.1300; "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304

[162] "4.1 Choose a Sustainable Hosting Provider," 2023, *Sustainable Web Design,* https://sustainablewebdesign.org/guidelines/4-1-choose-a-sustainable-hosting-provider/

usage effectiveness (WUE), and carbon usage effectiveness (CUE); take specific steps to lengthen the life of their hardware and equipment; recover, recycle, and upcycle waste, including equipment waste; utilize renewable electricity; and use proven and verifiable carbon offsets.

SUSTAINABLE ICT LEADER WHOLEGRAIN DIGITAL asks organizations to consider whether the vendor has a public environmental sustainability policy, whether they use green energy sources, whether they use carbon offset (and if so, which kinds), what their energy efficiency is (measured in PUE), and whether they offer tools to help clients improve the efficiency of their web applications.[163]

THE GREEN WEB FOUNDATION provides a free online directory of verified green data centre operators and web hosting providers by country.[164] Verified providers have provided evidence to the Green Web Foundation that they take steps to avoid, reduce, or offset GHG emissions caused by their services.[165]

Engage in Sustainable Life Cycle Management for ICT Hardware and Devices

Irrespective of whether organizations opt for internal or outsourced ICT infrastructure, they will likely own at least some ICT hardware, whether that be desktop computers and laptops, servers, data centres, networking equipment, or other ICT equipment. Indeed, none of the organizations that were interviewed for this study owned zero ICT hardware. This makes the management of ICT hardware and devices over their lifecycle an important component of organizational best practices for sustainable ICT.

Procurement

The first step in sustainable lifecycle management is procurement. Organizations can reduce the environmental impact of their ICT hardware and devices by ensuring they purchase the most sustainable options. While noted only briefly here, sustainable procurement is expanded on in Strategy IV: Source and Procure ICT Sustainably.

(Re)Use

Beyond procurement, organizations can reduce the environmental impact of their technology stack by implementing policies that prolong the lifespan of their ICT hardware and devices. Prolonging the lifespan of ICT hardware reduces its environmental impact in two ways. First, using ICT hardware for longer reduces

[163] Green, Tom, "How to choose a green web host," 2020, *Wholegrain Digital,* https://www.wholegraindigital.com/blog/choose-a-green-web-host/
[164] "The Green Web Directory," 2023, *The Green Web Foundation,* https://www.thegreenwebfoundation.org/tools/directory/
[165] "What we accept as evidence of green power," 2023, *The Green Web Foundation,* https://www.thegreenwebfoundation.org/what-we-accept-as-evidence-of-green-power/

the demand for new hardware to be produced. ICT hardware and devices typically have short lifespans, and because of this, replacing old hardware is a significant contributor to new demand.[166] Second, prolonging the lifespan of ICT devices helps to reduce their environmental impact *per year of use.* When thinking about the environmental impacts of ICT hardware, it is helpful to think about two broad categories. The first includes environmental impacts from *just* the use stage, such as energy consumption from hardware use: these are "dynamic" in the sense that they will either increase or decrease depending on how long the hardware is used. The second includes environmental impacts from the raw material extraction, manufacturing, transportation, and end-of-life stages of the technology lifecycle, such as embodied GHG emissions: these are "static" in the sense that they will remain the same irrespective of how long the hardware or device is used.

As discussed in Section I, this second category of "static" or "embodied" impacts accounts for the vast majority of environmental impacts for many ICT hardware over their lifecycles. It is also this second category of "static" impacts that prolonging the lifespan of ICT devices helps to address. For example, as is explained in Microsoft's online course, The Principles of Sustainable Software Engineering, if it takes 4,000 kg of carbon to produce a server with an expected lifespan of four years, then it can be said that this server emits approximately 1,000 kg of embodied carbon per year of use (e.g., 4,000 kg divided by four years equals 1,000 kg per year).[167] However, if we extend the server's lifespan to five years, for instance, by implementing good management practices to lengthen its lifespan, then we can, in turn, reduce its embodied carbon from 1,000 kg to 800 kg per year of use (e.g., 4,000 kg divided by five years equals 800 kg per year).[168]

There are a number of ways that organizations can increase the lifespan of their technology devices. For one, organizations can review ICT equipment policies to ensure they are not "refreshing" or automatically replacing technology hardware earlier than needed. Organizations can also increase the lifespan of their technology hardware and devices by ensuring they and their employees are maintaining hardware and devices properly. According to interviewees in this study, this may include upgrading instead of replacing older hardware and devices, taking advantage of repair and refurbishment programs, and donating or reselling old devices when they are no longer sufficient for the organization's needs but could still be used by other organizations or other individuals for other purposes. In addition to prolonging the life of ICT hardware and devices, organizations can prolong the life of the *materials used in their ICT hardware and devices* by ensuring they are recycled appropriately at the end of life.

[166] Forti, Vanessa et al., "The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential," 2020, *United Nations University, United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association,* https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf
[167] "Principle: Hardware Efficiency," 2023, *Microsoft,* https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-overview/6-hardware-efficiency
[168] "Principle: Hardware Efficiency," 2023, *Microsoft,* https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-overview/6-hardware-efficiency

End of Life

Sustainable lifecycle management for ICT hardware and devices ends with sustainable end-of-life management. As mentioned in the previous section, if the hardware or device is no longer sufficient for the organization's needs but could be used by other organizations for different purposes, then they should attempt to donate or resell the devices before recycling or disposing of them. If the hardware or devices are no longer suitable for any type of use, however, then the organization should investigate options for repair, refurbishment, and recycling. Many manufacturers provide direct avenues for refurbishment or recycling. For example, Apple maintains a robust trade-in and recycling program for its mobile phones, smart watches, tablets, computers, and other ICT products, which enables the manufacturer to use more recycled materials in new products.[169] In 2021, for example, nearly 20% of the materials used in Apple products came from recycled sources, including recycled tungsten, rare earth elements, and cobalt.[170]

If the original manufacturer does not maintain a trade-in, refurbishment, or recycling program, the organization should look for other avenues for recycling, such as government approved electronic products recycling centres. For example, the Electronic Products Recycling Association (EPRA) is an industry-led, not-for-profit organization that helps industry meet their extended producer responsibility obligations by managing government-approved programs for the collection and recycling of electronics products in nine Canadian provinces.[171] The EPRA has more than 2,500 collection sites across Canada and claims to have collected more than 1.2 million tonnes of electronics products since 2011.[172] Importantly, the EPRA only works with recyclers who have been verified to comply with Electronics Product Stewardship Canada's electronics recycling standard.[173] The EPRA independently audits and verifies recyclers under their Recycler Qualification Program.[174]

Manage Digital Resources Sustainably

ICT hardware and energy are used to produce a number of digital resources, including computing, memory, storage, and network capacity.[175] These digital resources are "the low-level resources required for digital products and services to operate."[176] They are effectively consumed by digital products and services like websites and software applications. Digital resources are important from a sustainability perspective because they are produced using energy and ICT hardware: as digital products and services consume digital resources, they, in turn, cause ICT hardware to consume more energy and increase total demand

169 "Trade In. Upgrade.," 2023, *Apple,* https://www.apple.com/ca/shop/trade-in
170 "Environmental Progress Report," 2021, *Apple,* https://www.apple.com/environment/pdf/Apple_Environmental_Progress_Report_2022.pdf
171 "What is a Steward," 2023, *EPRA,* https://epra.ca/what-is-a-steward
172 No citation. Information provided directly to ICTC.
173 "Electronics Recycling Standard," 2016, *RQP,* https://rqp.ca/wp-content/uploads/2018/09/ERS-2015-V3-16.12.29-EPSC.pdf
174 "The Recycler Qualification Office," 2023, *RQP,* https://rqp.ca/
175 "Definition for Digital resource primitives," 2021, *SDIA,* https://sdialliance.org/dictionary/digital-resource-primitives/
176 "Definition for Digital resource primitives," 2021, *SDIA,* https://sdialliance.org/dictionary/digital-resource-primitives/

for ICT hardware.[177] Because of this, unsustainable digital resource management can increase the environmental impact of an organization's technology stack, even when that organization designs their ICT infrastructure and manages its ICT hardware and devices in a sustainable way. In the subsections below, we review how different ICT stakeholders can make digital resource use more environmentally sustainable.

