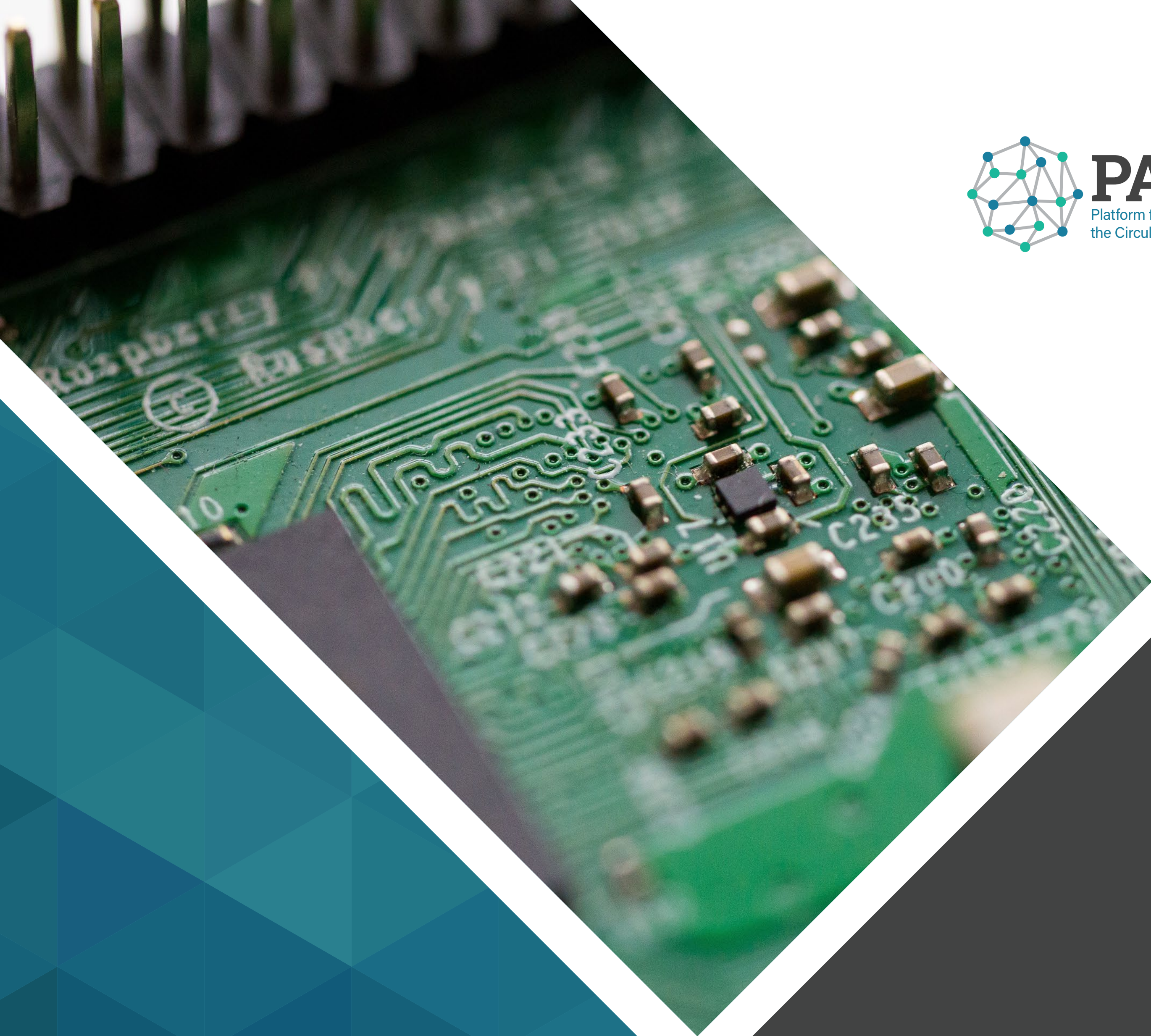


PACE
Platform for Accelerating the Circular Economy

Circular Economy Action Agenda

ELECTRONICS

In partnership with

accenture

CONTENTS

WHO WE ARE

PACE is a global community of leaders working together to accelerate the transition to a circular economy. We bring leaders together from across business, government and civil society to develop a collective agenda and drive ambitious action.

ACKNOWLEDGEMENTS

This is a publication of Platform for Accelerating the Circular Economy (PACE), developed in partnership with Accenture. The report was drafted by Franziska Zengerle (Accenture), Benoit Prunel (Accenture), Andrés Oliva Lozano (PACE Secretariat) and Ke Wang (PACE Secretariat), with support from Beth Hearn, Clara von der Ropp, and Rachel Tung of the PACE Secretariat.

The Circular Economy Action Agenda for Electronics has drawn from the insights developed by Circular Electronics Partnership (CEP), United Nations E-Waste Coalition, and discussions with the following organizations and experts:

Apple | Chris Busch, Lauren Casey, Susannah Calvin, Rob Guzzo

BT | Julia Denham

CalRecycle | Matt Sheehan, Teresa Bui, Matt Henigan, Zoe Heller

Chatham House | Patrick Schroeder

Chile Ministry of Environment | Joost Meijer, Claudia Guerrero

Circle Economy | Tamara Veldboer, Michelle Steenmeijer, Noah Baars

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH | Daniel Hinchliffe, Alexander Batteiger Daniel Hinchliffe, Alexander Batteiger

DSM | Imco Goudswaard, Kimberley Chan

Finnish Innovation Fund Sitra | Lotta Toivonen, Nani Pajunen

GEM | Yuping Zhang, Dong Deng

Ghana Ministry of Environment, Science, Technology and Innovation | Oliver Boachie

Global Electronics Council | Nancy Gillis, Shela Gobertina von Trapp

Golisano Institute for Sustainability;

REMADE Institute;

Member of International Resource Panel (UNEP) | Nabil Nasr

Huawei | Paolo Gemma

Institute for Global Environmental Strategies (IGES) | Chika Aoki-Suzuki, Toru Nishiyama

International Labour Organization (ILO) | Casper Edmonds, Shreya Ashu Goel, Hitomi Nakagome, Lene Olsen

International Telecommunication Union (ITU) | Garam Bel, Mijke Hertoghs, Reyna Ubeda

IVL Swedish Environmental Research Institute | Alexandra Wu

Life Cycle Initiative; ADDERE R&T | Claudia A. Peña

Philips | Harald Tepper, Eelco Smit, Sophie Thornander

Responsible Business Alliance (RBA) | Daniel Reid

Secretariat of the Basel, Rotterdam and Stockholm Conventions | Tatiana Terekhova, Carla Valle-Klann

Netherlands Organisation for Applied Scientific Research (TNO) | Elmer Rietveld, Ton Bastein

German Environment Agency (UBA) | Kristine Sperlich

United Nations Environment Programme (UNEP) | Claire Marion Thiebault, Ran Xie, Feng Wang, Amelie Ritscher, Sandra Averous-Monnery

United Nations Human Settlement Programme (UN-Habitat) | Marco Kamiya, Emilie Charlotte Claudie Martin, Tania Pei Yee Lim

United Nations Industrial Development Organization (UNIDO) | Alfredo Cueva, Keira Ives-Keeler

United Nations University (UNU); United Nations Institute for Training and Research (UNITAR) | Ruediger Kuehr

WEEE Nederlands | Reint Sekhuis

World Health Organization (WHO) | Marie-Noel Brune Drisse

In addition, we recognize further contributions to the Action Agenda reports from:

Kevin Moss (WRI), Wesley Spindler (Accenture), Quentin Drewell, Antonia Gawel (World Economic Forum), James Pennington (World Economic Forum), Neelam Melwani (Government of the Netherlands), Dorine Wytema (Government of the Netherlands), Jocelyn Blériot (Ellen MacArthur Foundation), Elisa Tonda (UNEP), Guillermo Gonzalez Caballero (Government of Chile), Takashi Ohtani (The University of Tokyo), Leah Bunce Karrer (GEF), Brendan Edgerton (WBCSD), Carolien van Brunshot (WBCSD), Jannica Pitkanen (United Nations Environment Management Group), Joshua Curtis (Accenture), Mika Sulkinoja (Sitra), Maria Hughes (Sitra), Vira Khoroshavina (IRP), Laura Malaguzzi Valeri (WRI), Edwina Hughes (WRI), Helen Ding (WRI), Romain Warnault (WRI), Shannon Collins (WRI), Stephanie Ross (Freelance Copyeditor) and the PACE Secretariat (Krista Kruft, Heyd Más, Lotte Holvast, Fruzsina Nagy, Lisa Walen, and Laura Ombelet).

This report has been produced by a team from the PACE Secretariat and Accenture. While the experts acknowledged in this section have provided significant input to the development of this report, the views and opinions expressed in this report are synthesized by the authors based on literature and consultations, and therefore do not necessarily reflect the official positions of every organization, company and government involved/cited. As each organization has unique circumstances, recommendations in this report are not intended to replace professional advice tailored to individual organizations.

PACE would like to thank all its donors for sharing our commitment to accelerate towards a global economic system that simultaneously enables human and environmental wellbeing.

IN SUPPORT OF THE CIRCULAR ECONOMY ACTION AGENDA

INGER ANDERSEN | Executive Director, UN Environment Programme

"Scaling up circularity and sustainable consumption and production is essential to address the three planetary crises we are facing: the climate crisis, the biodiversity and nature crisis, and pollution and waste crisis. The calls-to-action should inspire and redirect the efforts of government, business and finance, and consumers, because at the end of the day, each and every one of us has the power and responsibility to contribute to the transition."

TIM BENTON | Research Director, Emerging Risks, and Director, Energy, Environment and Resources Programme, Chatham House

"An inclusive circular economy that promotes sustainability and decent work will help countries to build prosperous economies and just societies. The economic recovery from the COVID pandemic is an opportunity for governments to collaborate and accelerate this shift from linear to circular internationally."

MARTIJN LOPES CARDOZO | CEO, Circle Economy

"The Circular Economy Action Agenda delivers the necessary insights and a strong narrative for action within four areas where urgent change is needed. By enabling cross-sectoral partnerships to tackle these challenges, PACE is proving itself as a conductive change agent to help close the global circularity gap. We look forward to collaborating and delivering results within these key areas together".

FRANS VAN HOUTEN | CEO, Royal Philips

"Transitioning to a circular economy requires all of us to team up and commit to doing things fundamentally different. The PACE Action Agenda will help guide and drive circular ways of working across the board, changing how we create value without devastating environmental impact. I call on all leaders to join PACE and commit to adopt climate actions and prioritize circularity."

LISA JACKSON | VP Environment, Policy and Social Initiatives, Apple

"Meeting our global circularity goals requires dedicated collaboration and partnership. PACE's electronics action agenda highlights important perspectives on shared challenges, and provides a foundation to drive collaboration. In bringing together governments, NGOs and the business sector, PACE has a unique opportunity to break through challenges which no organization can solve alone. Apple is committed to continued partnership in these critical efforts."

PETER LACY | Chief Responsibility Officer and Global Sustainability Services Lead, Accenture

"The circular economy offers an opportunity to unlock value and decouple growth from the use of scarce and harmful resources. This Action Agenda lays a foundation for the collaboration and innovation that is necessary to make production and consumption more sustainable for people and our planet. Now is the time to embrace end-to-end transformations that can create value while ensuring a more sustainable future."

DAME ELLEN MACARTHUR | Founder, Ellen MacArthur Foundation

"The circular economy is a solution framework that offers better growth while addressing the most pressing global challenges. The calls-to-action help reinforce the need for transformation of our most iconically linear value chains, towards an economy that eliminates waste, preserves the value of resources, and helps regenerate natural systems."

LLORENÇ MILÀ I CANALS | Head of Secretariat, Life Cycle Initiative (UNEP)

"The key for a transition to sustainable consumption and production patterns is anchored in the value chains – where circularity strategies are supported by strong life cycle thinking and assessment. We are proud to work with PACE partners in ensuring the calls-to-action address the key hotspots along these value chains' life cycle, to ensure we shift the needle on the planetary crises we face."

JANEZ POTOČNIK | Co-chair, International Resource Panel (UNEP)

"It was a pleasure to contribute to the development of the Action Agenda with our expertise in resource management issues. We are pleased with the clarity to which the reports have contributed. Now is the moment for stakeholders across all sectors to come together and pick up the calls-to-action."

STEVE SCHMIDA | Co-founder and Chief Innovation Officer, Resonance

"If we are to achieve the SDGs, circularity must be embedded into the very fabric of how industries and economies operate. The Circular Economy Action Agenda lays out a clear vision for how leaders from across business, government and civil society can partner together to drive sustainable, equitable action."

CAROLINA SCHMIDT | Minister of Environment, Chile

"We already know how the circular economy can make a key contribution to mitigate climate emissions. Now it's time to act. PACE's Action Agenda condenses and highlights the most urgent and effective pathways to unleash the transformation to a circular economy at a global level. Policy makers, scientists, businesses and citizens everywhere should put this powerful agenda into practice — today."

ANDREW STEER | President and CEO, World Resources Institute

"Circularity is the shape of the future. Shifting from the destructive take, make, waste model of the past is crucial if we are to achieve the SDGs. The new Circular Economy Action Agenda, which brings together insights from scientists, government officials, and business executives, presents a bold and clear way forward to a more sustainable approach that will benefit people and the planet."

MARIE FOSSUM STRANNEGÅRD | CEO, IVL Swedish Environmental Research Institute

"The Action Agenda is crucial reading for anyone working to improve social and environmental wellbeing through circular economy. We were glad to be part of the process to develop the reports and to be able to contribute with our decades of experience in translating environmental science into improvements in the society."

STIENTJE VAN VELDHOVEN | Minister for the Environment, The Netherlands

"The circular economy is our secret weapon for achieving our climate and sustainable development goals. PACE's Action Agenda demonstrates the need for a fundamental shift in the way we produce and consume. It contains concrete examples of a new economic reality taking shape. Let's use the Agenda to upscale cross-regional collaboration, build cross-sectoral partnerships and continue to build a circular world."

DOMINIC WAUGHRAY | Managing Director, Centre for Global Public Goods, World Economic Forum

"The twin crises of the pandemic and climate have underscored the need for more sustainable consumption and production. We must build on this momentum to forge new collaborations with policy makers, business leaders and consumers to ensure that resources are maximized, value chains are transformed and the circular transition can become a reality. The time is now."

MARINKE WIJNGAARD | Managing Director Circular Economy & Environment, TNO

"TNO is happy to be part of the PACE scientific community. We believe that through an integrated assessment of possible scenarios and through technological innovation we can find the right answer to every environmental question and make an accelerated transition to a circular economy feasible."

FOREWORD

We call on businesses, governments, and civil society leaders around the world to join us in raising the level of ambition to create a circular economy. Investing in a circular economy will be crucial to helping us realize the social, environmental, and economic benefits of the 2030 Agenda and the Paris Agreement, as well as to build a sustainable economic recovery from COVID-19.

This year over 200 circular economy experts from 100 businesses, governments and civil society organizations joined hands through PACE to develop the Circular Economy Action Agenda. The calls-to-action in the Agenda provide clear priorities for leaders around the world to join us in solving critical issues and taking advantage of open innovation opportunities.

Circular Action Means Impact. Embedding circular principles and goals across industries and governments' priorities will be crucial to reaching our 2050 net zero commitments. Changing the way we make and use products can contribute to addressing 45% of global greenhouse gas emissions, making a critical contribution to mitigating the impending climate crisis. Along the way, the widescale adoption of circular business models presents a US$4.5 trillion economic opportunity.

Circular Action is Urgent. Our current economic system is based on linear principles of extracting natural resources, using them up, and creating huge volumes of waste. Our use of resources has tripled since 1970, and could double again by 2060 if we continue business as usual. Despite advances in technology, the growth rate in material consumption continues to increase faster than our population growth, with many social and environmental impacts resulting from inequities in consumption and production.

Not only is this linear model unsustainable, the economic impacts of COVID-19 have shown how vulnerable we are to economic shocks resulting from any disruption in the current flow of resources.

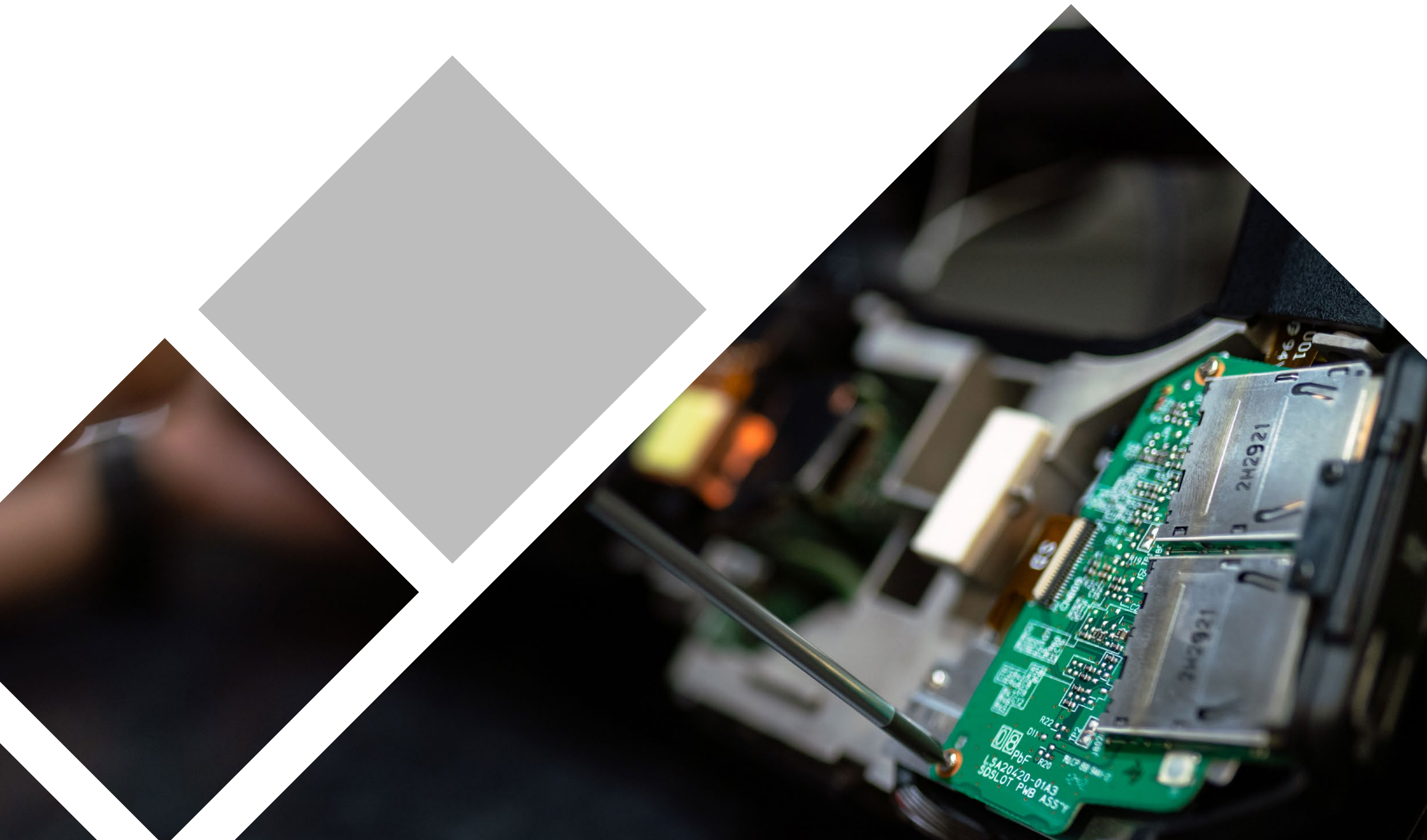
There is another way. By working towards a circular economy we can transition to a system that is designed to prevent waste and pollution, keep products and materials in use, and regenerate natural systems—leading to a more resilient economy.

Circular Action is Clear. While we have experienced an increase in interest in the circular economy, investments and scale are not happening fast enough. We believe that more alignment among leaders is required to show the way forward. These reports set out clear priorities for action in five critical focus areas—plastics, electronics, textiles, food, and capital equipment—providing important lessons that can be applied elsewhere.

There is much that can be done. Governments can set policy, companies can adapt their business models, the finance sector can invest, researchers can provide the scientific backing, and we can all do our part as individuals. But the biggest challenges mandate that we work together. That is why we join hands at PACE: creating the space for collaboration across sectors so that we can identify new solutions and scale up what works.

Join us as we take bold steps forward to create the better world we know is possible.

David B. McGinty
Global Director, PACE



Executive Summary

The Circular Economy Action Agenda has been designed to accelerate the transition to a circular economy—and to a better future for people and nature. It transforms existing knowledge into a collective agenda that will inform and mobilize action.

Electronics have transformed the way we live and work. Today's global consumer electronics market is worth an estimated $1 trillion, and is projected to continue growing. If current production and consumption modes continue in the same way, so too will our draw on natural resources and greenhouse gas emissions in the value chain. Electronics have already become the world's fastest-growing waste stream. The industry clearly needs to become more sustainable and resilient.

How can circular strategies contribute? Three objectives have been formulated based on existing visions of a circular economy for electronics: new products use more recycled and recyclable content; products and their components are used for longer; and end-of-use products are collected and recycled to a high standard.

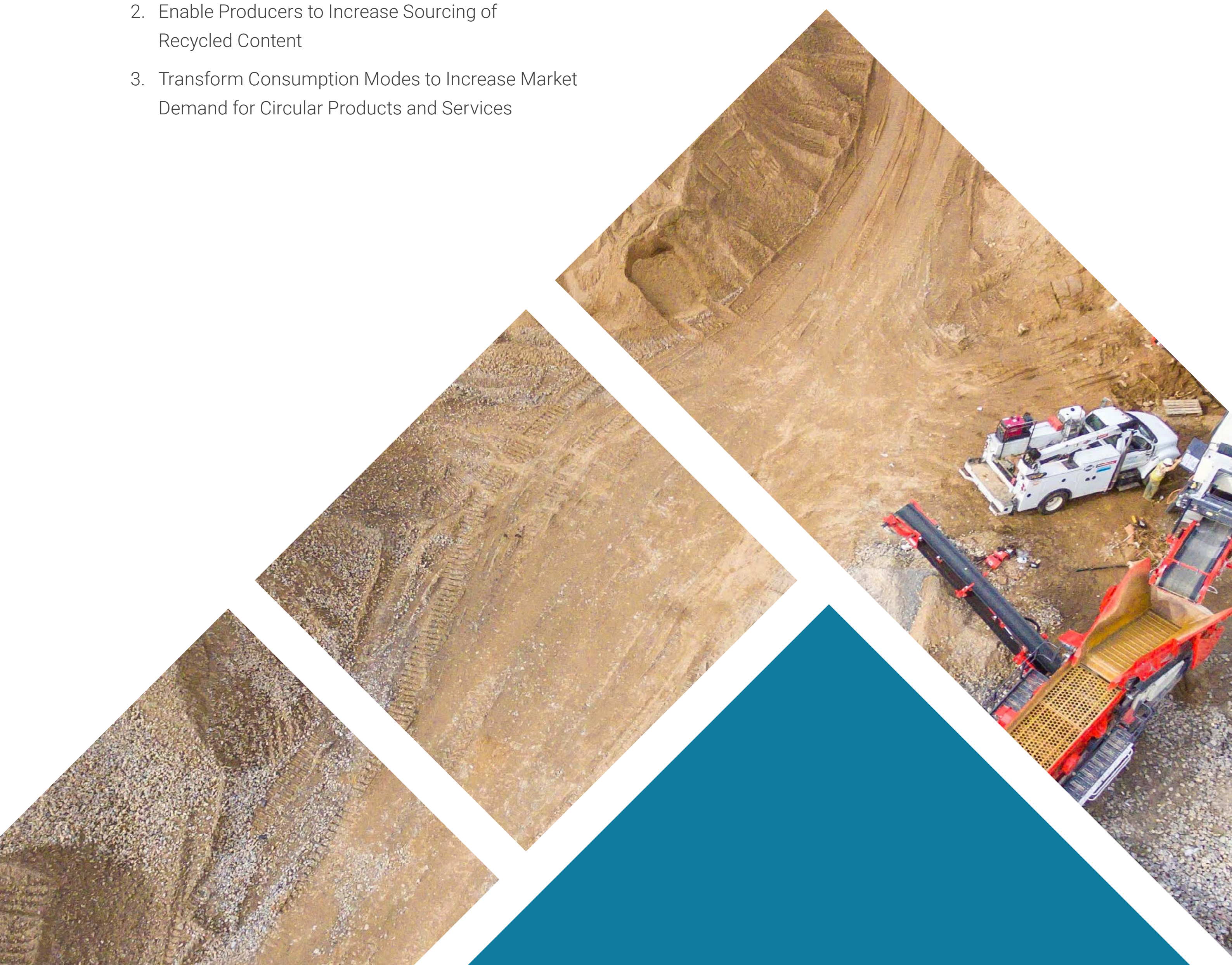
The circular economy originated from using natural resources more efficiently and sustainably, yet its impact goes well beyond resource use. A circular economy for electronics can bring clear benefits for human health and biodiversity, as well as resource use and climate change, by moving from substandard e-waste (mis)management to high-standard recycling, by phasing out hazardous substances, and by partly replacing virgin materials and new production with recycled contents and extended product use life. Economic benefits are also expected, from recovering valuable raw materials in e-waste, and from opportunities in new business models and sustainable enterprises. A circular economy for electronics presents the potential to advance decent work, though targeted efforts are needed to improve work conditions and safety across the value chain, create more formal jobs, integrate informal workers, and ensure the transition is just and inclusive.

Despite the dire need and important opportunities, a circular transition for the electronics industry faces many barriers beyond the control of any individual stakeholder. From literature study and interviews carried out for this report, 21 key barriers have been identified that work collectively to slow progress towards a circular economy for electronics.

Building on the impact and barrier assessments, we put forward 10 calls-to-action. Each call-to-action is a priority area where actions are most needed today, in order to overcome key barriers and to optimize the impact of the transition:

1. Incentivize and Support Product Design for Circularity
2. Enable Producers to Increase Sourcing of Recycled Content
3. Transform Consumption Modes to Increase Market Demand for Circular Products and Services
4. Guide and Support New Business Models for Environmental, Financial, and Social Triple-Win
5. Encourage Bring-Back by Consumers
6. Set Up Effective Collection Systems
7. Enable Efficiency and Transparency in Compliant and Responsible Transboundary Movement
8. Strategically Plan and Install Sorting, Pre-Processing, and Recycling Operations
9. Increase Incentives for Investment in Recycling Technologies and Facilities
10. Integrate and Advance Decent Work in the Transition to a Circular Economy for Electronics

A variety of actions can be taken up by different stakeholders under each call-to-action. Some examples are given. We invite every changemaker to come up with ideas and initiatives to address these calls-to-action, adapting them to different contexts.



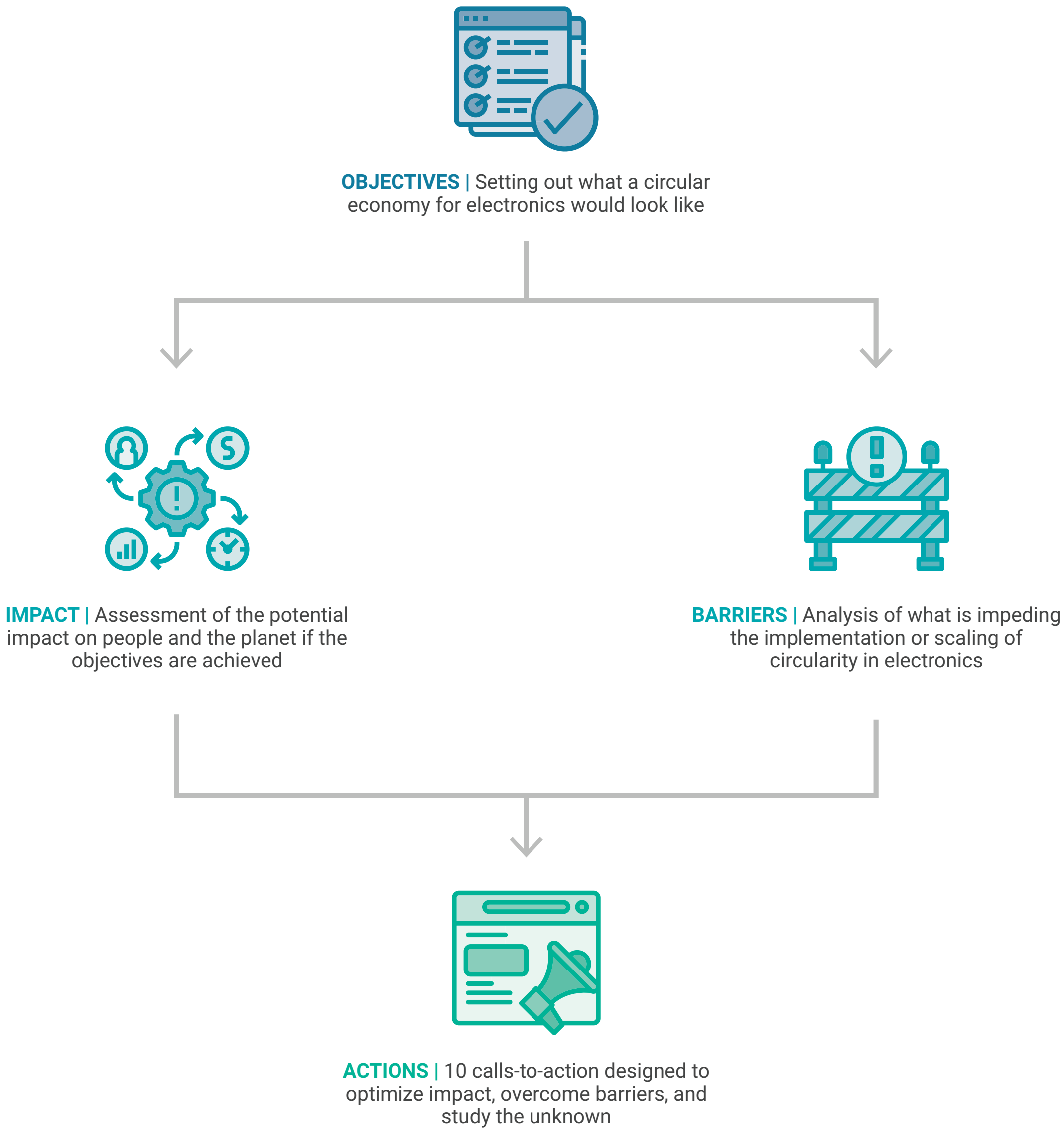
ABOUT THE ACTION AGENDA

The Circular Economy Action Agenda is designed as a rallying call for business, government, and civil society. It is currently made up of five publications: electronics, plastics, textiles, food, and capital equipment. The aim is to transform existing knowledge into a collective agenda that will inform and mobilize action within the PACE community and beyond.