Guidance for Web Developers and Designers

Web developers and designers can enable sustainable ICT by designing web applications and sites that consume digital resources efficiently. The following list summarizes a variety of resources that web developers and designers can use to achieve this goal:

DESIGNING FOR SUSTAINABILITY: A GUIDE TO BUILDING GREENER DIGITAL PRODUCTS and Services provides guidance to web designers on how to use content strategies, performance optimization, design and user experience, and green hosting to achieve sustainable web design.[178]

SUSTAINABLE WEB DESIGN is an online textbook that provides practical advice on how to build faster, more carbon-efficient websites.[179] The book's author, Tim Frick, has also published a series of blogs on his company's website on the topic of sustainable web design. In one of his blogs, Tim outlines key questions that web designers can use to guide their sustainable web design practice. These include: How quickly do assets download to a user's device? How quickly can users find the content they need, and how useful is that content once it is found? How quickly can all users accomplish tasks across devices and platforms at various bandwidth speeds? And are the servers hosting your digital products and services powered by renewable energy? The same blog lists a variety of tools and resources that designers can use to make their websites more sustainable, including tools and resources for web performance optimization, sustainable user experience design, sustainable content development, and green web hosting.

THE WEB SUSTAINABILITY GUIDELINES (WSG) 1.0 consists of 93 recommendations that explain how to design and implement digital products and services that are environmentally sustainable.[180] They recommend best practices for sustainable user experience design (e.g., avoiding unnecessary digital assets, opting for lightweight versions of media assets, and enabling efficient navigation and wayfinding, etc.), best practices for sustainable web development (e.g., limiting server requests, minimizing page weight, and using code splitting within projects, etc.), and

[177] "Definition for Digital resource primitives," 2021, *SDIA,* https://sdialliance.org/dictionary/digital-resource-primitives/; "The Principles of Sustainable Software Engineering," 2023, *Microsoft,* https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-overview/
[178] Frick, Tim, "Designing for Sustainability," 2016, *O'Reilly Media Inc.,* https://www.oreilly.com/library/view/designing-for-sustainability/9781491935767/
[179] Greenwood, Tom, "Sustainable Web Design," 2021, *A Book Apart,* https://abookapart.com/products/sustainable-web-design
[180] "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/

best practices for sustainable hosting and infrastructure design (e.g., choosing sustainable hosting providers, optimizing browser caching, reducing duplicate data, and compressing files, etc.). They also recommend making sustainability a core part of organizational and product strategy, for instance, by assigning sustainability representatives to product teams or communicating the environmental impact of user choices to users. In addition to the formal guidelines hosted by W3C, Sustainable Web Design hosts the Web Sustainability Guidelines on their website in an easy-to-navigate format, complete with four categories (e.g., UX design, web development, hosting and infrastructure, and businesses and product strategy), 26 tags (e.g., usability, KPIs, e-waste, HTML, CSS, etc.), and search functionality.[181]

Guidance for Software Developers

Software developers can enable sustainable ICT by building software products and services that are environmentally sustainable. The below list summarizes a few key resources that software developers can use to build environmentally sustainable software products and services:

THE PRINCIPLES OF SUSTAINABLE SOFTWARE ENGINEERING is a free online course about the principles of sustainable software development, which apply to all developers, irrespective of what domain they work in, what programming language or frameworks they use, and whether they use a cloud vendor or are self-hosted.[182] The principles suggest minimizing the amount of energy consumed and carbon emitted per unit of work, using electricity with a low carbon intensity, ensuring compatibility with old and legacy hardware, aligning design with climate and environmental commitments, and ensuring environmental impacts can be measured.

THE GREEN SOFTWARE FOUNDATION outlines ten principles that software developers can follow to minimize the environmental impact of their products and services.[183] These include focusing on and controlling features with high power consumption, reducing the use of data, removing unused or unwanted features, identifying and removing redundant loops, adapting applications to how devices consume and save energy, monitoring energy consumption in real time, choosing efficient programming languages, making calculated tradeoffs between the performance, accuracy, and energy consumption when using machine learning models, and using techniques like dynamic code analysis.

[181] "Web Sustainability Guidelines," 2023, *Sustainable Web Design,* https://sustainablewebdesign.org/guidelines/
[182] "The Principles of Sustainable Software Engineering," 2023, *Microsoft,* https://learn.microsoft.com/en-us/training/modules/sustainable-software-engineering-overview/
[183] "10 Recommendations for Green Software Development," *The Green Software Foundation,* https://greensoftware.foundation/articles/10-recommendations-for-green-software-development

BUILDING GREEN SOFTWARE provides guidance on how to build, host, and operate code in a more environmentally sustainable way.[184] It introduces the principles of sustainable software engineering and provides practical guidance on how to achieve code efficiency (e.g., how to write hyper-efficient code, how to balance tradeoffs between performance, efficiency, and sustainability, how to use green design patterns, etc.), operational efficiency (e.g., machine utilization, serverless, hyperscalers, etc.), carbon awareness (e.g., how to calculate the carbon intensity of electricity, the impact of demand shifting, real-world examples of carbon aware software, etc.), and environmental impact measurement (e.g., how energy, carbon intensity, and carbon emissions data works, methodologies for calculating GHG emissions, etc.).

Guidance for Technology Adopters and Users

Technology adopters and users can enable sustainable ICT by ensuring that they consume digital products and services, and in turn, digital resources, in an environmentally sustainable way. The below list provides a few key resources that this stakeholder group can use to tailor their use of digital products and services:

SUSTAINABLE IT PLAYBOOK FOR TECHNOLOGY LEADERS is a book by Niklas Sundberg that provides detailed advice on how organizations can manage their digital products and services in an environmentally sustainable way.[185] One topic that the book looks at in detail is how to design efficient and, therefore, environmentally sustainable applications and data architectures when using cloud services. Another topic that the book looks at in detail is how to approach application portfolio management (e.g., how an organization manages their suite of software applications) and application rationalization (e.g., the process of assessing and reducing the number of software applications an organization uses) from an environmental sustainability perspective. In addition to these two topics, the book discusses the importance of having a data management strategy that covers when an organization will duplicate or back up its data when it deletes unnecessary data and files, and what it will do to minimize the impact of their data on digital resource consumption.

THE SUSTAINABLE DIGITAL INFRASTRUCTURE ALLIANCE echoes some of the above recommendations while also asking users to only use applications when needed and to disable functionalities within applications that are not required.[186]

[184] Currie, Anne et al., "Building Green Software," 2024, *O'Reilly Media Inc.,* https://www.oreilly.com/library/view/building-green-software/9781098150617/
[185] Sundberg, Niklas, "Sustainable IT Playbook for Technology Leaders," October 2022, *Packt Publishing,* https://www.packtpub.com/product/sustainable-it-playbook-for-technology-leaders/9781803230344
[186] "Responsibilities across value chain" 2023, *SDIA,* https://knowledge.sdialliance.org/digital-environmental-footprint/responsibilities-across-value-chain

Conclusion

Due to the expansion of ICT across all sectors of the economy, nearly every organization is responsible for some combination of ICT infrastructure components, whether that be desktop computers and laptops, servers, data centres, networking equipment, software, or data.[187] Irrespective of what ICT infrastructure an organization has, adopting best practices for sustainable ICT can help reduce the environmental impact of their technology stack. In this section, we reviewed best practices that can be adopted by any type of organization to improve the environmental impact of their ICT, including sustainable ICT infrastructure design, sustainable lifecycle management, and sustainable digital resource management. In the next two sections, we turn to sustainability practices that can be adopted by two types of ICT stakeholders: first, we discuss what technology designers and developers can do to build more environmentally sustainable products and services, and second, we look at the role that technology buyers can play in incentivizing sustainability improvements across the ICT supply chain.