Our economy has been highly successful in increasing productivity and elevating the living standards of parts of the population. In doing so, it has also created many challenges, both environmentally and socially. The need for solutions is more urgent than ever. A circular economy has been proposed as a way to address these challenges, with the ambition to harmonize economic and ecological goals.

Researchers have already documented the challenges from the electronics value chain today, the need for a transition to circular economy, and the systemic change required for the transition.[1] This report builds on the existing literature to identify actions needed for a better and faster transition to a circular economy for electronics. Each report has four main chapters: Objectives, Impact, Barriers, and Actions (see Figure 1).

FIGURE 1 • Structure of the Action Agenda Reports



How we developed the Action Agenda

PACE brings leaders together from across sectors and industries to develop a collective agenda and drive ambitious action, creating a space for leaders to work in partnership and overcome challenges together. The Action Agenda is the result of collective efforts by working groups made up of representatives from business, government, civil society, finance, and research organizations, collaborating throughout 2020. In total, more than 200 experts from over 100 organizations have contributed via over 80 phone interviews, more than 20 group discussions and substantial written inputs. The reports try to integrate all insights, balance different viewpoints, and identify where further alignment is needed. We believe that this diversity of viewpoints is crucial for designing and realizing a better transition.

OBJECTIVES | What Do We Mean by a Circular Economy for Electronics?

We all desire and strive for a future of human and environmental wellbeing. The circular economy is a key path towards that future. This chapter explains how the community currently sees circular strategies being applied to electronics, and sets out three objectives.

Technological advancement, as well as improved accessibility and affordability, has led to a significant increase in the use of electronics worldwide, transforming the way we live and work (Forti et al. 2020). COVID-19 has emphasized—if not boosted—the relevance of electronics products and digital services in our societies. Many individuals and organizations, from schools to businesses, are increasing their investments in digitization.

Globally, sales of electrical and electronic equipment are projected to continue growing and, if current common production and consumption modes also continue, so too will the draw on natural resources, the amounts of e-waste generated, and the greenhouse gas emissions from fossil fuel use in the value chain (Forti et al. 2020). This emphasizes the need for all stakeholders to accelerate existing efforts to realize a more sustainable and resilient electronics industry. A circular economy for electronics is critical to achieving at least nine of the 17 Sustainable Development Goals (United Nations 2015). The coming decade will be critical for the electronics value chain to capitalize on its innovation, speed, and agility to contribute to this global agenda.

Leaders from the public, private, and civil society sectors are increasingly recognizing the need for system transformation. This report supports the need for collaborative action by presenting an Action Agenda for governments, businesses, financial institutions, NGOs, workers' and employers' organizations, international organizations, and research organizations to take the next steps in the transition to a circular economy for electronics.

A common definition of a circular economy for electronics forms the basis of this analysis.[2] Three objectives have been formulated based on the report "A New Circular Vision for Electronics", which was presented by PACE and the World Economic Forum in collaboration with the United Nations E-Waste Coalition in 2019 (PACE and World Economic Forum 2019), in line with the circular economy principles:[3]

1. New products use more recycled and recyclable content
2. Products and their components are used for longer
3. End-of-use products are collected and recycled to a high standard

1: NEW PRODUCTS USE MORE RECYCLED AND RECYCLABLE CONTENT

This objective is focused on designing products with circularity in mind: using more recycled materials, as well as materials that can be economically recycled in the future. Substances that are hazardous to human health and the environment are phased out to facilitate safe recycling. In addition, products are designed to incorporate easy disassembly at end-of-life without compromising product lifespans.

PRODUCT SCOPE

The Circular Economy Action Agenda for Electronics includes all types of electronic and electrical equipment as defined by the EU Waste Electrical and Electronic Equipment (WEEE) Directive. This specifically includes devices and equipment from six product categories: temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment, and small IT (European Parliament and European Council 2012). Batteries are not the focus of this report since they are often regulated separately.

From a market perspective, the report includes B2C, B2G and B2B devices and equipment sold in bulk and in individual units.

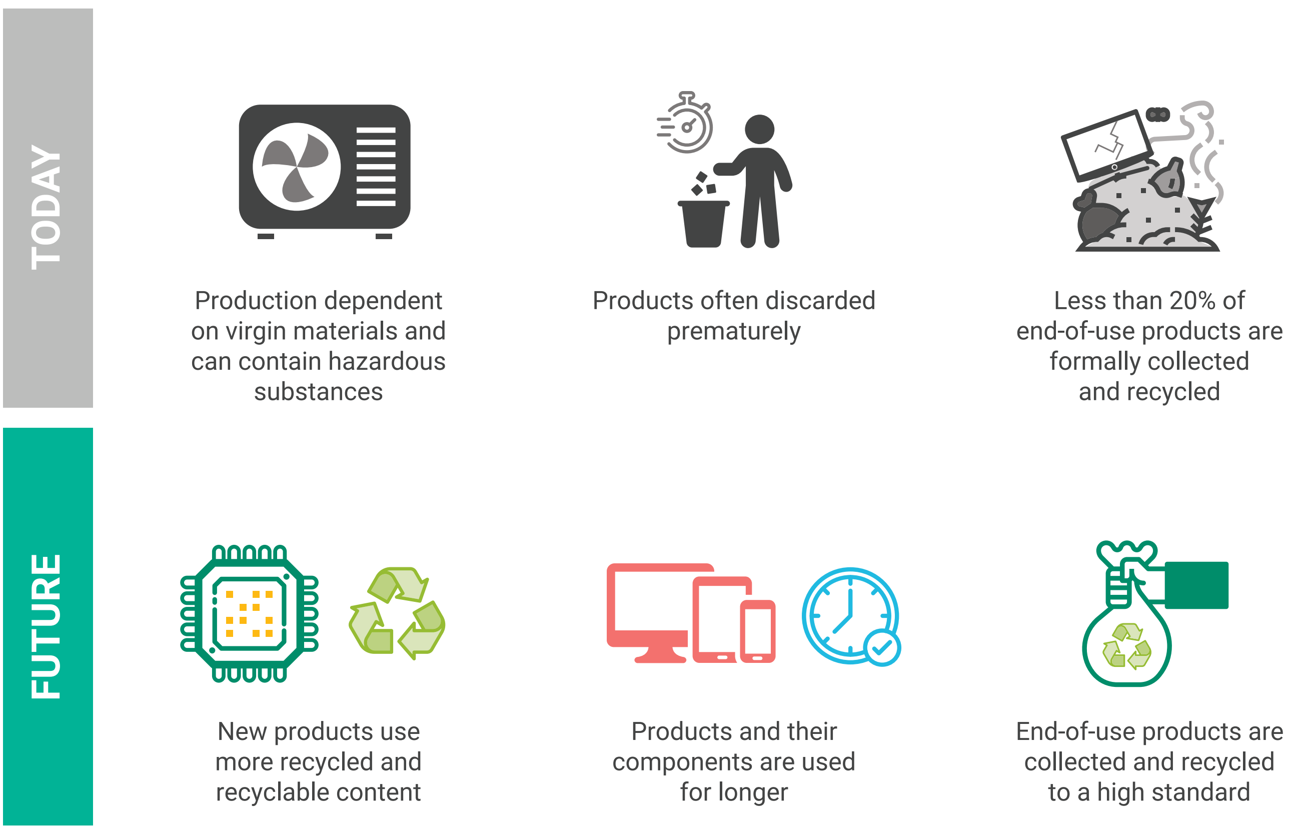
2: PRODUCTS AND THEIR COMPONENTS ARE USED FOR LONGER

This objective is focused on reducing environmental impacts from production and delaying waste flows by increasing the use life of electronic products and components. In a circular future, the technical life of a product or component is extended by designing for longevity, and the use life of the product or component is extended to match its technical life through robust options for reuse (in this report, reuse is defined as a broad term for use life extension of products and components through upgrade, second-hand markets, repair, refurbishment, remanufacturing, and parts harvesting).

3: END-OF-USE PRODUCTS ARE COLLECTED AND RECYCLED TO A HIGH STANDARD

Products that are no longer suitable for use or reuse are collected. Instead of being sent to landfill or incinerated, they are sorted and pre-processed with high precision. The parts are sent to specialized recyclers who recover materials at high rates and quality levels, while employing socially and environmentally responsible practices. There are no illegal shipments of e-waste.

FIGURE 2 • Major Challenges in the Electronics Value Chain Today and the Circular Objectives



IMPACT | How Might a Circular Economy for Electronics Affect People and Planet?

This chapter presents a literature-based assessment of how circular strategies may have an impact on the world, if achieved. Circularity alone cannot solve all today's problems. No solution alone can. It is therefore important to understand where circularity can deliver benefits, as well as areas that require attention or further research.

Circularity is not the end goal. It is, however, an important pathway contributing to the end goal, which is achieving greater human and planetary wellbeing—as described by the Sustainable Development Goals and the Paris Agreement. It is crucial to keep this north star in focus, and to steer the circular transition accordingly for a balanced, positive outcome.

The environmental and socio-economic impacts of the electronics industry today are already well documented (Forti et al. 2020; Circle Economy 2020a; PACE and World Economic Forum 2019). In this Action Agenda, we look to the future and ask the question: *if the circular objectives are achieved, how might people and planet be affected?* It is important to understand where the circular economy can deliver benefits, as well as where points of attention and knowledge gaps exist.

Science-based, forward-looking impact assessment of increased circularity is still a relatively new field. As an initial step towards this understanding, the three objectives defined in the previous chapter were assessed by a group of scientific experts (see Appendix), based on existing literature along five impact categories:[4]

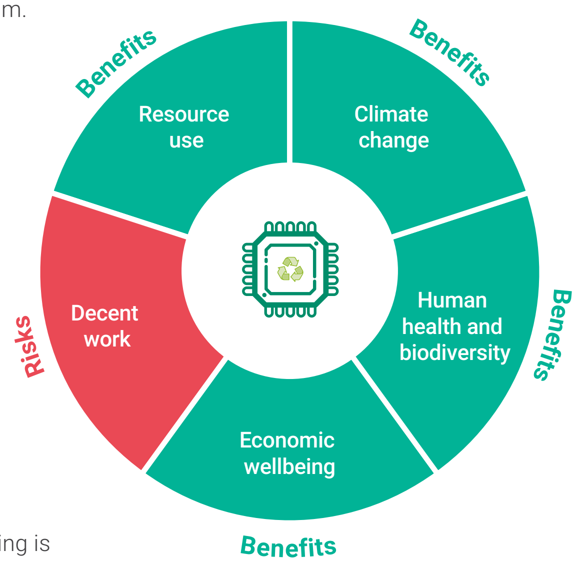
- **Resource use**: use of minerals and fossil resources.
- **Climate change**: greenhouse gas emissions from the value chain.
- **Human health and biodiversity**: largely as a consequence of land, water and chemical use, as well as air, water and soil pollution.
- **Economic wellbeing**: a broad category covering income, wealth, value added, and their distribution; trade, productivity, competitiveness, entrepreneurship, resilience, and investment.
- **Decent work:**[5] a broad category that includes the promotion and realisation of standards and fundamental principles and rights at work, creating greater opportunities for women and men to decent employment and income, enhancing social protection, and strengthening social dialogue.

The figures below give an impression of how each circular objective may affect the five impact categories: could it bring benefits, trade-offs, risks, or is it uncertain due to insufficient knowledge or evidence? A more detailed analysis can be found in the Appendix. It should be cautioned that impacts are almost always complex, with boundary conditions, caveats, and exceptions, and always evolving, e.g. as new technologies emerge. Therefore, these qualitative labels should never be seen as absolute or static.

Any complex transition comes with pros and cons. We should not be locked into inaction for fear of the risks and uncertainties. Quite the opposite; we should take proactive action to optimize the impact of a circular transition, including leveraging win-wins for maximum benefits, mitigating trade-offs and risks, and investigating the yet unknown.

FIGURE 3 • Expected Impact of New Products Using More Recycled and Recyclable Content

RESOURCE USE | Replacing virgin materials with recycled content in new product manufacturing will reduce electronics' overall resource use. However, the electronics industry is not the main user of the base metals (e.g. iron, aluminum, copper) or precious metals (e.g. gold) that drive mining decisions (European Commission. Directorate General for Internal Market, Industry, Entrepreneurship and SMEs et al. 2017); critical metals used in electronics are often by-products of mining. Therefore, circularity in electronics alone is not expected to have a major impact on mining, except for specific metals such as tin and tantalum.



CLIMATE CHANGE | Substituting virgin materials with recycled materials will reduce CO_2 emissions from electronics, as the production of recycled materials is on average much less CO_2 intensive (e.g. -95% of CO_2/ton for recycled aluminum, -83% of CO_2/ton for recycled plastic (Material Economics 2018)).

HUMAN HEALTH AND BIODIVERSITY | Phasing out already identified hazardous substances (e.g. certain flame retardants, lead, mercury) and potentially next generation hazardous substances (still under debate) can reduce associated adverse health effects for workers in manufacturing, repair, and recycling.

ECONOMIC WELLBEING | Increasing recycled content in new products will stimulate the secondary materials market, estimated to be worth approximately \$57 billion in the electronics industry in 2019 (Forti et al. 2020).

DECENT WORK | Although no major impact on employment in mining is expected, some jobs may be affected, especially artisanal and small-scale mining, which play a significant role in the global markets for cobalt, tin, and tantalum, and are especially vulnerable to a reduction in demand (Montt, Fraga, and Harsdorff 2018). The extension of social protection, skills development, and alternative income-generating opportunities for displaced workers will be important.

FIGURE 4 • Expected Impact of Using Products and their Components for Longer

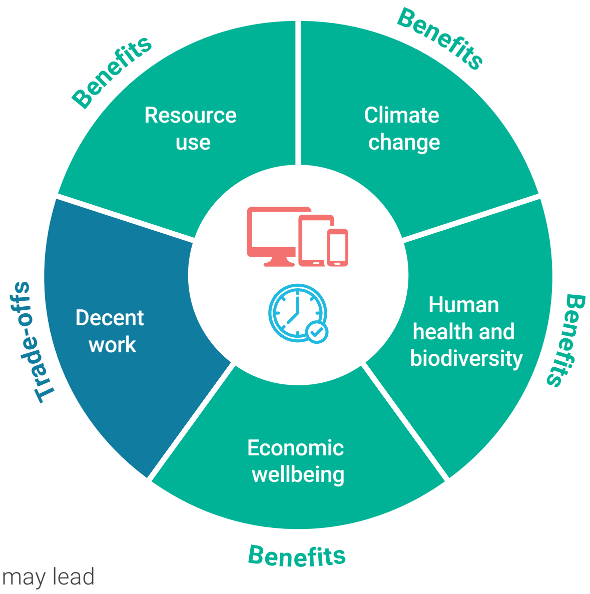
RESOURCE USE | Extending the use life of electronics is likely to reduce the industry's overall use of virgin mineral and fossil resources, or at least slow down the increase in resource use of a growing global electronics market. Nevertheless, circularity in electronics alone is not expected to have a major impact on mining (see Figure 3).

CLIMATE CHANGE | Similarly, use life extension can reduce, or at least slow down the increase in, emissions from new production, especially since electronics manufacturing is concentrated in countries with high carbon-intensive coal-fired power in their energy mix. In most cases, greenhouse gas savings from displaced new production can outweigh emissions from reverse logistics and potential energy efficiency improvements of new products (Parajuly et al. 2019).

HUMAN HEALTH AND BIODIVERSITY | Use life extension may displace some new production and reduce the amount of e-waste, therefore reducing environmental hazards associated with the production phase and e-waste (mis)management, including soil, air, and water toxicity that poses health risks to both local communities and wildlife.

ECONOMIC WELLBEING | The value opportunity of refurbishment and reuse is estimated at $10-20 billion for ICT devices alone (Lacy, Spindler, and Long 2020), generating new business models and sustainable enterprises. There are also benefits for consumer savings.

DECENT WORK | Reduced demand for new electronics products may lead to some job losses in electronics manufacturing. On the other hand, new job opportunities will emerge in repair and remanufacturing (Montt, Fraga, and Harsdorff 2018; ILO 2019; Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development 2017; Circle Economy 2020a).



"The Action Agenda by PACE helps create the systemic change needed for transitioning to a circular economy in key sectors. The calls-to-action provide us an opportunity to reach multiple goals, from our climate goals to halting biodiversity loss, reducing our overconsumption of resources, and increasing societal wellbeing by transitioning to a circular economy."

Mari Pantsar, Director, Sustainability Solutions, The Finnish Innovation Fund Sitra

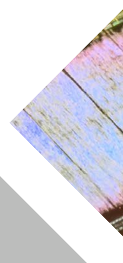
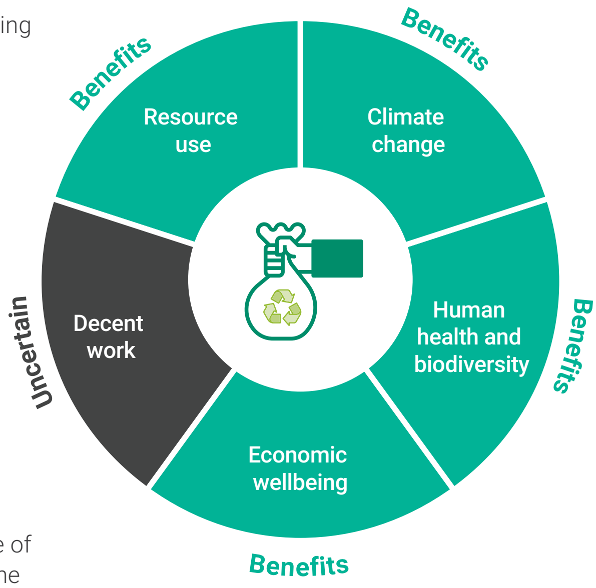


FIGURE 5 • Expected Impact of Collecting End-of-Use Products and Recycling to a High Standard



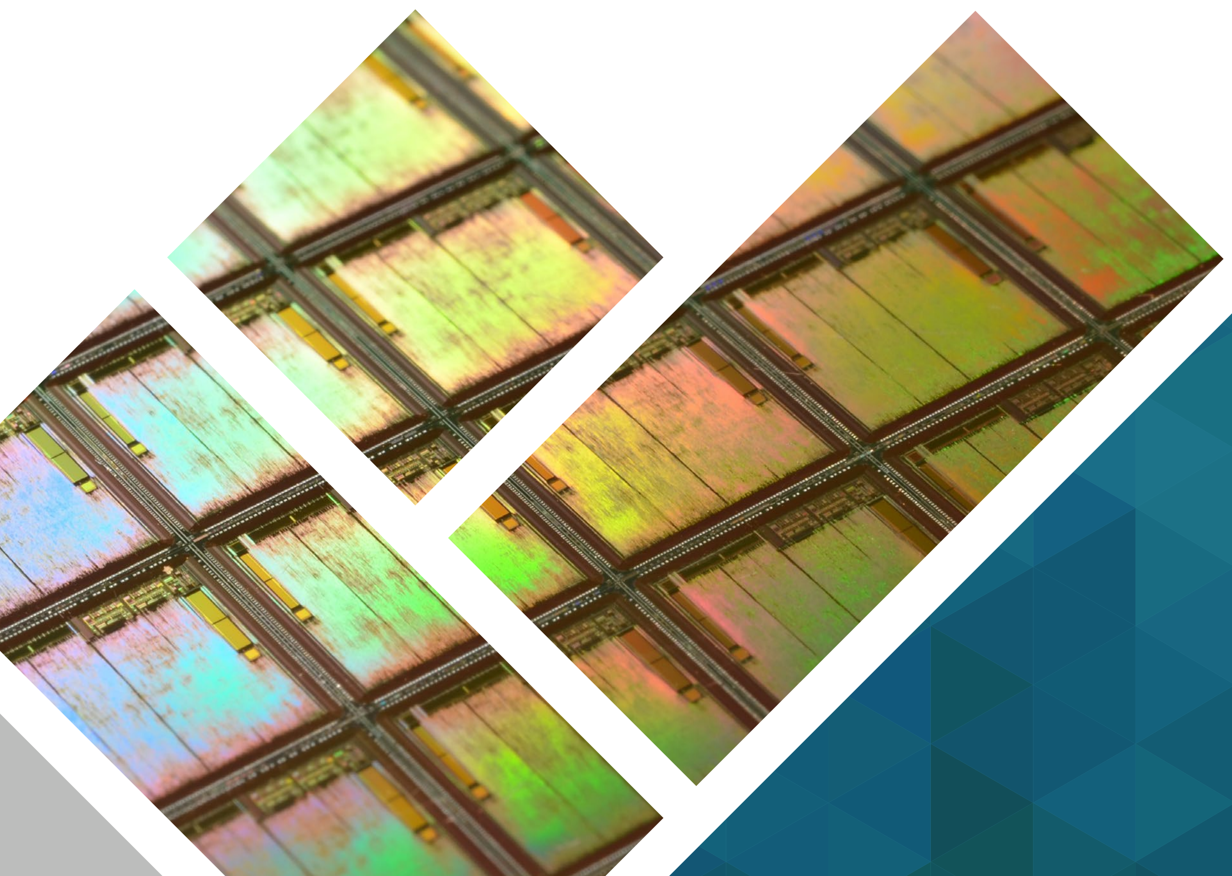
RESOURCE USE | Greater volumes and quality of secondary materials will enable substitution of virgin materials with recycled materials in new product manufacturing. Nevertheless, circularity in electronics alone is not expected to have a major impact on mining (see Figure 3).

CLIMATE CHANGE | Substituting virgin materials with recycled materials will reduce CO_2 emissions from electronics (see Figure 3). Proper recycling of coolants in e.g. refrigerators can further reduce greenhouse gas emissions.

HUMAN HEALTH AND BIODIVERSITY | By transitioning to recycling with high environmental and safety standards, skin diseases, respiratory problems, altered neurodevelopment, cardiovascular problems, and further diseases associated with poorly regulated e-waste recycling systems can be avoided. Local ecotoxicity in the form of air, soil, and water pollution from pollutants released during substandard recycling processes or dumping will be reduced. This has positive health effects for local communities and reduces local wildlife exposure to hazardous substances (Laurenti, Moberg, and Stenmarck 2017; Forti et al. 2020).

ECONOMIC WELLBEING | The value of raw materials in total global e-waste is approximately $57 billion, mainly in the form of iron, copper, and gold (Forti et al. 2020). How the value recovery will be distributed across different countries depends on whether recycling is managed via local or global value chains.

DECENT WORK | Better management of e-waste can be an engine of job creation in both low- and high-income countries. Formalizing the recycling economy could bring fair wages for workers, reduce child labor, and provide safer working conditions; it is still uncertain whether formalization will lead to net job gains or losses, and whether the transition will be inclusive for vulnerable communities (ILO 2019).



BARRIERS | What is Hindering the Transition to a Circular Economy for Electronics?

This chapter analyzes what is currently impeding the implementation or scaling-up of circular strategies, considering all angles including policy, business models, finance, technology, information, culture, and behavior.

The impact assessment concludes that a circular economy for electronics is expected to bring not only environmental benefits, but also significant economic opportunities, especially if the costs of recovering material value are reduced through increased recyclability and highly efficient recycling processes. There is a growing momentum of sustainability consciousness in business and society that can facilitate the needed transition: in 2019, 99% of CEOs of large global companies said that sustainability is relevant for the long-term success of their companies (United Nations Global Compact and Accenture 2019). Consumers are increasingly interested in the recyclability of products, and 50% are open to using second-hand or refurbished electronics products (WRAP 2017). New technologies also make a difference for the transition: cloud technology can optimize the use of servers, leading to lower energy consumption and making electronics reuse easier by removing data security concerns (Ellen MacArthur Foundation 2018a). Product passports and advances in recycling technology can improve recycling rates, as well as the quality of recycled materials (PACE, World Economic Forum, and Accenture 2019).

Despite these significant opportunities, the transition to a circular economy for electronics still faces many barriers beyond the control of any individual stakeholder. From a literature study (labeled as * in the References) and interviews, as well as insights shared by the Circular Electronics Partnership and the UN E-Waste Coalition, we have identified 21 key barriers that may work collectively to slow progress towards the vision of a circular economy for electronics. There are links, connections, and overlaps between these, depending on the perspective of analysis. The goal is not to produce an exhaustive list of all barriers, but rather to highlight critical ones where collaborative action is needed to overcome them.

Cross-Cutting Barriers

Externalities are not accounted for – externalities are a consequence of an industrial activity that affect another party who did not choose to incur the cost or benefit, and can be negative or positive. Current price points of electronics products do not account for their negative externalities, including greenhouse gas emissions, health hazards, biodiversity loss, and resource use. This puts products that reduce externalities (such as with increased circularity), while incurring higher costs in doing so, at a competitive disadvantage.

Lack of industry-wide agreed standards and definitions for design for circularity – there is currently a lack of international standards for what constitutes products or services designed for circularity. Various terms relating to circular product design, e.g. repairable or durable, are not yet defined at industry level. A common vocabulary will help support harmonization efforts in government policies, procurement practices, and certification schemes. To date, standards are being developed that cover some of these aspects (e.g. by the European Committee for Electrotechnical Standardization, CENELEC, or the International Organization for Standardization, ISO).

Limited guidance to balance design requirements – designing an electronics product for circularity requires designers to evaluate and balance requirements relating to usability, longevity, recyclability, data security, product safety, and production cost. The order of priority of different requirements depends on the product category and specific product characteristics. To date, an evaluation of circularity criteria is rarely a structural part of the design process. Better data on lifecycle impacts is needed to support fact-based design decisions.

Lack of incentives to design for circularity – currently, negative externalities of linear design are not priced in, and designing products and services for circularity can increase costs for manufacturers in the short term. At the same time, benefits from circular products and services, for example through increased customer loyalty, are more difficult to quantify. Many businesses do not yet see the circular economy as a customer value-creating opportunity. In this context, design for circularity is not often prioritized by corporate decision-makers, and designers lack a clear mandate for prioritizing circularity criteria (PACE, World Economic Forum, and Accenture 2019).

Insufficient integration of circular economy principles in organizational procurement and end-of-use management – organizational procurement accounts for a significant share of market demand for electronics products and services. However, circular economy principles and criteria are insufficiently integrated in procurement processes and the decisions of large-scale public and private sector buyers, resulting for example in tenders being limited specifically to new equipment. Organizational end-of-use management guidelines can also be a barrier to circularity, demanding destruction of devices and equipment at the end of their use cycles, or prohibiting the return of products back to the manufacturer for refurbishment or remanufacturing because, for example, trade with private parties may not be allowed.

Low awareness of the environmental and social hazards of e-waste – while the health hazards of e-waste are known, especially for pregnant women and children, there is currently limited scientific research on the macroeconomic and societal cost of e-waste dumping (WHO interview 2020). The general public is usually unaware of the negative environmental and social impacts of e-waste. This limits both consumer behavior change and public demand for government and business action.

Barriers to Using More Recycled and Recyclable Content in New Products

Limited collaboration across the value chain – recyclers are seldom involved in product design processes and have little insight into design decision-making, while designers often lack insight into the projected lifecycle and end-of-use strategies for the products they are developing. This leads to a lack of innovation regarding coherent design strategies for disassembly, safe disposal, and high quality material recovery, and a lack of effective recycling technologies and processes that complement design for recycling through, for example, reducing shredding of end-of-use products. In the case of closed loop recycling, even closer collaboration between manufacturers (including designers, material engineers, procurement, raw material suppliers, potentially also marketing specialists) and recyclers is required.

Lack of transparency on origin, quality, and recycled content of secondary materials – scrap materials often pass through multiple traders, which limits the ability of recyclers to obtain details on the materials' origin, chain of custody, or method of collection. The quality of scrap material is not well labeled either, due to inconsistent labeling or a lack of transparency about material types and grades. In addition, there is a lack of processes that can certify the origin of materials, material quality, and recycled content. In effect, recyclers struggle to provide the same level of quality and environmental, health and safety assurance for secondary materials as other suppliers can for virgin materials. For some manufacturers this is a key barrier to secondary material sourcing.

Unstable secondary material supply – electronics manufacturers who plan to increase recycled content in new product manufacturing face barriers in planning procurement decisions on a material and product level. Especially where secondary material markets are less robust and not integrated with primary material markets, recyclers often cannot guarantee long-term supply, e.g. due to complex supply chains compounded by shifting waste shipment regulations or their interpretation (insights from the Circular Electronics Partnership; see also the barrier "Complex regulatory processes and high transaction costs for reverse logistics with circular objectives"). The medium- and long-term volumes, qualities, and prices of recycled materials are rather uncertain. This puts secondary materials at a disadvantage compared to today's flexible supply chain for virgin materials.

Barriers to Using Products or Their Components for Longer

Insufficient consumer access to repair and refurbishment services – due to growing product complexity, design characteristics (e.g. irreversible adhesives), and software restrictions, consumers have very limited options to perform small repairs to their own electronics products. Often repairability is also limited for safety and liability reasons. For example, battery packs are shielded from access by the consumer to avoid safety hazards. The high labor costs of repair, coupled with new products with low prices and better features, has made repair shops less accessible, especially in developed economies. Product categories covered by professional repair or refurbishment are usually limited only to smartphones, laptops, and computers, and less available for other electronics products.