[187] What is IT Infrastructure," 2021, IBM, https://www.ibm.com/topics/infrastructure; "Digital Infrastructure," 2021, *SDIA,* https://knowledge.sdialliance.org/glossary/digital-infrastructure

BUILD ENVIRONMENTALLY SUSTAINABLE PRODUCTS AND SERVICES

It is said that over 80% of a product's environmental impacts are determined during its design.[188] While in reality, this figure varies by product and industry, design can significantly alter what environmental impacts occur during later stages of the product lifecycle, including raw material extraction, manufacturing, distribution, use, and end of life. For example, the types of materials that are specified during the design phase for a piece of ICT hardware will later impact whether it is possible to disassemble, recycle, or safely dispose of it. Similarly, whether a software application is designed to include a variety of redundant features, as opposed to just the features that users need, will impact how much energy the application consumes when it is used.[189] Unfortunately, many technology professionals do not consider the environmental impact of their design decisions when designing or updating their products and services. In response to a survey that ICTC ran in 2023, 39% of technology designers and developers indicated that they do not factor environmental impact or environmental sustainability into the way they design technology.[190] While 59% of technology designers and developers indicated that they do consider environmental impact or environmental sustainability, half indicated that they only do so minimally.[191]

Because of the complex relationship between environmental impact and design, designers have spent the last 30 years developing a common framework for sustainable design called "ecological design." In 1996, Sim Van der Ryn and Stuart Cowan defined eco-design as "any form of design that minimizes environmentally destructive impacts."[192] Today, eco-design is a rich field that employs a variety of tools to calculate and reduce the environmental impact of products and services. At a high level, eco-design requires designers to identify what environmental laws and requirements might apply to their products and services and adhere to them, gather information about the environmental impact of their products and services from later stages of the product lifecycle, reduce environmental impacts of products and services by utilizing eco-design tools and methodologies, and make a constant effort to improve their approach to eco-design.[193]

Given the complexity of the ICT supply chain, designing environmentally sustainable technologies is no easy feat. In this section, we detail how ICT companies can design technology with environmental sustainability in mind. We discuss three ways ICT product and service designers can implement eco-design within their organizations, including ecolabels, industry standards for sustainable ICT, and lifecycle assessments.

188 "Sustainable Product Policy," 2023, *European Commission,* https://joint-research-centre.ec.europa.eu/scientific-activities-z/sustainable-product-policy_en
189 "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/
190 Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada
191 Clark, Allison and Matthews, Mairead, "Advancing Environmentally Sustainable ICT in Canada," November 2023, *ICTC,* https://www.digitalthinktankictc.com/policy-briefs/advancing-environmentally-sustainable-ict-in-canada
192 Van der Ryn, Sim and Cowan, Stuart, "Ecological Design," 1996 and 2013, *Island Press,* https://www.google.ca/books/edition/Ecological_Design_Tenth_Anniversary_Edit/PEBs_eoIOdgC?
193 "ECMA – 341: Environmental Design Considerations for ICT & CE Products," 2010, *ECMA International,* https://ecma-international.org/wp-content/uploads/ECMA-341_4th_edition_december_2010.pdf

Leverage Environmental Labels for Eco-Design

ICT product and service designers can implement eco-design by adhering to environmental labels. Environmental labels, or "ecolabels," are specialized marks that companies can place on their products and services to distinguish them as environmentally sustainable. In order to use an ecolabel on their products and services, companies must first adhere to the environmental criteria specified by the ecolabel's manager and gain the ecolabel manager's approval. Importantly, not all ecolabels are made equal: ISO 14024 is an international standard that designates the highest-quality ecolabels, known as "Type I environmental labels."[194] In order to become recognized as a Type I environmental label, the ecolabel manager must follow specific best practices, including when defining their ecolabel's product categories, determining what environmental criteria they will use, and assessing companies' compliance.[195]

Adhering to ecolabels provides a number of benefits to ICT product and service designers. For one, ecolabels give ICT product and service designers access to clear, up-to-date, and ready-to-adopt environmental criteria that are relevant to their specific products and services. The criteria are developed in collaboration with industry, meaning they are likely to be achievable and aligned with business realities. They are also reviewed on a regular basis, meaning they are likely to incorporate up-to-date research and best practices. Many ecolabel managers also provide independent verification services, meaning they can independently verify whether organizations are complying with environmental criteria. Finally, once an organization has completed all the necessary steps, ecolabels can provide them with an easy way to communicate their environmental sustainability measures to clients and customers.

ICT product and service designers have a number of ecolabels that they can choose from depending on the type of product or service that they provide. Two examples of Type I ecolabels that were developed for the ICT sector are EPEAT and TCO Certified.[196] EPEAT and TCO Certified apply to a range of electronic and technology products, including desktop and personal computers, computer displays, notebooks, tablets, mobile phones, servers, headsets, imaging equipment, projectors, photovoltaic modules and inverters, and televisions. ECOLOGO is another Type I ecolabel that applies to a wide variety of products but also includes electronics and information and communications technologies.[197] Finally, ENERGY STAR is an ecolabel that helps identify energy-efficient appliances and equipment.[198]

[194] "ISO 14024:2018 Environmental labels and declarations Type I environmental labelling Principles and procedures," 2023, *ISO,* https://www.iso.org/standard/72458.html
[195] "ISO 14024:2018 Environmental labels and declarations Type I environmental labelling Principles and procedures," 2023, *ISO,* https://www.iso.org/standard/72458.html
[196] "EPEAT," 2023, Green Electronics Council dba Global Electronics Council, https://www.epeat.net/; "TCO Certified," 2023, *TCO Development,* https://tcocertified.com/
[197] "ECOLOGO Certification," 2023, *UL LLC.,* https://www.ul.com/services/ecologo-certification
[198] "ENERGY STAR," 2023, *ENERGY STAR* https://www.energystar.gov/

While the guidance provided by each ecolabel manager and for each product and service category is different, there are some commonalities. For example, ICT ecolabels ask technology manufacturers to reduce, monitor, and report their use of hazardous substances and chemicals of concern.[199] They also ask manufacturers to reduce their energy consumption by aligning products with energy efficiency standards and to reduce non-renewable energy consumption by utilizing more renewable energy sources. In terms of reducing raw material extraction, ecolabels ask manufacturers to use more recycled, post-consumer, and renewable materials; share information about their use of recycled, post-consumer, and renewable materials; design products in a way that enhances their recyclability; share information about the recyclability of their products; and not introduce physical or technical barriers to recycling during the manufacturing process.[200] In terms of extending the product lifecycle, ecolabels ask ICT manufacturers to design durable and repairable products, maintain robust warranty and repair programs, make replacement components available, and share information about repair. Ecolabels also ask ICT manufacturers to measure and report their GHG emissions at both the organizational and product levels, conduct lifecycle assessments for their products and services, share environmental impact data with customers and partners, and improve their adherence to environmental regulations by implementing environmental management systems.[201]

The above summary is only a small snapshot of the guidance provided by environmental labels. For more information about the guidance that environmental labels provide and to obtain environmental criteria for specific products and services, reference the environmental criteria resources provided by ICT ecolabel managers.

Leverage Industry Standards for Eco-Design

Industry standards are another way for ICT product and service designers to implement eco-design. Industry standards are "voluntary agreements that establish requirements for products, practices, or operations in a given field."[202] They can be developed for a wide variety of reasons: to facilitate interoperability between different types of ICT hardware and software, to facilitate the use of best practices for privacy and security, or to ensure products and services meet accessibility requirements. In the case of sustainable ICT, the purpose of industry standards is to facilitate the use of best practices for environmentally sustainable technology design.

199 "Environmental and social criteria with direct impact ," 2023, *TCO Development,* https://tcocertified.com/criteria-overview/; "About EPEAT: Overview of the EPEAT Ecolabel," 2023, Green Electronics Council dba Global Electronics Council, https://www.epeat.net/about-epeat
200 "Environmental and social criteria with direct impact ," 2023, TCO Development, https://tcocertified.com/criteria-overview/;; "About EPEAT: Overview of the EPEAT Ecolabel," 2023, *Green Electronics Council dba Global Electronics Council,* https://www.epeat.net/about-epeat
201 "Environmental and social criteria with direct impact ," 2023, TCO Development, https://tcocertified.com/criteria-overview/;; "About EPEAT: Overview of the EPEAT Ecolabel," 2023, *Green Electronics Council dba Global Electronics Council,* https://www.epeat.net/about-epeat
202 "Standards," 2023, *PennState University Libraries,* https://guides.libraries.psu.edu/c.php?g=311177&p=2080103

Companies can implement eco-design by aligning their product and service design with the guidance included in sustainable ICT standards. The benefit of using a pre-existing standard is that individual companies do not need to develop their own best practices for sustainable ICT, which can be a time-intensive task. Instead, companies can adopt ready-to-implement guidance from a standard relevant to their product, service, or field of work. Like ecolabels, standards are regularly reviewed to ensure they are still relevant, are up to date, and are applicable to current business realities.

ICT product and service designers have various options when it comes to industry standards for sustainable ICT. Many international standards-setting organizations have developed standards for sustainable ICT, including the International Telecommunications Union, the International Organization for Standardization, the Institute of Electrical and Electronics Engineers, the International Electrotechnical Commission, the European Telecommunications Standards Institute, and ECMA International. Globally, more than 150 standards covering a vast number of topics have been developed for the ICT sector. Some examples are ECMA 341, which provides guidance on environmental design considerations for ICT and CE (consumer electronics) (consumer electronics) products; ITU-T L.1060, which provides general principles for the green supply chain management of the ICT manufacturing industry; ITU-T L.1304, which provides guidance on the use of sustainability criteria for data centre procurement; ITU-T L.1300, which provides guidance on best practices for green data centres; and WSG 1.0, which provides guidance on how to make websites and digital products sustainable.[203] With so many sustainable ICT standards available, organizations like the International Federation of Global and Green Information Communications Technology have also developed online courses to help technology designers and developers learn about and navigate sustainable ICT standards.[204]

Of the more than 150 sustainable ICT standards available, approximately half focus on energy efficiency, a quarter focus on reducing material waste, a fifth focus on reducing GHG emissions, a tenth focus on reducing hazardous chemical use and reducing air pollution, and a handful focus on reducing freshwater use and reducing land system change. In the subsections below, we provide a high-level summary of the guidance sustainable ICT standards provide, as well as where ICT companies can go to obtain more detailed information.

[203] "ITU Recommendation L.1060," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1060-202107-I; "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304; "ITU Recommendation L.1300," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1300; "ECMA – 341: Environmental Design Considerations for ICT & CE Products," 2010, *ECMA International,* https://ecma-international.org/wp-content/uploads/ECMA-341_4th_edition_december_2010.pdf; "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/

[204] "The "Green IT Professional" Certification," 2023, *IFGICT,* https://ifgict.org/green-it-professional-gitp/

ENERGY EFFICIENCY Many sustainable ICT standards, including those published by ECMA[205] and ETSI,[206] provide guidance on how to measure energy consumption and energy efficiency in ICT products. Others, such as ISO 50001,[207] provide guidance on how to track, manage, and improve energy efficiency over time. Still, others specify how to design ICT products according to good energy management practices, such as by using energy sources efficiently, building energy-saving modes into components and devices, including mechanisms to reuse waste energy, making energy consumption and efficiency data available to partners and end-users, and using renewable energy sources when possible (see ETSI,[208] ECMA,[209] and ITU[210] standards). Additionally, standards like ECMA 341 suggest taking a lifecycle approach so as to maximize energy efficiency across a product's lifecycle instead of just focusing on one phase at a time.[211]

While difficult to see, digital products like websites and software programs have environmental impacts in the real world. Whether executed locally, on the web, or in the cloud, storing, transferring, and processing data requires energy, making energy efficiency a key consideration for digital product and service design. To reduce energy demand by web and software solutions, guidelines like the Web Sustainability Guidelines (WSG) 1.0[212] suggest opting for environmentally sustainable user experience design, such as by avoiding unnecessary digital assets, opting for lightweight versions of media assets and enabling efficient navigation and wayfinding; employing best practices for sustainable web development, such as limiting server requests, minimizing page weight, and using code splitting within projects; and implementing best practices for environmentally sustainable hosting and infrastructure design, such as by choosing sustainable hosting providers, optimizing browser caching, reducing duplicate data, and compressing files.

REDUCING MATERIAL WASTE Sustainable ICT standards, including those published by ETSI,[213] ITU,[214] and ECMA,[215] specify that ICT manufacturers should maximize their use of recycled and bio-based materials in products; share data with partners, end-users, and recycling centres about the recyclability of specific components and parts; and design products in a way that facilitates repair, reuse, and recycling later on, such as by reducing the number of materials per component or part, not using manufacturing processes that reduce recyclability, and making it easy to separate products into individual components and parts. Additionally, sustainable ICT standards ask ICT manufacturers to maintain robust repair and recycling programs to extend the lifecycle of ICT products and materials during their use stage, in turn reducing their environmental impact per year of use.

[205] "Standards," 2023, *ECMA International,* https://www.ecma-international.org/publications-and-standards/standards//
[206] "Standards," 2023, *ETSI,* https://www.etsi.org/standards
[207] "ISO 50001 Energy management," 2023, *ISO,* https://www.iso.org/iso-50001-energy-management.html
[208] "Standards," 2023, *ETSI,* https://www.etsi.org/standards
[209] "Standards," 2023, *ECMA International,* https://www.ecma-international.org/publications-and-standards/standards/
[210] "ITU-T Recommendations," 2023, *International Telecommunications Union,* https://www.itu.int/ITU-T/recommendations/index.aspxL
[211] "ECMA – 341: Environmental Design Considerations for ICT & CE Products," 2010, *ECMA International,* https://ecma-international.org/wp-content/uploads/ECMA-341_4th_edition_december_2010.pdf
[212] "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/
[213] "Standards," 2023, *ETSI,* https://www.etsi.org/standards
[214] "ITU-T Recommendations," 2023, *International Telecommunications Union,* https://www.itu.int/ITU-T/recommendations/index.aspx
[215] "Standards," 2023, *ECMA International,* https://www.ecma-international.org/publications-and-standards/standards/

REDUCING GHG EMISSIONS Several sustainable ICT standards provide guidance on how to evaluate the GHG emissions associated with ICT products and services. For example, IEC TR 62725:2013 provides users with guidance on the methodologies that they can use to evaluate the carbon footprint of electrical and electronic products over their lifecycles.[216] ICT Sector Guidance Built on the GHG Product Lifecycle Accounting and Reporting Standard meanwhile provides guidance on how to calculate the GHG emissions associated with ICT products and services using the GHG Protocol Product Lifecycle Accounting and Reporting Standard.[217] DIMPACT, which is a collaborative initiative between 22 media, entertainment, and technology companies and the University of Bristol's Computer Science Department, has published a series of reports about how to assess the GHG emissions associated with different types of digital products and services.[218] Similarly, Sustainable Web Design hosts regularly updated guidance on how to estimate the GHG emissions associated with digital products and services, including an open, standardized methodology for estimating digital emissions.[219] It is important to note that different approaches to estimating the GHG emissions associated with digital products and services will yield different results: technology designers and developers should be aware of the strengths and weaknesses of different methodologies prior to utilizing an approach.[220]

As noted in the section on energy efficiency, energy consumption is highly related to GHG emissions. Accordingly, much of the guidance provided in the Web Sustainability Guidelines (WSG) 1.0[221] is also relevant for reducing the GHG emissions of intangible, digital products and services. Similarly, GHG emissions are highly related to raw material extraction and procession and ICT manufacturing and production: many of the standards that focus on these areas of the ICT supply chain have direct impacts on the amount of GHG emissions associated with ICT hardware and devices.

REDUCING HAZARDOUS SUBSTANCE USE Sustainable ICT standards, such as ITU-T REC L.1015, specify that ICT manufacturers should meet the substance restriction requirements laid out in the European Union Restriction of Hazardous Substances (RoHS) Directive; disclose substances of very high concern (SVHC) under the European Union Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation; and limit quantities of hazardous substances like chlorine and bromine, as well as heavy metals like lead, cadmium, mercury, and hexavalent chromium.[222]

216 "IEC TR 62725:2013: Analysis of quantification methodologies of greenhouse gas emissions for electrical and electronic products and systems," 2013, *IEC,* https://webstore.iec.ch/publication/7400
217 "ICT Sector Guidance built on the GHG Protocol Product Lifecycle Accounting and Reporting Standard," 2017, *GHG Protocol,* https://ghgprotocol.org/sites/default/files/2023-03/GHGP-ICTSG - ALL Chapters.pdf
218 "A collection of articles we're reading that are shaping the understanding of the energy and carbon impacts of digital value chain emissions," 2023, *DIMPACT,* https://dimpact.org/resources
219 "Estimating Digital Emissions: The Formulas," 2023, *Sustainable Web Design,* https://sustainablewebdesign.org/calculating-digital-emissions/#toc-2
220 "Why We Don't Report Website Carbon Emissions," October 2023, *DebugBear,* https://www.debugbear.com/blog/website-carbon-emissions
221 "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/
222 "ITU-T Recommendation L.1015: Criteria for evaluation of the environmental impact of mobile phones," 2023, *International Telecommunications Union,* https://www.itu.int/itu-t/recommendations/rec.aspx?rec=13719

The above summary is only a small snapshot of the guidance provided by sustainable ICT standards. For more information about the guidance that sustainable ICT standards provide, refer directly to the standards documents that are referenced in the section above.