Challenging business case for product use extension – business models to extend electronics product use, including but not limited to product-as-a-service, may incur higher operational costs in monitoring, maintenance, repair/refurbishment, testing, and logistics (Circle Economy 2018). On the other hand, they may be disadvantaged in buying decisions, especially for products with rapid innovation cycles (Ellen MacArthur Foundation 2018a; Ranta et al. 2018). Furthermore, some business models require a larger upfront investment with a longer payback time, adding to financing challenges. There is also a need to measure the benefits of product use extension models to avoid a perceived risk of cannibalizing new product sales, discouraging producers from innovating in this space (Ellen MacArthur Foundation 2018b). There are successful examples of use extension business models in the industry, though broader uptake may have been impeded by the abovementioned challenges.

Barriers to Collecting End-of-Use Products and Recycling to a High Standard

Inconsistent/incompatible e-waste regulations and enforcement globally – 78 countries, covering 71% of the global population, had an e-waste policy, legislation, or regulation in place by 2019. However, how legally binding these are and the scope of the legislation (e.g. the product categories covered) differs across countries. Legally binding policies are not always well enforced, mainly due to a lack of financing or enforcement options (Forti et al. 2020).

Lack of formal e-waste collection globally – in 2019, 53.6 million metric tons of e-waste was generated, of which just 17.4% was documented for formal collection and recycling globally (Forti et al. 2020). Formal collection rates vary strongly by region, but are overall quite low worldwide: ranging from 42.5% in Europe to 0.9% in Africa (Forti et al. 2020). In low- and middle-income countries, there is often very limited financing for a formal and functional collection infrastructure and ecosystem. Informally collected e-waste often ends up with illegal or hazardous treatment, which has severe social, health, and environmental challenges (ILO 2019).

Limited incentives for consumers to bring back electronics at end-of-use – consumers,[6] in particular individuals, often lack awareness about the environmental, health, and safety impacts of e-waste—and even when awareness is present, behaviors do not necessarily change. There is limited knowledge about options for correct disposal. Social and financial incentives for consumers to get informed and invest the time to bring back end-of-use electronics, especially smaller devices, are limited. What is more, data security concerns and the wish to store an old device as a back-up pose disincentives for bring-back, and ultimately prevent potential second-use and closed loop material recycling (Casey, Lichrou, and Fitzpatrick 2019).

Complex and inconsistent electronics classifications – international reverse logistics processes for end-of-use electronics are highly dependent on two classifications: 1) is the product classified as “used EEE” or as “WEEE”?, and 2) is it classified as “non-hazardous waste” or as “hazardous waste”? In cases where the product is classified as “WEEE” and “hazardous”, international reverse logistics processes need to follow the rules of the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal. In 2019, an addendum to the revised technical guidelines from 2014 was introduced with the objective of clarifying these definitions. Discussions within the Basel Convention are still ongoing, and the technical guidelines so far have only been approved on an interim basis (Secretariat of the Basel Convention n.d.). The complex and inconsistently applied classification for electronics and the effects on reverse logistics are a barrier to a circular economy for electronics (Forti et al. 2020; PACE and World Economic Forum 2019).

Complex regulatory processes and high transaction costs for reverse logistics with circular objectives – the objective of the Basel Convention[7] is to avoid the environmentally and socially detrimental trading of hazardous waste. Under the Convention, certain transboundary movements of hazardous waste are banned, while others require an approval process based on the Prior Informed Consent Regulation (PIC) process, administered by the authorities of the importing, exporting, and any transit countries. Currently, for some trade cases with circular objectives, PIC processes can take years to go through, involving high transaction costs and adding operational constraints for manufacturers and recyclers. Lack of training, for example of trade officials, is part of the cause. In addition, there is also a need to reduce costs for domestic reverse logistics processes in some countries.

Underdevelopment of sorting and pre-processing technology – sorting and pre-processing technologies cannot keep up with advancing material complexity and fast changes to the design of new electronics products. An electronics product can be made up of more than 1,000 different substances (Needhidasan, Samuel and Chidambaram 2014) and up to 60 elements from the periodic table (Forti et al. 2020, PACE and World Economic Forum 2019). This makes it difficult for sorting and pre-processing to deliver the purer streams that are needed for high quality recycling (PACE, World Economic Forum, and Accenture 2019). New technologies such as disassembly robots able to use dismantling commands stored in product passports, and intelligent sorting systems using machine vision, provide opportunities—but will also require investment (PACE, World Economic Forum, and Accenture 2019).

Lack of mechanisms for safe treatment and recycling of hazardous e-waste – e-waste can contain hazardous substances (e.g. certain flame retardants, lead, and mercury). In the treatment of e-waste, it is important to protect workers and avoid the release of these substances into the environment. The compliant recycling of hazardous e-waste (e.g. contaminated plastics) incurs technical costs and requires proper training. Various countries lack the technological capabilities or access to the facilities they need to recycle hazardous e-waste (Forti et al. 2020). In some jurisdictions waste treatment laws disincentivize any processes other than mechanical separation, for example permits may be required for any waste treatment that uses heat, water, or chemicals, making hazardous e-waste recycling operations uneconomical (California Code of Regulations n.d.).

Limited incentives for investment in recycling infrastructure – volatile market prices for raw materials, difficult-to-aggregate scrap volumes, and uncertain market demands lead to unstable revenues for recycling operations. In addition to competition from virgin materials, recycling practices not complying with environmental and safety regulations can undercut market prices (Magalini and Huisman 2018). This lack of level playing field limits compliant recyclers in increasing capital expenditure investment and expanding their operations. In low- and middle-income countries, there is a need to foster an enabling environment (for example through reducing business registration costs) for new sustainable e-waste enterprises (ILO 2014). Strong informal sector activity in e-waste collection and recycling may disincentivize investment from global recycling companies, due to the business risks linked to engaging with the informal economy (Circular Electronics Partnership 2021).

ACTIONS | Where is Action Most Needed for a Better and Faster Transition?

Findings from the impact and barrier analysis are synthesized into 10 calls-to-action to overcome the barriers towards a circular economy for electronics, and to optimize impact by amplifying wins, mitigating trade-offs, and researching the yet unknown.

Building on the impact and barrier assessment presented in previous chapters, we put forward 10 calls-to-action for a better and faster transition to a circular economy for electronics. This is not a complete list of everything that needs to be done. Nor should the list stay static, as the world evolves rapidly. Instead, each call-to-action is an area where actions are most needed today, to overcome key barriers to a transition and to optimize impact. Under each call-to-action, a variety of actions can be taken up by different stakeholders. Some examples are given in this report, though they are neither exhaustive nor prescriptive. We invite every changemaker to come up with ideas and initiatives to address these calls-to-action, adapting them to different contexts. A summary of how each stakeholder group (governments, businesses, civil society, finance, research organizations) can drive the change can be found at the end of this chapter.

Call-to-Action 1 | Incentivize and Support Product Design for Circularity

Designing electronics products for longevity (making products durable, easy-to-upgrade, or easy-to-repair), recyclability (easy-to-disassemble, with safe inputs), and with recycled content is the starting point for achieving all circular objectives. In addition to circularity, there are other design requirements that electronics products need to fulfill, e.g. regulatory requirements regarding product safety, customer requirements regarding functionality, and economic requirements regarding production costs. Too often circularity is not prioritized in the product development phase, as it can present new engineering challenges and be associated with higher costs and limited financial benefits for companies (Ranta et al. 2018).

Governments can play a crucial role in stimulating design for circularity. Metrics for measuring circular design criteria such as longevity and recyclability (with understanding of the inherent trade-offs) need to be developed, and can be used either as regulatory requirements or as a basis for economic incentives such as public procurement criteria, rewards/penalties in taxation rates, or Extended Producer Responsibility (EPR) fees. Policies can mandate circularity in product design, as the broadened Ecodesign framework in the European Commission's Circular Economy Action Plan aims to do (European Commission 2020). Manufacturers, recyclers, and researchers should work together to align product design and innovation with existing and emerging dismantling and recycling solutions. Solutions and best practices to balance design requirements and trade-offs need to be shared (with consideration of intellectual property protection), to support an industry-wide take-up of circular design practices.

WHERE CAN WE START:

- **International standardization institutions, in collaboration with electronics manufacturers, can define what constitutes a circular electronics product and service**,[8] including clear definitions and measurement methods for priority aspects such as longevity, recyclability, and recycled content, taking into account the differences between product categories as well as trade-offs between approaches.
- **Governments can incentivize product design for circularity and the sales of circular products and services** (as defined by global standards) through policies such as reduced VAT, compulsory extended warranty periods, subsidies, and modulated EPR fees.
- **Governments in a region can collaborate to harmonize circularity criteria for imported electronics products**, such as restrictions on hazardous substances, longevity, repairability, and availability of spare parts.
- **Manufacturers, recyclers, and research organizations can collaborate to develop viable design strategies and technical solutions**; businesses, schools, and universities can add them to training courses or curricula for current and future electronics product designers.
- **Electronics manufacturers can commit to circularity at the leadership level** and integrate product circularity in their sustainability strategies, identifying areas of focus and setting measurable targets.
- **Electronics manufacturers, industry associations, and research organizations can extend and promote the use of lifecycle assessments** in the assessment of trade-offs between design requirements and the definition of appropriate circular design strategies at the product level (Life Cycle Initiative 2020).
- **Industry associations and civil society actors can establish a pre-competitive collaboration platform** for cross-value chain knowledge sharing and best practice exchange regarding design for circularity. In addition, broader industry-level targets and specific goals need to be defined.
- **Recyclers can adjust recycling processes to complement design for recyclability**, and optimize the recovery of materials at high rates and quality levels (see also calls-to-action 8 and 9).

Call-to-Action 2 | Enable Producers to Increase Sourcing of Recycled Content

Increasing the amount of recycled content in electronics manufacturing is essential for slowing down the demand for virgin materials in this growing industry. However, two issues are making it difficult for electronics manufacturers to increase sourcing of secondary materials: first, secondary materials can often not compete with virgin materials in terms of corporate social responsibility, legal or quality assurance, due to a lack of transparency about scrap material origin and content (e.g. contaminants, material grade, % recycled content) and a lack of certification processes. Second, an unstable supply and lack of insight into supply forecasts discourage manufacturers from long-term sourcing decisions for recycled materials.

Digital solutions, such as Global Battery Alliance's battery passport, can potentially facilitate higher transparency and traceability of material flow in the electronics value chain (World Economic Forum 2020). The development of standardized indicators and definitions for material quality and quantity (e.g. volume, material types, recycled content), as well as data about the chain of custody (e.g. origin, destination, previous owners) and environment, health and safety practices (e.g. worker safety, environmental management systems), can form the basis for further coordinated action (Circular Electronics Partnership 2021). Some large manufacturers such as Apple and Dell have signaled their demand for quality, recycled materials via ambitious targets for recycled content. A platform to share supply and demand forecasts vertically between recyclers and manufacturers could help to direct investment and stabilize secondary material supplies to meet demand.

WHERE CAN WE START:

- **Recyclers, manufacturers, materials producers, and standardization institutions can collaboratively develop standards** for secondary materials.
- **NGOs, businesses, and governments can raise public awareness** on the environmental and social benefits of responsible secondary materials, to encourage market demand.
- **Businesses can collaborate with research organizations to pilot digital solutions for increased product traceability and transparency,** building on standardized indicators.
- **Recyclers, in collaboration with standardization and certification institutions, can set up certification processes for secondary materials** for their origin, content, and quality.
- **Electronics manufacturers and recyclers can establish an industry platform** for increased transparency about supply and demand for critical materials in electronics production.

"As a global environmental policy research institute based in Japan, we believe the role of manufacturers in Asia and the Pacific is particularly crucial to creating more circular products. We see that manufacturers could play a vital role in sourcing reasonable and responsible recycled content, as this is key to creating more inherently sustainable goods. By highlighting this need, PACE helps raise public awareness on the benefits of responsible secondary materials, which we hope will in turn stimulate circular economy transition."

Yasuo Takahashi, Executive Director, Institute for Global Environmental Strategies

Call-to-Action 3 | Transform Consumption Modes to Increase Market Demand for Circular Products and Services

There is a lack of specific market demand for circular electronics products and services. Circular economy considerations are often not integrated into organizational procurement and end-of-use management processes. As a result, requirements in public tenders often prohibit the offering of circular solutions by specifying that only new systems can be purchased, or by prohibiting products' return to the manufacturer for refurbishment, for example because trade with private parties is not allowed. It is also not uncommon that organizational guidelines specifically demand the destruction of used IT equipment due to fears about incomplete data cleansing and misuse. The lack of demand, from large-scale buyers as well as individual consumers, keeps the industry from scaling-up the design and development of products or solutions integrating circular principles.

There is a clear need for increasing market demand to kickstart the positive demand-supply cycle that is needed for the transition to a circular economy for electronics. As already demonstrated in other areas of sustainability, large buyers such as governments and corporates can be highly effective in helping the supply chain achieve the economy of scale. Many organizations have ramped up their efforts in sustainable procurement and green IT over the past decade. For example, the Global Electronics Council is supporting the integration of circularity criteria for electronics in sustainable procurement programs, working with large-scale purchasers and manufacturers to develop a purchaser guide on circularity in IT procurement, as well as launching a global government call-to-action for sustainable procurement. These trends need to continue and scale. For individual consumers, civil society can play an active role in awareness raising and information sharing, to influence consumption patterns and buying decisions.

WHERE CAN WE START:

- **Governments and businesses can revisit organizational procurement guidelines**, reconsidering specifications that prevent circularity and integrating circularity criteria in evaluation processes.
- **Governments and businesses can commit to a % of total yearly spend that includes a preference for circular products and services**.
- **Electronics manufacturers and distributors can incorporate circular economy** in discussions with large-scale purchasers, highlighting the environmental and social benefits, and test the appeal of new value propositions.
- **Civil society can raise consumer awareness** about the benefits of products and services that integrate circular principles.

Call-to-Action 4 | Guide and Support New Business Models for Environmental, Financial, and Social Triple-Win

In addition to product design, business models hold significant potential as a complementary enabler of all three circular objectives. New business models, including but not limited to product-as-a-service, may help extend the use life of the product or its components to match their technical life, through activities such as maintenance, upgrade, repair, refurbishment, remanufacturing, and parts harvesting. These business models may, at least in theory, internalize the economic benefits of design for longevity, and develop stronger customer relationships (Lacy, Spindler, and Long 2020), and there are clear success stories (Accenture 2020). However, in many cases, the implementation of such new business models faces practical challenges (see the barriers chapter). Their effectiveness of extending use life and delivering environmental benefits is yet to be validated. There is also a need for better understanding of their social impacts, such as new sustainable enterprise and job creation opportunities.

The new business models need to achieve an environmental, social and financial triple-win, to thrive, scale and contribute in a meaningful way towards the wellbeing of people and planet. Research organizations need to develop science-based tools to guide business model design and implementation for net positive environmental and social outcomes. Governments and finance need to provide policy and financial support to the new business models, based on metrics measuring their actual environmental and social impact. Civil society needs to increase awareness and accessibility of relevant business process innovations in e.g. accounting, finance, and legal, especially for small and medium-sized companies that may lack in-house resources.