Leverage Life Cycle Assessments for Eco-Design

Lifecycle thinking is one of the core principles of eco-design.[223] It acknowledges that different phases of a product's lifecycle are interdependent and that trying to improve environmental impacts in one phase may worsen impacts in another. For instance, hardware designed to be more energetically efficient in the use phase typically requires more energy during the manufacturing phase—at times negating efficiency gains. By incorporating lifecycle thinking into design, eco-design ensures that the product or service is as environmentally sustainable as possible overall and not just within one phase of the product's life.[224]

Lifecycle assessments (LCAs) operationalize the concept of lifecycle thinking by using a specific methodology to estimate the environmental impact of products or services. They can be used by technology designers and developers to estimate the future environmental impact of design decisions, to compare different versions of ICT products and components, and to identify the most sustainable choice. As noted in Section I, technology products and services have a broad range of environmental impacts. To account for the full scope of ICT's environmental impact, LCAs should take into account multivariate criteria. For example, the International Telecommunication Unions' Methodology for Environmental Lifecycle Assessment of ICT Goods, Networks, and Services suggests considering climate change, ozone depletion, human toxicity (cancer and non-cancer effects), respiratory inorganics or particulate matter, ionizing radiation (human health, ecosystems), eutrophication (aquatic, terrestrial), photochemical ozone formation, acidification, ecotoxicity (freshwater), land use, and resource depletion (water, mineral, fossil).[225]

When conducting lifecycle assessments, organizations should follow a standardized approach. This helps to ensure that the approach is robust and in line with best practices and that lifecycle assessments from different organizations are comparable. Organizations have several international standards that they can choose from when selecting a methodology for their lifecycle assessments. This includes the International Telecommunications Union's L.1410: Methodology for Environmental Lifecycle Assessment of ICT Goods, Networks, and Services;[226] ETSI's ES 2013 199: Methodology for Environmental Lifecycle Assessments of ICT Goods, Networks, and Services;[227] NegaOctet's Methodology for Measuring the Environmental Impact of Digital Services;[228] and the International Organization

[223] "ECMA – 341: Environmental Design Considerations for ICT & CE Products," 2010, *ECMA International,* https://ecma-international.org/wp-content/uploads/ECMA-341_4th_edition_december_2010.pdf
[224] Liu, Ran et al., "Impacts of the Digital Transformation on the Environment and Sustainability, 2019, *Oko-Institute EV,* https://www.researchgate.net/publication/342039732_Impacts_of_the_digital_transformation_on_the_environment_and_sustainability
[225] "ITU Recommendation L.1410," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1410-201412-I/en
[226] "ITU Recommendation L.1410," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1410-201412-I/en
[227] "ETSI ES 203 199 V1.3.1," 2015, *ETSI,* https://www.etsi.org/deliver/etsi_es/203100_203199/203199/01.03.01_60/es_203199v010301p.pdf
[228] "NegaOctet: Reducing the environmental impact of digital services," 2021, *NegaOctet,* https://negaoctet.org/en/home/#Negaoctet

for Standardization's ISO 14044:2006: Lifecycle Assessment Requirements and Guidelines.[229] In addition to relying on standards, organizations can use existing datasets to acquire relevant data for their lifecycle assessments. For example, the NegaOctet database provides environmental impact data for more than 1,500 pieces of ICT equipment and up to 30 impact categories.[230]

While LCAs were originally designed for tangible products like laptops and servers, several organizations are working to adapt LCAs to intangible digital products like websites and software applications. DIMPACT, which is a collaborative initiative between 22 media, entertainment, and technology companies and the University of Bristol's Computer Science Department, has published a series of reports about how to assess the GHG emissions associated with different types of digital products and services.[231] Mightybytes has explored the concept of a "digital lifecycle assessment," which "applies the rigour of an LCA to digital products and services."[232] The Sustainable Digital Infrastructure Initiative is meanwhile developing the concept of a "digital environmental footprint," which measures the total environmental impact of activities in the digital economy.[233] It is important to note that different ways of estimating the lifecycle impacts of digital products and services will yield different results: technology designers and developers should be aware of the strengths and weaknesses of different methodologies prior to selecting an approach.[234]

Importantly, LCAs differ from product carbon footprint (PCF) assessments, which only quantify CO_2 equivalent emissions. While product carbon footprint assessments can help assess a product's impact on climate change, an LCA is more robust and can help mitigate negative implications beyond CO_2 equivalent emissions.

Conclusion

How products and services are designed can significantly alter what environmental impacts occur during the later stages of the product lifecycle, including raw material extraction, manufacturing, distribution, use, and end-of-life. Eco-design is an approach to design that recognizes the relationship between design and environmental impact and seeks to minimize the environmental impact of products and services over their lifecycle.[235] In this section, we reviewed three of the ways technology designers and developers can apply eco-design to their products and services, including ecolabels, industry standards for sustainable ICT, and lifecycle assessments. In the next section, we turn our focus to how procurement can incentivize sustainability improvements along the ICT supply chain.

[229] "ISO 14044:2006 Environmental management Lifecycle assessment Requirements and guidelines ," 2023, *ISO,* https://www.iso.org/standard/38498.html
[230] "NegaOctet: Reducing the environmental impact of digital services," 2021, *NegaOctet,* https://negaoctet.org/en/home/#Negaoctet
[231] "A collection of articles we're reading that are shaping the understanding of the energy and carbon impacts of digital value chain emissions," 2023, *DIMPACT,* https://dimpact.org/resources
[232] Frick, Tim, "Understanding Digital Life Cycle Assessments (DLCAs)," 2023, *Mightybytes,* https://www.mightybytes.com/blog/digital-life-cycle-assessment/
[233] Schulze, Max, "Creating a digital environmental footprint: a Lifecycle Assessment approach (EN) ," 2022, *Bits & Baume,* https://media.ccc.de/v/bitsundbaeume-20667-creating-a-digital-environmental-footprint-a-life-cycle-assessment-approach-en-
[234] "Why We Don't Report Website Carbon Emissions," October 2023, *DebugBear,* https://www.debugbear.com/blog/website-carbon-emissions
[235] Van der Ryn, Sim and Cowan, Stuart, "Ecological Design," 1996 and 2013, *Island Press,* https://www.google.ca/books/edition/Ecological_Design_Tenth_Anniversary_Edit/PEBs_eoIOdgC?hl=en&gbpv=0

SOURCE AND PROCURE ICT SUSTAINABLY

While technology designers and developers can implement eco-design in their products and services, technology buyers and technology adopters are in a unique position to incentivize sustainability improvements across the supply chain (that said, because of how horizontally integrated ICT product and service providers are, many technology designers and developers are also technology adopters). Through their technology purchases and interactions with ICT firms, technology buyers and technology adopters send designers and developers important signals about the types of products and services they want to see in the marketplace. Unfortunately, technology companies report rarely, if ever, being asked by Canadian customers about the environmental sustainability of their ICT products and services, giving them little incentive to prioritize sustainable ICT. Likewise, though some governments are in the process of developing a new approach, most governments and MASH-sector (Municipalities, Academic Institutions, Schools and Hospitals) organizations do not include sustainable ICT requirements in their RFIs, RFQs, RFPs, or supplier contracts.

One of the ways technology adopters can respond to this challenge is by engaging in green technology adoption and procurement. In this section, we introduce the core principles of sustainable procurement, discuss how to adapt sustainable procurement to the context of ICT, and review two resources procurement teams can rely on when engaging in sustainable procurement for ICT, ecolabels, and international standards.

Provide Training on Sustainable Procurement

Sustainable procurement is a standardized approach to product and service procurement that considers environmental sustainability criteria in addition to things like cost, timeline, and supplier diversity. For example, organizations can engage in green procurement by incorporating standardized environmental sustainability language and criteria into RFIs, RFPs, RFQs, contracts, and supplier agreements. This lets ICT firms know that environmental sustainability will be a deciding factor in who will win bids and contracts and sets organizations up to award contracts based on environmental sustainability criteria. Adopting standardized criteria also enables organizations to maximize their impact on sustainable ICT: while some organizations will be too small to incentivize sustainability improvements from suppliers on their own, many organizations adopting the same language and criteria can send a strong message to ICT designers and developers.