WHERE CAN WE START:

- **Governments can provide legal clarity regarding the liability of manufacturers and independent repair providers** for product defects and related consequences.
- **Financial services institutions or industry associations can consider establishing a collective insurance scheme** for independent repair providers.
- **Electronics manufacturers can promote repair**, through providing information about maintenance options for consumers and through scaling training and certification programs for repair and refurbishment to independent service providers.
- **Financial services providers can improve access to capital** for product use extension business models.
- **Research organizations, in collaboration with producers, can improve knowledge about the business performance and the environmental and decent work impact of product-as-a-service business models**, depending on the context and type of device or equipment.
- **Accountants, business consultants, and companies can propose specific changes for adapting accounting to a circular economy for electronics**, recognizing disincentives of current depreciation rules and taking into account key aspects of new business models, e.g. the estimation of residual value of assets in product-as-a-service business models.

"Electronics are ubiquitous. While this illustrates the industry's success, it also exposes the risk of continuing to depend on linear business models. The Circular Electronics Partnership (CEP), a partnership of seven organizations and the largest companies from across the electronics value chain, has emerged in response to the opportunity in scaling circular design principles, closed loop systems, and responsible business models. We look forward to leveraging the progressive business voice of the CEP platform across sectors to collectively achieve our vision for circular electronics."

Brendan Edgerton, Director, Circular Economy, World Business Council for Sustainable Development

PARTNERS IN ACTION | Eco-Design Blog

Advancing Circular Design Through Open Communication

It is widely recognized that 80% of the total environmental impact of a product is determined in the design phase. Among the first industry players to recognize the potential environmental savings this creates was the Dutch electronics manufacturer Philips, who introduced their first eco-design initiative as early as 1994. Philips applies lifecycle analysis to their products to identify their environmental impact and monitor improvements. In 2020, they shared their vision for best practices, including the environmental hotspots for devices as well as design challenges and their view on regulatory limitations.

“Circular design requires a shift in mindset: from designing for ‘today’ to designing for ‘tomorrow’ and beyond,” says Robert Metzke, Head of Sustainability at Philips. “That’s why we have started speaking very openly about our understanding of circular design and the processes implemented, to make sure that design holistically considers all aspects of the product development phase.” To advance circular design for electronics, more value chain dialogue and best practice sharing is needed.

PARTNERS IN ACTION | Sustainable Business Model Innovation Framework

Integrating Analysis, Design, and Decision-Making for Circular and Sustainable Business Models

In our efforts to achieve a sustainable and circular society, business change is indispensable. In this transition it becomes even more apparent that ‘no business is an island’. Circular material flows require materials management typically beyond the scope of a single organization; sustainability is determined at all stages of the supply chain and often requires behavior change from multiple people. The shift to circularity and sustainability requires leadership and strategic support within organizations.

“Sustainable business model innovation provides a useful lens to deal with these challenges in a cohesive way,” says Frank Berkers, leading networked business modelling expert at TNO. “Still, the shift to circular requires hard work and perseverance.” TNO has developed a Sustainable Business Model Innovation Framework, which not only supports the steps of the business model innovation process, but also combines multi-actor and multi-value business model design with multi-level analysis from the national, regional, sector and value chain economic structures, as well as impact and lifecycle analysis and material flow models and approaches, to support decision-making and attitudes towards circular and sustainable innovations. With this framework, TNO aims to support organizations to make the shift as a system.

Call-to-Action 5 | Encourage Bring-Back by Consumers

This call-to-action emphasizes proactive bring-back by consumers. Consumers may lack awareness about the environmental and socio-economic impacts of end-of-use electronics, and so they underestimate the importance of proactive bring-back. Even if awareness is there, it does not always lead to action due to, for example, limited knowledge about local options for bring-back, or a lack of incentives. There are also disincentives for bring-back, such as data privacy concerns or the wish to keep old devices as a back-up. As a result, millions of unused laptops, tablets, and smartphones are stored for years in homes (Casey, Lichrou, and Fitzpatrick 2019), instead of being brought back to formal collection points. Given that every smartphone put on the market contains on average 6.7 grams of precious and critical materials (e.g. gold, palladium, silver, or cobalt), increasing collection and recycling rates via active bring-back could represent an economic opportunity (Gurita, Fröhling, and Bongaerts 2018). The reuse market can also benefit from timely bring-back, once an individual replaces a functioning device with a newer model.

Options for used electronics bring-back have increased and become more convenient over the past decade, for example via manufacturers' rebuying programs or take-back kiosks for smartphones (e.g. ecoATM) (Holgate 2018). In Europe and other regions, the clear responsibility of producers and EPR organizations is to achieve the collection and recovery targets regulated by the WEEE Directive. There are also inspiring examples from emerging markets and developing countries where digital technology is used to facilitate a hybrid bring-back and collection model: via an app managed by recyclers, individuals can communicate when they have e-waste that could be collected. The recyclers then collaborate with informal collectors to pick up the waste. Building on these positive examples, EPR organizations, manufacturers, and recyclers need more targeted and innovative measures to encourage bring-back.

WHERE CAN WE START:

- **Electronics manufacturers and resellers can establish buy-back programs** for consumer electronics.
- **Electronics manufacturers can guarantee safe data cleansing options and provide instructions for data purging to consumers** in all electronic devices that store personal and/or confidential data.
- **EPR organizations and electronics manufacturers, in collaboration with municipalities and recyclers, can provide convenient, free or even refunded bring-back options for consumers' end-of-use devices**, exploring innovative measures to increase bring-back (e.g. deposit schemes, take-back via parcel service, door-stepping campaigns, or solutions building on digital technology).
- **Research organizations can develop a clear understanding of consumer motivations related to bring-back**, and propose strategies for effectively incentivizing bring-back by consumers.
- **NGOs can organize consumer awareness campaigns** on the potential environmental, social, and economic benefits of bring-back.

Call-to-Action 6 | Set Up Effective Collection Systems

E-waste contains valuable materials, but may also contain hazardous substances (e.g. lead, mercury, certain flame retardants, chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HFCs)). In licensed recycling facilities, hazardous substances are treated in compliance with environmental and health and safety regulations, and some are able to be recycled. When end-of-use electronics are not formally collected, they are often treated using sub-standard recycling practices without adequate protective controls, leading to local ecotoxicity and severe health effects for workers (Forti et al. 2020). In addition, opportunities for formal employment and increased resource efficiency through reuse and high quality recycling are lost.

The ultimate means for an effective collection system and e-waste recycling in compliance with high social and environmental standards is a clear legal framework for e-waste management that is enforced by the responsible governments. Extended Producer Responsibility (EPR) is a common mechanism for financing end-of-use collection and recycling. Various projects are ongoing to extend the principle of producer responsibility to further countries; some countries have EPR legislation in place that is yet to be fully implemented. Public-private sector collaboration is key. Governments, producers, and Producer Responsibility Organizations need to work together to develop collection mechanisms that suit the local context, for example whether the collection is by companies or by government. Where EPR schemes may take time to be fully deployed, other financing mechanisms should be used in the interim. Informal collectors can be highly effective and need to be better integrated, so that informally collected e-waste can enter formal recycling that is done in a safe way and protects human rights (GIZ 2020).

WHERE CAN WE START:

- **Electronics manufacturers can start collection without waiting for fully enforced EPR schemes,** e.g. by integrating take-back or buy-back in B2B contracts.
- **Governments can establish and enforce a clear legal framework for e-waste collection and recycling** in line with environmental and labor standards.
- **Governments, in cooperation with electronics manufacturers and recyclers, can establish an EPR scheme** to ensure producers finance collection and recycling. Importers of used electronics should be considered producers under EPR legislation.
- **Electronics manufacturers and civil society can explore options for global harmonization of EPR regulations**, and start discussions with governments for developing international and potentially global EPR regulation.
- **Civil society, governments, and businesses can foster cooperation between informal collectors and formal recyclers** in low- and middle-income countries, for example by setting up incentive mechanisms for informally collected e-waste to enter sound recycling.
- **Governments can harmonize and improve documentation of e-waste collection** through, for example, taking into account use times of electronics placed on the market, or including e-waste recycled by compliant recyclers outside of EPR schemes in the measurement. This data can provide a more refined picture of waste flows as a basis for strategies to increase collection rates.

"BMZ supports its partner countries in introducing socially and environmentally sound e-waste management systems through projects on the ground, advisory support, and networking, e.g. through the PREVENT Waste Alliance. Finding ways to maintain livelihoods of informal sector actors, while upgrading and integrating their activities into formal recycling systems, is of high importance to avoid the most polluting impacts. To bring about this change, alliances are instrumental. Commitments and cooperation from actors in PACE can help drive change."

Daniel Haas, Senior Policy Advisor, Federal Ministry for Economic Cooperation and Development (BMZ), Germany

PARTNERS IN ACTION | Take-Back Models in China

Leveraging Digital Technologies to Facilitate E-Waste Collection

Founded in Shenzhen, China, in 2001, GEM has been pioneering innovation in collection solutions, recycling technology, and products with recycled content. Across the globe, their green recycling facilities are operated under the concept "limited resources, infinite recycling". In order to increase the collection rate of e-waste, GEM has been testing different models for collection; ranging from collection contracts with large companies and organizations to door-to-door household collection via online appointments.

"The key to the success of our hybrid bring-back and collection model is digital technology," says Dr. Yu-Ping Zhang, Vice President of GEM. Via an app managed by GEM, individuals or companies can signal that they have used electronics that are ready for collection. GEM then organizes the pick-up—sometimes collaborating with informal waste collectors—to ensure that the collected e-waste flows into formal recycling facilities for environmentally and socially responsible treatment.

PARTNERS IN ACTION | Circular Economy Approach for the Electronics Sector in Nigeria

Fostering Producer Responsibility

In order to tackle the challenges posed by the ever-growing volume of e-waste in Nigeria, the Nigerian government and the UN Environment Programme (UNEP) launched the project "Circular Economy Approaches for the Electronics Sector in Nigeria" in June 2019, funded by the Global Environment Facility (GEF). The project unites public and private sectors as well as civil society organizations for a shared goal: to establish a financially self-sustaining circular economy approach for electronics in Nigeria, preserving the environment while providing safe jobs for thousands of Nigerians.

"We need all stakeholders along the value chain to collaborate," says Professor Aliyu Jauro, Director General of the National Environmental Standards and Regulations Enforcement Agency (NESREA) Nigeria. "This is key to operationalize the EPR regulation and advance towards a circular economy for electronics." By engaging with key stakeholders, in particular global producers (such as HP, Dell, Philips, and Microsoft) that signed up to the E-waste Producer Responsibility Organization of Nigeria (EPRON), UNEP supports the Nigerian government in setting up the EPR system and exploring the most efficient collection channels and recycling routes, to improve circularity of the electronics sector.

Call-to-Action 7 | Enable Efficiency and Transparency in Compliant and Responsible Transboundary Movement

Reverse logistics and the related transboundary movements of scrap materials, used electronics, and e-waste can play a central role in a circular economy, as it enables reuse, remanufacturing, refurbishment, and recycling with economy of scale. The transboundary movement of end-of-use electronics that are classified as hazardous waste is regulated by the Basel Convention, to prohibit illegal trade and dumping. While strong regulation is absolutely necessary to protect human health and the environment from the potential hazards of e-waste mismanagement, it has posed some practical challenges for those seeking to build a legal reverse supply chain for responsible reuse and recycling. Key barriers include inconsistent classification and inefficiencies in approval processes (see the barriers chapter).

This call-to-action focuses on the creation of more efficient reverse supply chains for environmentally sound management, in compliance with the Basel Convention. For reverse logistics to play their role in a global circular economy, companies, governments, and competent authorities to the Basel Convention need to work together to find pragmatic solutions that ensure protection from potential hazards of e-waste mismanagement and are in compliance with the Basel Convention, while enabling responsible and efficient transboundary movement processes and exceeding the social and environmental outcomes achieved today.

WHERE CAN WE START:

- **Competent authorities to the Basel Convention can team up with trade ministries, private sector, and standardization institutions to develop certification**, for e.g. collectors in exporting countries and recovery facilities in importing countries, to be used as a basis for establishing "green lanes" for shipments on defined routes under a trusted trader system.
- **Competent authorities to the Basel Convention, trade ministries, and other appropriate authorities of countries hosting intergovernmental organizations within their respective mandates (e.g. EU, USMCA, ASEAN, ECOWAS) can take the lead in developing "green lanes" of trusted traders**, piloting regional facilitation schemes for safe and responsible transboundary movements for environmentally sound management.
- **Governments can invest in digitized procedures to speed up approval processes, while at the same time ensuring compliance with the Basel Convention**; potentially teaming up with other initiatives for higher efficiency at customs.
- **Governments, especially parties to the Basel Convention, can continue efforts to harmonize classifications of electronics**, especially "used EEE" vs. "WEEE" and "waste" vs. "hazardous waste".

Call-to-Action 8 | Strategically Plan and Install Sorting, Pre-Processing, and Recycling Operations

High quality recycling infrastructure for e-waste today is mostly centralized in industrialized countries. With the increasing amount of e-waste, including domestic waste in developing countries, there is a need for more formal facilities globally. Furthermore, income from the growing recycling market should be distributed in a way that supports economic wellbeing in different geographies. Sorting, pre-processing, and recycling facilities are large capital investments with lock-in for decades, requiring economies of scale. Therefore, they need to be planned carefully with holistic considerations. Location, capacity, and speciality are all important. Will there be a stable and sufficient inflow of after-use electronics? Will such inflow involve transboundary movement, and can compliant and efficient processes be set up? Are there relevant industries in the vicinity to take up the recycled materials? How can the carbon footprint of the reverse logistics be reduced?

Some countries are coming together to discuss e-waste policies and regional coordination—for example, the UNIDO - GEF PREAL project in Latin America.[9] There is a need to increase this type of dialogue, bringing governments and businesses from one region round the table to develop viable solutions that are supported by all stakeholders. A better understanding of the social, environmental, and economic consequences of different global or local recycling models is an important basis for these discussions.

WHERE CAN WE START:

- **Businesses and governments can work together to scope regional collaborations** to develop sorting, pre-processing, and recycling ecosystems, for example a regional hub or a more distributed value chain, balancing economies of scale with value sharing and local expertise.
- **Governments can create favorable investment conditions for experienced recyclers** to bring the technical expertise required to the region or country.
- **Governments can foster an enabling environment for a new generation of sustainable enterprises** in e-waste management.
- **Research organizations can develop data and knowledge** about the economic, environmental, and social impacts of different global recycling models, to inform strategic decision-making.

Call-to-Action 9 | Increase Incentives for Investment in Recycling Technologies and Facilities

E-waste recycling economics depend largely on the amount of stable scrap material inflow and logistics costs, precious metal content, purity of materials, and compliance and de-pollution costs (Magalini and Huisman 2018). In the current market a variety of factors is limiting the economic viability of e-waste recycling, and subsequently incentives for investment in infrastructure and technological innovation, especially in sorting and pre-processing, are few and far between. These factors include under-developed reverse logistics, increasing technical complexity, decreasing concentration of high-value materials, and an unlevel field of competition, as discussed in the barriers chapter.