Sustainable procurement is an important part of an organization's sustainability strategy because the environmental impacts that occur in an organization's supply chain tend to be much higher than those that occur in their own internal operations. For example, a GHG reporting firm, CDP, estimates that an organization's supply chain emissions are, on average, 11.4 times higher than their operational emissions.[236] Similarly, Niklas Sundberg reports that approximately 78% of GHG emissions in the IT and software industry are scope 3 emissions, in other words, indirect emissions from other parts of the value chain.[237] If organizations do not include sustainable procurement in their sustainability strategies, they will neglect to address a large portion of their total environmental impact. Unfortunately, many procurement professionals are never taught how to consider the environmental impact of their technology purchases or how to distinguish sustainable from unsustainable suppliers. In response to a survey conducted by ICTC, for example, more than a quarter (27%) of ICT professionals indicated that they lacked the required knowledge, skills, and expertise to implement sustainable ICT practices.

Organizations can overcome this challenge by incorporating sustainable procurement into their environmental sustainability strategies and by providing their employees with sustainable procurement training. Sustainable procurement training can focus on a broad range of topics, such as the principles and purpose of sustainable procurement, how to include sustainability language and criteria in RFIs, RFQs, RFPs, and supplier contracts, how to request and manage environmental impact data from suppliers, and how to use tools like ecolabels and international standards to engage in sustainable procurement. Fortunately, sustainable procurement is a well-developed field with a variety of available training resources:

ECO CANADA'S SUSTAINABLE PROCUREMENT: PURCHASING THE FUTURE WE WANT is an online course that provides organizations with practical advice on how to make more sustainable purchasing decisions. The course teaches organizations how to adopt sustainable procurement and how to break down organizational silos between sustainability and purchasing.[238]

ECOVADIS' SUSTAINABLE PROCUREMENT GLOSSARY is an online glossary of terms and concepts related to sustainable procurement.[239]

SUSTAINABLE PROCUREMENT ESSENTIALS is an online course designed for any type of professional who is interested in building out their organization's sustainable procurement capacity but does not know where to begin. The course teaches a high-level overview of sustainable procurement practices and is suitable for organizations of all sizes.[240]

[236] "Global Supply Chain Report 2020," 2021, *CDP,* https://cdn.cdp.net/cdp-production/cms/reports/documents/000/005/554/original/CDP_SC_Report_2020.pdf?1614160765
[237] "What are scope 3 emissions?," 2023, *GHG Protocol,* https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf
[238] "Sustainable Procurement: Purchasing the Future We Want Practical Steps to Help Your Organization Make More Sustainable Purchasing Decisions," 2023, *Eco Canada,* https://eco.ca/online-learning/sustainable-procurement-purchasing-the-future-we-want/
[239] "Sustainable Procurement Glossary," 2023, *EcoVadis,* https://ecovadis.com/glossary/
[240] "Online Training Courses," 2023, *Sustainable Procurement Institute,* https://buyingsustainably.com/courses/

SUSTAINABLE PROCUREMENT FOR PROFESSIONALS is an online course designed specifically for purchasing professionals. The course provides a comprehensive overview of sustainable procurement, including green and ethical procurement. It teaches professionals how to implement a broad range of tools and techniques for sustainable procurement and enables professionals to improve the environmental impact of their purchasing decisions.[241]

SUSTAINABILITY ADVANTAGE'S SUSTAINABLE PROCUREMENT TOOLKIT is a free online toolkit that organizations can use to rapidly integrate sustainable procurement elements into their existing procurement processes. The toolkit includes a sustainable procurement bid appraisal template, a supplier assessment tool, a product specifications checklist, sample terms and conditions, and a total cost of ownership tool.[242]

Adapt Sustainable Procurement to ICT

Adapting broad sustainable procurement practices to ICT infrastructure, products, and services is no easy task. The ICT supply chain has several unique characteristics that make sustainable ICT procurement very different from that of other industries. The ICT supply chain is comprised of a complex system of international vendors, suppliers, service providers, and contractors.[243] It is extremely complex, containing a large number of steps and companies from design to manufacturing, assembly, and fulfillment.[244] Many of the brand name companies that organizations are familiar with are only directly responsible for things like production design, selecting preferred suppliers, and interacting with customers, while the majority of manufacturing and procurement activities are outsourced to other companies.[245] All of these factors make the ICT supply chain more opaque and less transparent than other, shorter and regionally-located supply chains. Additionally, as was noted by interviewees in this study, the complexity of the ICT supply chain makes it difficult for brand name companies to readily implement changes to their products and services: due to how much of the ICT supply chain is outsourced, it can take brand name companies up to three years to implement changes to their production designs.

For Canadian organizations, the ICT supply chain is also geographically very distant. North America lacks domestic production capacity for many ICT products and components, and because of this, it relies heavily on products and suppliers from other countries.[246] For example, a high percentage of printed circuit boards and displays are produced in China.[247]

[241] "Online Training Courses," 2023, *Sustainable Procurement Institute,* https://buyingsustainably.com/courses/
[242] "Sustainable Procurement," 2023, *Sustainability Advantage,* https://sustainabilityadvantage.com/sp/toolkit/
[243] "Information and Communications Technology Supply Chain Risk Management," 2023, *Cybersecurity and Infrastructure Security Agency,* https://www.cisa.gov/information-and-communications-technology-supply-chain-risk-management
[244] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf
[245] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf
[246] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf
[247] "Assessment of the Critical Supply Chains Supporting the US ICT Industry," February 2022, *US Department of Commerce and US Department of Homeland Security,"* https://www.commerce.gov/sites/default/files/2022-02/Assessment-Critical-Supply-Chains-Supporting-US-ICT-Industry.pdf

As a result of these unique characteristics, it is important for organizations to not just adopt sustainable procurement practices but also tailor these practices to the context of ICT. Fortunately, there are a variety of resources that organizations can rely on when doing so:

GREEN ECONOMY CANADA AND HP'S SELF-ASSESSMENT TOOL is a free online tool that helps organizations assess their approach to green information technology procurement and identify areas for improvement.[248]

GREEN ECONOMY CANADA AND HP'S RFX GUIDE is a free online guide that helps organizations develop specific criteria to include in their bid documents, including RFPs, RFIs, and RFQs. The RFX guide was designed specifically for the ICT sector, so its criteria are relevant to ICT products and services suppliers.[249]

CIRCULAR AND SUSTAINABLE PUBLIC PROCUREMENT FOR ICTS is a free online course to help organizations adopt sustainable procurement for ICT. The course is designed for public sector procurement planners and professionals. It teaches participants how to "align ICT circularity and sustainability goals with existing or newly created policies," "establish measurement indicators and track progress," "create a publicly available circular and sustainable procurement policy," "allow adequate time and resources for procurement planning when developing calls for tender," "engage with ICT suppliers on circularity and sustainability when developing policy and strategy and as part of a procurement process," "add sustainability to procurement processes and guidance to reflect circular and sustainable aims and contract conditions," and "use international standards, including ITU recommendations, for direction on how to implement and enforce circular and sustainable ICT procurement and management."[250]

ITU-T L. SUPPLEMENT 20: GREEN PUBLIC ICT PROCUREMENT is an international standard document that helps organizations improve their approach to green ICT goods and services procurement. The standard was developed for public organizations but can be adapted to other types of organizations if needed.[251]

ITU-T L.1300: BEST PRACTICES FOR GREEN DATA CENTRES AND ITU-T L.1304: PROCUREMENT CRITERIA FOR SUSTAINABLE DATA CENTRES are two international standards that help organizations identify procurement criteria for sustainable data centres.[252]

[248] "Sustainable IT Procurement," 2023, *Green Economy Canada,* https://greeneconomy.ca/sustainable-it-procurement/
[249] "Sustainable IT Procurement," 2023, *Green Economy Canada,* https://greeneconomy.ca/sustainable-it-procurement/
[250] "Circular and Sustainable Public Procurement for ICTs," 2023, *International Telecommunications Union Academy,* https://academy.itu.int/training-courses/full-catalogue/circular-and-sustainable-public-procurement-icts
[251] "ITU Recommendation Supplement L.Sup20: Green public ICT procurement," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.Sup20-201510-I/en
[252] "ITU Recommendation L.1300," 2023, International Telecommunications Union, https://www.itu.int/rec/T-REC-L.1300; "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304