Nevertheless, some recyclers have been growing their businesses over the past few years, focusing on sweet spots such as precious metal recycling. In the area of pre-processing, high-precision dismantling instead of shredding can enable the recovery of more valuable materials from end-of-use smartphones. To scale recycling operations in general, and increase investment in sorting and pre-processing technology in particular, economic incentives need to be strengthened. In the near term, particularly in low- and middle-income countries, proper manual dismantling can be incentivized. Governments need to create a level playing field for compliant recyclers. Financial institutions, governments, and manufacturers can support investment in the recycling sector through innovation funds, sales incentives, EPR schemes, and commitments to increasing sourcing of secondary materials.

WHERE CAN WE START:

- **Governments can improve enforcement of existing labor, environmental, and e-waste regulations** to ensure a level playing field for compliant actors**.**
- **Civil society actors and businesses can drive market-wide adoption** of good environmental and health and safety practices.
- **Electronics manufacturers can issue public commitments to increase the recycled content in new product manufacturing**, as a powerful signal to stimulate further development of the secondary materials supply chain.
- **Governments and financial institutions can set up funds for sorting and pre-processing**, including both technology innovation (such as automation) and high quality manual dismantling (particularly relevant for low- and middle-income countries).
- **Governments can stimulate the recycled materials market** by, for example tax incentives, subsidies, and recycled content targets for manufacturers, to steer the shift from virgin to secondary material production.
- **Research organizations can conduct studies on the local business environment for secondary materials** (e.g. production costs compared to virgin materials), to inform policymakers on needed interventions.

Call-to-Action 10 | Integrate and Advance Decent Work in the Transition to a Circular Economy for Electronics

The electronics value chain is highly complex and involves various industry segments that are critical for advancing decent work, including virgin material mining, original design manufacturing (ODM), and e-waste collection and recycling. As discussed in the impact chapter, the transition to a circular economy for electronics has the potential for sustainable enterprise and formal job creation. However, there is uncertainty regarding improvements to working conditions and the number of formal jobs that can be generated. For the transition to be effective and socially inclusive, the decent work aspect must be integrated from the beginning, in line with the ILO *Guidelines for a Just Transition*, and in consultation with employers' associations and workers' organizations (ILO 2015).

Businesses have been joining efforts in committing to and auditing value chain partners' performance in the areas of labor, health and safety, environment, ethics, and management systems, for example via the Responsible Business Alliance (RBA) or the Joint Audit Corporation (JAC). This type of joint action of big brands and companies is critical to raising awareness for integrating decent work in the transition to a circular economy, to increase effectiveness of risk monitoring, and to avoid competitive pressure playing against individual efforts. To ensure that the circular economy is advancing decent work, workers need to be part of the transition and included in social dialogue among industry alliances, governments, employers', and workers' organizations. The formalization of e-waste management among workers, enterprises, and cooperatives can take years. In the meantime, pragmatic solutions to improve the health and safety of informal waste workers, to extend social security to these workers, and to establish informal-formal partnerships are urgently needed (STEP 2020).

WHERE CAN WE START:

- **Governments have the duty to adopt, implement, and enforce labor laws and regulations** to ensure that the fundamental principles and rights at work and ratified international labor conventions protect and apply to all workers engaged in the electronics value chain, as well as creating an enabling environment for social dialogue among actors from government, employers' associations, and workers' organizations**.**
- **Governments, employers' associations, and workers' organizations can develop and implement measures to support the formalization of enterprises**, creating an enabling environment for enterprises that provide sustainable services in product use extension and e-waste management.
- **Corporates can extend supply chain auditing to downstream partners including collection, sorting, pre-processing, and recycling.**
- **Governments, employers' associations, and workers' organizations can specifically include informal workers in the development of professional collection and recycling infrastructure,** for example by setting up informal-formal partnerships to divert collected e-waste from sub-standard recycling, protecting their safety and health, extending the coverage of social protection to e-waste workers and their families, investing in up- and re-skilling programs, and supporting workers to transition into formal employment.
- **Governments, with the support of research organizations, employers' associations, workers' organizations, and NGOs, can collect data and improve knowledge about labor conditions** in the local e-waste value chain and the opportunities to transition to a circular economy, using the data to raise awareness and design effective policies.
- **Electronics manufacturers, recyclers, material suppliers, and NGOs can raise awareness on decent work** and integrate social aspects into discussions regarding material traceability and assurance.

PARTNERS IN ACTION | Daisy and Dave

Facilitating Smartphone Disassembly with the Aid of Robots

In 2016, Apple introduced the first mechanical colleague to their electronics recycling team: disassembly robot Liam, an expert in taking apart the iPhone 6, enabling Apple to recover valuable materials stored in its devices. Only four years later, the team was extended by more advanced Daisy and Dave. Daisy is familiar with 15 different versions of the iPhone and can dismantle 200 devices an hour, while Dave is capable of disassembling the iPhone's Taptic Engine.

"Businesses have an urgent responsibility to channel their best thinking toward conserving our planet's finite resources. Apple has an ambitious goal of closing the loop on our supply chain and to one day no longer mine materials from the earth," says Sarah Chandler, Senior Director of Environment and Supply Chain Innovation. "Many of our products now contain higher percentages of recycled material than ever before, but we won't be content until that number hits 100% for all of our devices. Achieving this critical goal will also help us to further reduce our carbon footprint, and we're dedicating Apple's unmatched innovative capacity to meet our goals and demonstrate what's possible to our industry peers." Thanks to novel technologies used in the robots, Apple can recover key materials, such as tungsten and rare earth magnets, in higher quantities and at higher qualities than most conventional recycling processes. Apple's disassembly robots are pointing the way to a future of resource recovery.

PARTNERS IN ACTION | Global Dialogue Forum on Decent Work in the Management of E-Waste

A Significant Step Towards Inclusive Circular Electronics

In addition to having negative effects on the environment, poor management of e-waste poses a severe threat to the health of workers handling this hazardous waste. In some developing countries, e-waste is often handled by informal workers under poor working conditions, with limited opportunities to organize and better their livelihoods. To address the challenges and opportunities in this sector, the International Labour Organization (ILO) convened a global meeting to adopt far-reaching consensus on ways to advance decent work in the management of e-waste.

"There is an urgent need to raise awareness about the growing challenges posed by e-waste, and effectively engage all relevant stakeholders," says Alette van Leur, Director of the Sectoral Policies Department at the ILO. "The circular economy for electronics has the potential to create decent jobs, but targeted efforts are needed to ensure the transition is just and inclusive." The Global Dialogue Forum was an important platform for fostering dialog and collaboration among governments and employers' and workers' organizations, and ensuring that efforts to advance circularity simultaneously promote decent work across the e-waste value chain.

How Can I Drive the Change?

GOVERNMENTS

Governments can drive the transition towards a circular economy for electronics by creating a business environment in which negative externalities are internalized, thereby aligning economic incentives with positive environmental and social outcomes. This can include:

- Implement and enforce adequate legal frameworks for decent work, including support for the integration of informal workers.
- Create and implement outcome-oriented regulation for environmentally sound e-waste management, including EPR as a key policy instrument.
- Invest in waste management infrastructure.
- Provide policy incentives for the uptake of circular design and investment in refurbishment, remanufacturing, and sorting and pre-processing technologies.
- Adjust public procurement guidelines and processes to effectively integrate circularity.

BUSINESS

The critical actions of businesses will depend on their position in the value chain. Here are a few starting points:

- **Brands and manufacturers** can: commit to circularity at the leadership level; test new value propositions built around circular products and services; integrate circularity in design decisions; increase options for product repair and refurbishment; finance collection; increase sourcing of secondary materials; increase transparency along the supply chain (in particular on chemicals content); and extend supply chain auditing to downstream partners to advance decent work and improve environmental practices.
- Collaborating with other value chain actors, **recyclers** can: co-develop standards and certification for secondary materials; help product designers better understand how to design for recyclability; co-deploy collection mechanisms and EPR schemes; get access to information on chemicals in products and identify innovation opportunities in sorting, pre-processing, and recycling technologies; and integrate informal workers in the development of professional collection and recycling infrastructure.

CIVIL SOCIETY

Organizations across the spectrum of civil society can spur action in a multitude of ways. Key actions include:

- Convene cross-sectoral, multinational stakeholders to develop and implement coordinated circular transition strategies and measures.
- Coordinate the development of standards in, for example, circularity definitions, metrics, secondary material quality, and certification.
- Raise awareness on the environmental, social, and health impacts of the electronics lifecycle. Communicate benefits of circular solutions and nudge consumer behavior change in, for example, purchasing decisions and bring-back.
- Elevate and connect circularity of electronics with broader transformations such as the Sustainable Development Goals and digitization.

FINANCE

Significant investments are required to scale the transition to a circular economy for electronics. Different types of financial organizations can play different roles in enabling the change:

- Development banks can provide seed funding to support investments in the establishment of an e-waste management infrastructure in emerging markets.
- Asset managers and impact investors can support access to capital for private sector investments in clean technologies and circular business models via dedicated funds.
- Risk managers can adopt a longer-term perspective and price-in resilience of business models and value chains.
- Financial advisors can also support companies in developing green bonds for investment in clean technologies.

RESEARCH

Research organizations are critical for continuing development of the knowledge base to guide and support the complex and interdependent transition to a circular economy in electronics, including:

- Collect data on e-waste flows and informal workers.
- Advance understanding of the environmental and socioeconomic impacts of circular strategies. Develop metrics to measure impact and progress.
- Develop science-based decision support tools for product design, business models, and policies, to balance and optimize impacts over the lifecycle.
- Understand behavior and change management. Develop effective strategies for both consumer behavior and organizational change.
- Develop new technologies in areas such as automated remanufacturing, refurbishment, sorting, and pre-processing.

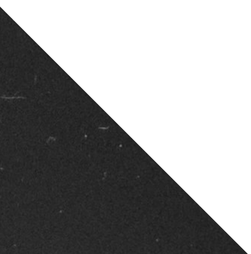
Conclusion

A circular economy is a key component of the much-needed transformation of the electronics value chain towards sustainable development. In a circular economy for electronics, new products use more recycled and recyclable content; products and their components are used for longer; and end-of-use products are collected and recycled to a high standard.

In the transition to a circular economy for electronics, **let's keep aligned to the north stars** of greater human and planetary wellbeing. Circularity is not the end goal in itself, but an important means towards the end goal, a global economic system that enables human and environmental wellbeing. A circular economy for electronics can have profound effects across resource use, climate change, human health, biodiversity, economic wellbeing, and decent work outcomes. Actions are needed to remove barriers and amplify the benefits, as well as to ensure the transition is just and inclusive. **Let's be guided by science**, to develop holistic indicators and set balanced targets, which are crucial to design the transition, monitor the progress and evaluate the impact, in alignment with the north stars.

The transition path to a circular economy is challenged by barriers, many beyond the control of any individual stakeholder. Governments, businesses, civil society, finance institutions, research organizations—**let's team up** to take actions to move the needle. Each of us has a role to play in the calls-to-action, and there are specific actions that we can already take up today. Many leaders across the PACE community and beyond are already taking action. **Let's take ownership** and do what we can to drive the change. The PACE Secretariat looks forward to hearing from and working with you, to map progress, co-create actions, build new partnerships, demonstrate best practices, share learnings, and drive new commitments throughout the year and beyond to drive electronics system change at scale.

Let's get to work!



APPENDIX | Impact Assessment

This Appendix provides more details of the Impact Assessment, synthesized based on inputs from Michelle Steenmeijer (Circle Economy), Shreya Goel (ILO), Hitomi Nakagome (ILO), Elmer Rietveld (TNO), Ton Bastein (TNO), Claudia A. Peña (Life Cycle Initiative; ADDERE R&T), Alexandra Wu (IVL), and several other working group members.

New Products Use More Recycled and Recyclable Content

RESOURCE USE

Replacing virgin materials with recycled content in new product manufacturing will reduce the electronics industry's overall resource use, in particular metals. Using recycled materials in electronics alone is not expected to have a major impact on mining, except for specific metals such as tin and tantalum. From a global perspective, the electronics industry is not the main user of the base metals (e.g. iron, aluminium, copper) or precious metals (e.g. gold, silver) that drive mining decisions (European Commission. Directorate General for Internal Market, Industry, Entrepreneurship and SMEs et al. 2017). Rare earth metals (e.g. neodymium, cerium) and several other critical metals (e.g. cobalt, gallium, indium) used in electronics are often byproducts from the production of aluminum, copper, lead, and zinc (Wilburn 2012). In addition, even in a fully circular economy for electronics, recycled materials will likely not meet the demand of the growing global electronics market (European Commission. Directorate General for Internal Market, Industry, Entrepreneurship and SMEs et al. 2017). In the case of special metals for which the electronics industry represents a significant share of global demand (e.g. tin, tantalum), recycling these materials in electronics could potentially drive a small reduction or avoid an increase in mining activity (Fairphone and Dragonfly Initiative 2017; Parajuly et al. 2019).

CLIMATE CHANGE

Substituting virgin materials with recycled materials will reduce CO_2 emissions from the electronics industry, as the production of recycled materials is on average much less energy intensive (OECD 2017). For instance, the energy footprint of producing a ton of recycled aluminum is 5% that of virgin aluminum production (Material Economics 2018). Recycling of rare earth elements using manual dismantling lowers lifecycle energy consumption by 88% (Sprecher et al. 2014). Even shredding for rare earth metals, which is less efficient than manual dismantling, uses 58% less energy, compared to baseline primary production (Sprecher et al. 2014).

HUMAN HEALTH AND BIODIVERSITY

Increasing recycled content may reduce the negative impacts of resource extraction (e.g. ecotoxicity, deforestation) in specific cases (e.g. tin, tantalum) where the electronics industry is the key user, especially if the extraction is by artisanal and small-scale mines with no environmental performance reporting (Circle Economy 2020a).

If recycled content displaces the need for virgin material processing (including smelting and refining), the impacts on human health and biodiversity will be positive (Miliute-Plepiene and Youhanan 2019; OECD 2017). Rare earth recovered from recycling (either manual dismantling or shredding) has a 81-98% lower human toxicity potential, compared to baseline primary production (Sprecher et al. 2014). Savings with regards to water consumption are also expected, as secondary metal production requires less water than primary metal production, due to the avoidance of intensive consumptive operations in mineral extraction and processing (OECD 2017).

Phasing out already identified hazardous substances (e.g. certain flame retardants, lead, mercury) and potentially next generation hazardous substances (still under debate) can reduce associated adverse health effects for workers in manufacturing, repair, and recycling. There may be beneficial ripple effects if adjacent industries start using the same safer alternative materials.

ECONOMIC WELLBEING

The geographical redistribution of revenues and income from achieving this objective will depend on whether recycling and secondary material production is managed via local or global value chains. For a further assessment on the economic impacts of recycling, see the "economic wellbeing" section under the third objective.

DECENT WORK

Any major employment decline in extraction operations from a reduction in virgin material demand in the electronics industry is unlikely, as mining decisions are not driven by the electronics sector. Nevertheless, more recycled content in new products may result in a decline in jobs in artisanal and small-scale mining, which plays a significant role in the global markets for cobalt, tin, and tantalum, and is especially vulnerable to a reduction in demand for these virgin materials (Montt, Fraga, and Harsdorff 2018; Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) 2017; Circle Economy 2020a). While often exploitative and dangerous, artisanal and small-scale mining provides a livelihood to many that have few other employment opportunities (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) 2017). Reduced demand for mining would mean a loss of income, or cause a shift to unknown alternative forms of income (Circle Economy 2020a). Especially in countries that suffer weak administration and where resource rich areas are ruled by conflict groups, the alternative sources of income are unclear and might lead to vulnerable groups joining these conflict groups (Circle Economy 2020a). The right to organize and demand better working conditions, as well the extension of social protection, skills development, and alternative income-generating opportunities for displaced workers, will be critical factors for a socially inclusive and just transition.