Leverage Environmental Labels for Sustainable ICT Procurement

Technology buyers and adopters can implement sustainable procurement using environmental labels. Environmental labels, or "ecolabels," are specialized marks that companies can place on their products and services to distinguish them as environmentally sustainable. In order to use an ecolabel on their products and services, companies must first adhere to the environmental criteria specified by the ecolabel's manager and gain the ecolabel manager's approval. Importantly, not all ecolabels are made equal: ISO 14024 is an international standard that designates the highest-quality ecolabels, known as "Type I environmental labels."[253] In order to become recognized as a Type I environmental label, the ecolabel manager must follow specific best practices, including when defining their ecolabel's product categories, determining what environmental criteria they will use, and assessing companies' compliance.[254]

Using ecolabels provides a number of benefits to technology adopters. For one, the environmental criteria that ecolabels rely on are developed in collaboration with industry, meaning they are likely to be achievable for ICT brands and likely to be aligned with business realities. As was discussed in the previous section, because of how complex the ICT supply chain is, it can take brands several years to implement design changes. The environmental criteria that ecolabels rely on are also reviewed on a regular basis, meaning they are likely to incorporate up-to-date research and best practices. In terms of reliability, many ecolabel managers will independently verify whether companies comply with their environmental criteria. This provides an easy way for technology buyers and adopters to verify whether companies are actually implementing sustainable ICT practices in the real world. Finally, many ecolabels are free for technology buyers and adopters to use. The majority of ecolabels for ICT products and services are free for technology buyers and adopters, and instead charge fees to vendors for their use.

Technology adopters have various ecolabels that they can choose from depending on the type of product or service they provide. Two examples of Type I ecolabels that were developed for the ICT sector are EPEAT and TCO Certified.[255] EPEAT and TCO Certified apply to a range of electronic and technology products, including desktop and personal computers, computer displays, notebooks, tablets, mobile phones, servers, headsets, imaging equipment, projectors, photovoltaic modules and inverters, and televisions. ECOLOGO is another Type I ecolabel that applies to a wide variety of products but also includes electronics and information and communications technologies.[256] Finally, ENERGY STAR is an ecolabel that helps identify energy-efficient appliances and equipment.[257] For more information about the environmental criteria that ICT ecolabels use, refer to the previous section on Leveraging Environmental Labels for Eco-Design.

[253] "ISO 14024:2018 Environmental labels and declarations Type I environmental labelling Principles and procedures," 2023, *ISO,* https://www.iso.org/standard/72458.html
[254] "ISO 14024:2018 Environmental labels and declarations Type I environmental labelling Principles and procedures," 2023, *ISO,* https://www.iso.org/standard/72458.html
[255] "EPEAT," 2023, Green Electronics Council dba Global Electronics Council, https://www.epeat.net/; TCO Certified," 2023, *TCO Development,* https://tcocertified.com/
[256] "ECOLOGO Certification," 2023, *UL LLC.,* https://www.ul.com/services/ecologo-certification
[257] "ENERGY STAR," 2023, *ENERGY STAR* https://www.energystar.gov/

Leverage Industry Standards for Sustainable Procurement

Industry standards are another way for ICT buyers and adopters to implement eco-design. Industry standards are "voluntary agreements that establish requirements for products, practices, or operations in a given field."[258] They can be developed for a wide variety of reasons—to facilitate interoperability between different types of ICT hardware and software, to facilitate the use of best practices for privacy and security, or to ensure products and services meet accessibility requirements. In the case of sustainable ICT, the purpose of industry standards is to facilitate the use of best practices for environmentally sustainable technology design. Organizations can use sustainable ICT standards for sustainable procurement by adhering to their product and service specifications to the guidance provided by standards for sustainable ICT.

ICT buyers and adopters have a number of options when it comes to industry standards for sustainable ICT. Some examples are ECMA 341, which provides guidance on environmental design considerations for ICT and CE products; ITU-T L.1060, which provides general principles for the green supply chain management of the ICT manufacturing industry; ITU-T L.1304, which provides guidance on the use of sustainability criteria for data centre procurement; ITU-T L.1300, which provides guidance on best practices for green data centres; and WSG 1.0, which provides guidance on how to make websites and digital products sustainable.[259] With so many sustainable ICT standards available, organizations like the International Federation of Global and Green Information Communications Technology have also developed online courses to help technology designers and developers learn about and navigate sustainable ICT standards.[260]

Of the more than 150 sustainable ICT standards available, approximately half focus on energy efficiency, a quarter focus on reducing material waste, a fifth focus on reducing GHG emissions, a tenth focus on reducing hazardous chemical use and reducing air pollution, and a handful focus on reducing freshwater use and reducing land system change. For more specific information about the guidance provided by sustainable ICT standards, refer to the previous section on Leveraging Industry Standards for Eco-Design.

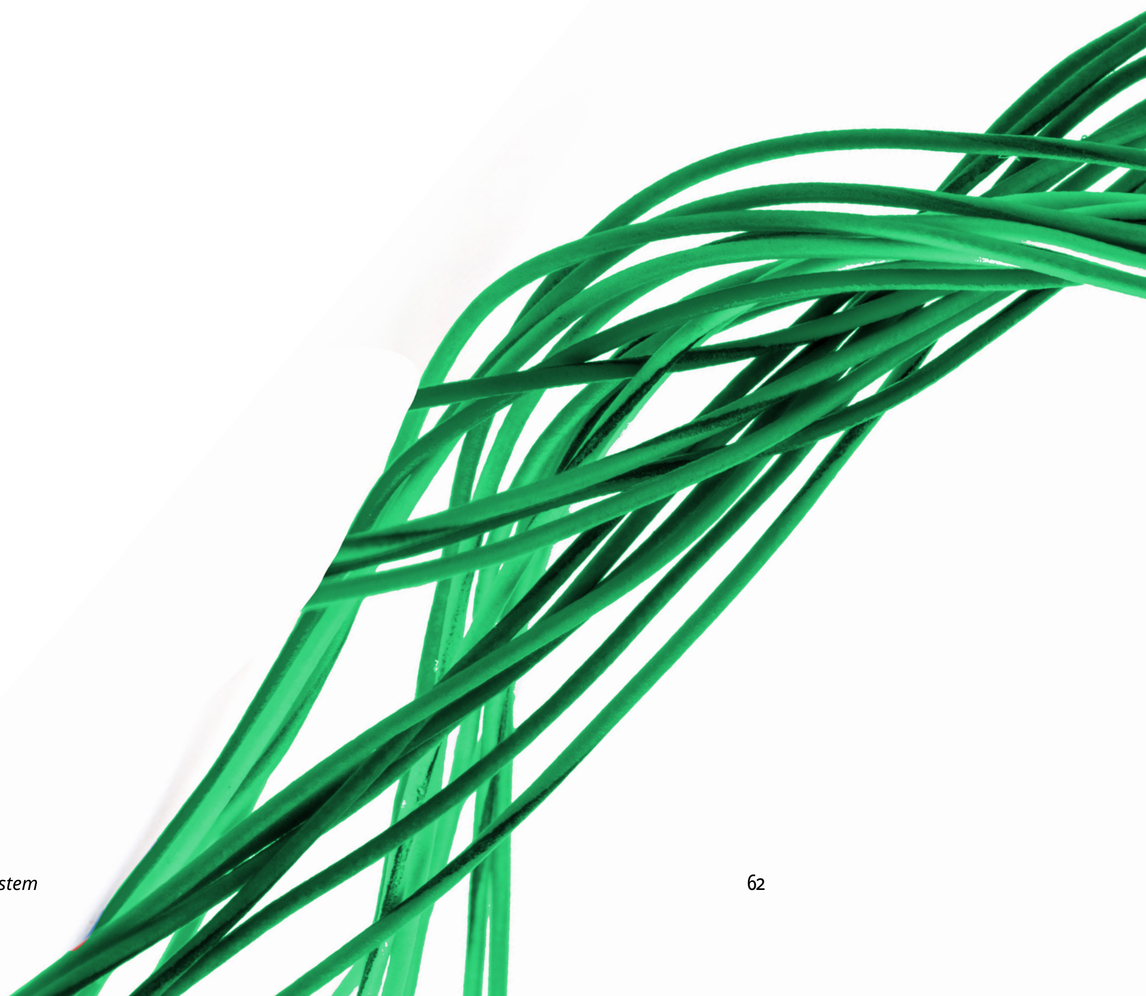
[258] "Standards," 2023, *PennState University Libraries,* https://guides.libraries.psu.edu/c.php?

[259] "ITU Recommendation L.1304," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1304; "ITU Recommendation L.1300," 2023, *International Telecommunications Union,* https://www.itu.int/rec/T-REC-L.1300; "ECMA – 341: Environmental Design Considerations for ICT & CE Products," 2010, *ECMA International,* https://ecma-international.org/wp-content/uploads/ECMA-341_4th_edition_december_2010.pdf; "Web Sustainability Guidelines (WSG) 1.0," 2023, *W3C Community Group Draft Report,* https://w3c.github.io/sustyweb/

[260] "The "Green IT Professional" Certification," 2023, *IFGICT,* https://ifgict.org/green-it-professional-gitp/

Conclusion

Technology designers and developers rely on their clients and customers to signal what types of products and services they want to see in the marketplace. Unfortunately, technology companies report rarely, if ever, being asked by Canadian customers about the environmental sustainability of their ICT products and services. One of the ways technology adopters can respond to this challenge is by using sustainable ICT procurement practices to incentivize sustainability improvements across the supply chain. In order to source and procure ICT sustainably, organizations should include sustainable procurement in their organization-wide sustainability strategies, provide their employees with sustainable procurement training, adapt sustainable procurement practices to the context of ICT, and leverage tools like ecolabels and industry standards in their procurement practices.



Conclusion

Amid climate change, more frequent and extreme weather events, resource scarcity, and other environmental challenges, reducing the environmental impact of the global economy is a key priority. The urgent need to address climate change and environmental harm is putting environmental criteria at the forefront of economic and financial decisions and is creating new criteria for firm and industry success. While high-emitting and material-intensive sectors will be at the forefront of these changes, all sectors will be impacted, including ICT, which, despite being perceived as having minimal environmental impacts, contributes extensively to environmental harm.

ICT products and services are poised for growth, threatening to increase the environmental impact of the ICT sector. As the ICT sector expands, it will be important for ICT designers, developers, and adopters to become more aware of the environmental impact of their ICT operations, infrastructure, products and services, and adopt strategies for sustainable ICT. This report introduced four strategies that organizations can adopt to limit the environmental impact of their ICT, including developing an organization-wide environmental sustainability strategy, adopting best practices for sustainable ICT infrastructure, building environmentally sustainable products and services, and sourcing and procuring ICT sustainably.

In addition to implementing internal strategies for the ICT sector to minimize its environmental impact, ICT companies, product and service designers, and adopters will need to work together. As noted in a recent policy brief by ICTC, sector-wide challenges are impacting the ability of organizations to adopt sustainable ICT strategies, including a lack of awareness among ICT professionals about the environmental impacts of ICT, a lack of the organizational capacity, knowledge, and skills needed to implement sustainable ICT, and a lack of data and reporting standards for sustainable ICT. Beyond individual organizations adopting sustainable ICT strategies and ensuring their strategies align with standardized practices and reporting frameworks, it will be important for actors from across the ICT sector to work together to increase awareness about the environmental impacts of ICT, engage in education and capacity building, and importantly, adopt standardized methods to track and share environmental data.

Research Methodology

This report is the culmination of a series of research activities undertaken by ICTC over the past two years, including three knowledge syntheses, a series of key informant interviews, an industry survey, and a policy roundtable. These research activities are described in more detail in the sections below.

KNOWLEDGE SYNTHESES

ICTC worked with external vendors to conduct three knowledge syntheses related to sustainable ICT: one about the environmental impacts of ICT, one about global policy responses to sustainable ICT, and one about standards and best practices for sustainable ICT. The specific methodology for each knowledge synthesis is described in more detail below.

Knowledge Synthesis of the Environmental Impacts of ICT

ICTC worked with an MA student from Brock University's Master of Sustainability program to conduct a knowledge synthesis of the environmental impacts of ICT. ICTC and the MA student conducted a comprehensive review of the relevant literature, identified themes across the literature, and then collated this information within a report. In terms of methodology, ICTC and the student conducted literature searches in various databases, gathered relevant articles, screened the titles and abstracts and then the full texts against predetermined eligibility criteria, coded the eligible articles, extracted relevant data, and then thematically analyzed and collated the data.

To be included in the knowledge synthesis, the publications needed to discuss the negative environmental, ecological, or climatic impacts of the ICT sector. They also needed to be written in English, published after January 1, 2022, and focused primarily on OECD countries unless an exception was required to account for the full ICT supply chain. In total, the databases provided 919 articles, of which 103 articles were duplicates, yielding a new total of 816. Of these, 111 articles made it through the screening stages to be included in the final knowledge synthesis.

Knowledge Synthesis of Global Policy Responses to Sustainable ICT

ICTC contracted a team of private consultants and academics from the Universities of British Columbia and Waterloo to conduct a knowledge synthesis of global policy responses to sustainable ICT. To generate a long list of relevant resources, the research team used an exhaustive search strategy that sought to identify all the literature on the topic rather than only a representative sample. They took an iterative approach so that they could assess and amend their keywords and database list as they evaluated the long list of resources.

The articles included publications by the public sector and arm's length organizations at the national, subnational, and supranational levels, as well as large tech companies' environmental and sustainability plans. To be included in the knowledge synthesis, the articles needed to discuss policy and best practices and/or provide solutions to ICT's environmental impact. The articles also needed to be published since 2010 and pertain to Canada, the United States, or Europe. An initial 190 documents were identified, and 41 were moved forward to the final coding stage for inclusion in the knowledge synthesis. The eligible documents were coded, relevant data and information were extracted, and then a summary report was prepared.

Knowledge Synthesis of Standards for Sustainable ICT

ICT contracted a team of not-for-profit consultants and academics from Laval University and the University of Ottawa to conduct a knowledge synthesis of global standards for sustainable ICT. The team conducted a search of relevant databases for international standards using a list of key terms, including terms like "sustainable," "ICT," "IT," "carbon emissions," "associated with ICT or IT," "IT standards," "green IT," and more. The initial search yielded 211 relevant documents, which, following screening, was reduced to 157. To be included in the knowledge synthesis and list of relevant documents, the document had to be a standard or best practice, address one or more of the environmental impacts of ICT (e.g., e-waste, energy efficiency, energy consumption, water consumption, GHG emissions, air, water, or soil pollution, etc.), or discuss the circular economy, sustainable management, lifecycle assessment, of environmental footprint assessment in the contact of ICT. Documents published before 2015 were excluded, as were documents about the use of ICT to achieve sustainability in other sectors. The eligible documents were coded, relevant data and information were extracted, and then a summary report was prepared.

KEY INFORMANT INTERVIEWS

ICTC conducted a series of key informant interviews with ICT buyers, ICT designers and developers, sustainable ICT experts, and ICT sustainability certification managers. In total, ICTC conducted 33 interviews with individuals from these stakeholder groups. This included six technology buyers, ten sustainable ICT experts, 24 ICT designers and developers, and two sustainable ICT certification managers (numbers do not sum to 33 as interviews could fall into more than one category). The interviews were semi-structured and lasted approximately 30 minutes to one hour, depending on the interviewee's level and scope of expertise. The interviews were recorded and transcribed and then coded and thematically analyzed using NVIVO.

SURVEY OF CANADIAN ORGANIZATIONS

In May 2023, ICTC conducted a survey of 500 professionals from across Canada who, in their current role, are responsible for ICT procurement, ICT operations management, or ICT product and service development. The first of its kind in Canada, the survey benchmarked the state of sustainability in Canada's ICT ecosystem, including whether organizations are thinking about sustainability from an ICT perspective, how organizations are approaching sustainable ICT, and what challenges organizations face in advancing sustainable ICT.

SUSTAINABLE ICT ROUNDTABLE

In April 2023, ICTC partnered with the Digital Governance Council to hold a policy roundtable on advancing sustainable ICT in Canada. Roundtable participants discussed how they measure the environmental impacts of ICT, the current state of ICT sustainability in Canada's ICT sector and progress to date, ongoing challenges to accomplishing sustainable ICT, and potential responses to these challenges, such as standards and best practices for sustainable ICT development and procurement. The policy roundtable engaged 22 participants from across the ICT sector, including from public, private, and industry organizations. The policy roundtable was conducted virtually via Zoom, and participants were guided through collaborative exercises using a variety of online facilitation tools.