Increasing the use of recycled materials in the electronics sector will bring new opportunities for high-skilled jobs in areas related to material recycling and secondary production. The adoption of new technologies in smelting and (urban) mining and the move towards automation may change the skill set required in the industry. The impact of such a transition on decent work will depend on the extent to which skills development measures are implemented (ILO 2018).

Product or Component Use Life is Significantly Extended

RESOURCE USE

Extending the use life of electronics reduces the material intensity of the industry and is likely to reduce overall use of virgin mineral and fossil resources, or at least slow down the increase in resource use of a growing global electronics market. Extending device use life by 50% could reduce replacement rates by a third. This would have been equivalent to avoiding the accumulation of 50 million end-of-use mobile devices in the United States in 2010 (OECD 2012). Such lifetime extensions are assumed to decrease the demand for new products and the need for end-of-use management, therefore reducing the overall resource use of the electronics industry. Nevertheless, extending the lifetime of electronics products and components alone is not expected to have a major impact on mining (see previous).

CLIMATE CHANGE

The climate impacts of extending product or component lifetimes are beneficial. If it reduces demand for new products, emissions from electronics manufacturing, which are currently concentrated in countries with large shares of carbon-intensive coal-fired power in their energy mix, would be reduced. In most cases, greenhouse gas savings from new production outweigh emissions from reverse logistics and potential energy efficiency improvements of new products (Parajuly et al. 2019; Montalvo, Peck, and Rietveld 2016). Detailed assessments on product level depend on the carbon footprint of material and component production, the electricity mix during the use phase, CO_2 intensity of reverse logistics operations, and on whether sorting, pre-processing, recycling, and reuse operations are strategically planned on the regional and global level (Parajuly et al. 2019). For instance, for a smartphone, the production phase is the main contributor of greenhouse gas emissions in the mobile phone lifecycle: usually accounting for more than 75% of total emissions (Clément, Jacquemotte, and Hilty 2020). Modular design strategies for smartphones have the potential to reduce climate impact by 28% per year in use, based on a repair scenario that extends the lifetime from three to five years (Proske, Clemm, and Richter 2016). Another study based on the UK context notes that extending the lifetime of toasters by 10% would result in net savings of around 4,000 tons of CO_2 equivalent, and prevent around 60 tons of waste per annum.

HUMAN HEALTH AND BIODIVERSITY

If longer use life reduces new product manufacturing and e-waste generation, it will benefit human health and biodiversity by reducing environmental hazards associated with the production phase and waste management. Electronics manufacturing has been linked to heavy-metal soil pollution, which poses high carcinogenic and non-carcinogenic risks to the public, especially to children and those living in the most severely polluted regions (Wu et al. 2018). Air pollution and toxic wastewater can also result in health risks for local people living around the industry plants (van der Velden and Taylor 2017). Additionally, diminished e-waste generation is expected to lead to a decrease in the exposure of local people and wildlife to hazardous substances, as well as a reduction in air, water, and soil pollution currently associated with e-waste management (Laurenti, Moberg, and Stenmarck 2017; Forti et al. 2020).

ECONOMIC WELLBEING

Increasing the use life of electronics products and components will likely provide a benefit for economic wellbeing, driven by a new generation of sustainable enterprises and business models. There is an opportunity for enterprises focused on repair, refurbishment, resale, and product-as-a-service. The global value opportunity of refurbishment and reuse is estimated at $10-$20 billion for ICT devices alone, generating new business models and sustainable enterprises (Lacy, Long, and Spindler 2020). In Europe, implementing circular strategies in electronics aimed at increasing the lifetime of a product or component (i.e. refurbishment, re-use, remanufacturing) is expected to lead to an increase of 0.02-0.11% in GDP (Best, Duin, and Chelminska 2018).

There might be trade-offs in some countries if potential reductions in primary material sourcing and new product manufacturing are not balanced by new economic activity. How improved GDP, revenues, and income from electronics life extension will be distributed depends on whether reuse is managed via local or global value chains.

DECENT WORK

Extending the use life of electronics products and components could lead to potential trade-offs from an employment perspective. Assuming that the achievement of this objective results in a reduced demand for new electronics products, job losses might be observed in electronics manufacturing, which is concentrated in emerging markets (Montt, Fraga, and Harsdorff 2018; Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development 2017; Circle Economy 2020a). Such a reduction could also reduce the number of low-threshold jobs that could pull many out of poverty, for instance women, who account for a significant share of employment in low-paid electronics manufacturing jobs in low- and middle-income countries (Circle Economy 2020a). Additional job or income losses may occur in some mining, especially artisanal and small-scale mining in low-income countries (see "decent work" under the first objective).

On the other hand, new job opportunities are expected to emerge in repair, refurbishment, second-hand markets, and product-as-a-service, especially in countries where the products are consumed (Montt, Fraga, and Harsdorff 2018; ILO 2019). How many jobs will be created is still unclear. Many studies predict an increase in demand for jobs aimed at increasing the use life of electronic products (see Montalvo, Peck, and Rietveld 2016), while others predict that the implementation of such strategies will have a minimal effect on total job creation: for instance, a net increase of 0-0.04% in Europe (Best, Duin, and Chelminska 2018). The quality and safety of the jobs created is unclear, and will depend on the outcomes of decision-making processes between policymakers, companies, and workers. Additionally, the rise of new business models such as products-as-a-service also raises some uncertainty regarding the organization of work.

End-of-Use Products are Collected and Recycled to a High Standard

RESOURCE USE

Greater volumes and quality of secondary materials will allow for the substitution of virgin materials by recycled materials in new product manufacturing. The recycling technique used will influence the recovery rate and displacement of virgin material production. While manual disassembly allows for, in principle, most electronic material to be recovered, shredding leads to lower recovery rates (OECD 2012). Nevertheless, end-of-use collection and recycling of electronics alone is not expected to have a major impact on mining (see previous).

CLIMATE CHANGE

If end-of-use products are collected and recycled to a high standard, substituting virgin materials with recycled materials will reduce greenhouse gas emissions from the electronics industry. The extent of the reduction potential will be dependent on the recycling process and efficiency. In particular, certain electronic products (such as refrigerators and air conditioners) use potent greenhouse gases such as fluorinated gases, with much higher global warming potential than CO_2. Proper collection and recycling of these products will therefore be crucial for greenhouse gas emission reduction (GIZ 2017).

HUMAN HEALTH AND BIODIVERSITY

Electronics may contain hazardous substances that are not dangerous during normal use, but can cause environmental and health damage if recycling is not managed appropriately, for example when e-waste is manually broken down and dismantled, burned, leached, and melted without adequate protection measures, which is often the case in informal recycling. By transitioning to recycling with high environmental and safety standards, health hazards associated with poorly regulated e-waste recycling systems, including skin diseases, altered neurodevelopment, respiratory and cardiovascular problems, can be avoided (Forti et al. 2020). Local ecotoxicity in the form of air, soil, and water pollution from pollutants released during unregulated recycling processes or dumping will be reduced. This has positive health effects for local people, and reduces the exposure of local wildlife to hazardous substances (Laurenti, Moberg, and Stenmarck 2017; Forti et al. 2020). A potential reduction in informal e-waste treatment or landfilling would also reduce pollution in the food chain and drinking water, and lead to an increase agricultural yields (Circle Economy 2020a).

ECONOMIC WELLBEING

The total value of raw materials in global e-waste is estimated at $57 billion, mainly coming from iron, copper and gold (Forti et al. 2020). The magnitude of this economic value is echoed by other studies: recovery of valuable materials in the information and communications technology industry (ICT) alone is estimated to present a $2.5-$5 billion value opportunity (Lacy, Long, and Spindler 2020); China's e-waste had a recycling potential estimated at $16 billion in 2010, which is anticipated to reach $73 billion by 2030 due to the increasing consumption of electronics (Zeng et al. 2016). It should be noted that the costs to recover that value need to be factored in. Added value from (urban) mining will depend on improvements in recyclability, and the increased efficiency of recycling processes to reduce processing costs for recovering the raw material value in e-waste.

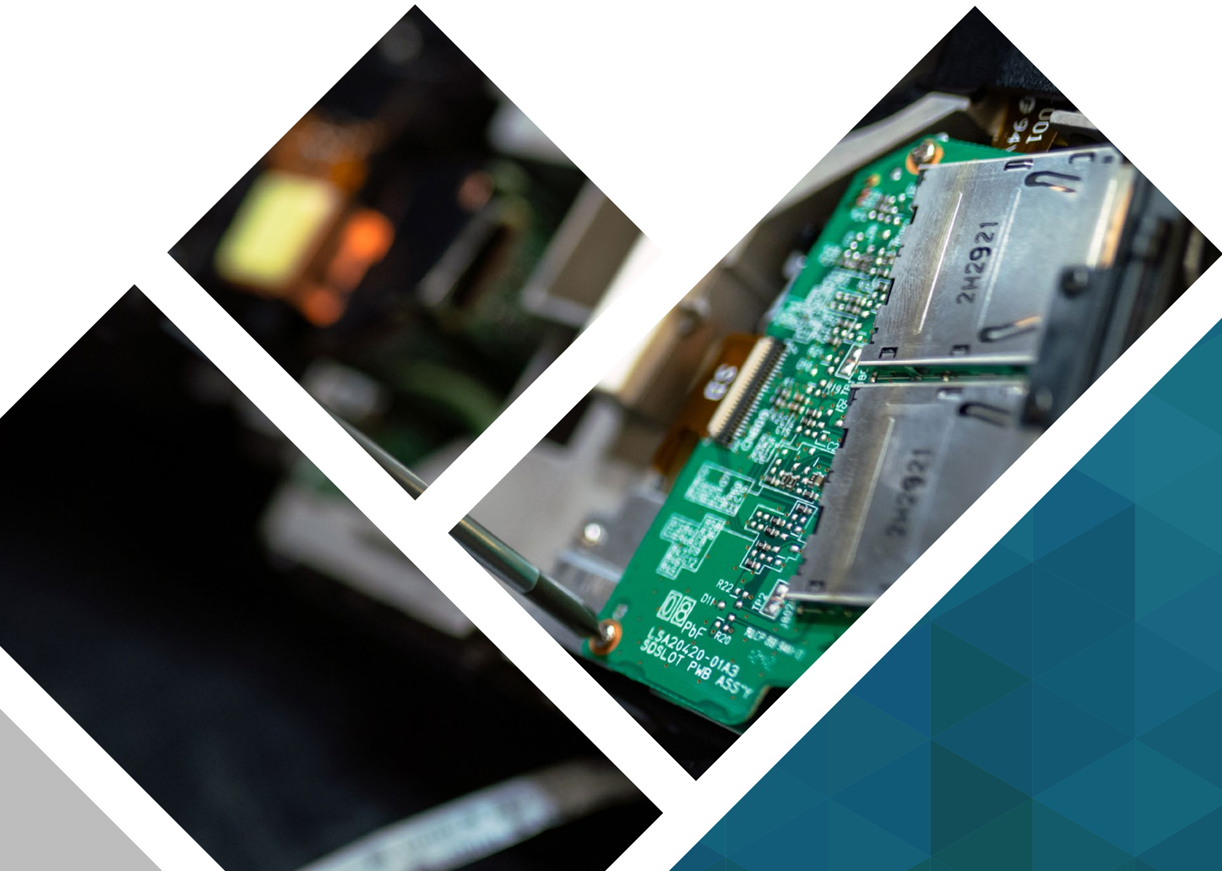
Increasing end-of-use collection and recycling is expected to increase value in downstream operations and reduce value in upstream ones, assuming that secondary material production displaces some primary extraction or processing. The results of this transition will be highly dependent on whether countries choose a global approach to recycling, or if collection, sorting, and recycling is conducted at the local level, close to the centers of consumption. Recycling is not location-specific per se, unlike mining. Therefore, the recycling industry can be introduced in a region with lower economic prosperity, whether that be on a more local/country level, or globally.

DECENT WORK

Increasing end-of-use collection and recycling is expected to increase jobs in these activities. Manual sorting and dismantling are usually more effective at extracting and creating value from e-waste than shredding (ILO 2019). These tasks are labor-intensive, and the entry level for these jobs is relatively low. Several studies have confirmed that better management of this fast-growing waste stream can be an engine of job creation in both low- and high-income countries (see ILO 2019). Jobs in the reprocessing of lead and secondary precious metals, for instance, are predicted to grow by 15% and 11.2% respectively by 2030 (ILO 2018). One study estimated that every 1,000 tons of e-waste processed in the UK creates 40 additional jobs in collection and sorting (Friends of the Earth 2010).

In some developing countries, the e-waste recycling sector remains mostly informal. Formalizing the recycling economy could bring fair wages for workers, reduce child labor, and provide safer working conditions (ILO 2019; WHO n.d.). While there are improvement opportunities, it is still uncertain whether a shift to greater formality in the recycling industry will create or take away jobs, and whether the transition will be inclusive for the informal sector and vulnerable communities (ILO 2019).

It should be noted that actual impacts, in any of the five areas assessed, are affected by many different factors and trends in society, for example global population, behavioral and consumption patterns, and cultural and socio-economic context. How each of the impact areas will change over time is an aggregated result of forces often pulling in different directions. A circular transition is just one of these forces, and by itself cannot guarantee the net impact to move in a certain direction. This report analyzes possible impacts from increased circularity alone, without considering other ongoing changes.



ENDNOTES

1. Interested readers can refer to the work of the World Economic Forum, Accenture, the UN E-waste Coalition, and PACE.

2. While we aim to build a unified and global perspective on electronics designed for the circular economy, we recognize a wide variety of issues, maturity, and priorities for circularity across different parts of the world.

3. Ellen MacArthur Foundation's three circular economy principles: design out waste and pollution; keep products/materials in use; regenerate natural systems.

4. All five impact categories are affected by many different factors and trends in society. How each of them will change over time is an aggregated result of forces often pulling in different directions. Circular transition is just one of these forces, and by itself cannot guarantee the net impact to move in a certain direction. This report analyzes possible impacts from increased circularity alone, without considering other ongoing changes.

5. A full definition of decent work by the International Labour Organization is: "Decent work sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives, and equality of opportunity and treatment for all women and men."

6. The term "consumer" refers broadly to individuals, governments, businesses, and organizations buying and using electronics products.

7. Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal. The multilateral treaty became effective in 1992 and has been signed by 188 parties (Secretariat of the Basel Convention n.d.).

8. First steps towards standardization are underway (e.g. ISO/TC 323).

9. UNIDO - GEF (2017), Project 5554: "Strengthening of National Initiatives and Enhancement of Regional Cooperation for the Environmentally Sound Management of POPs in Waste of Electronic or Electrical Equipment (WEEE) in Latin-American Countries". (UNIDO n.d., 2020).

REFERENCES

Accenture. 2020. 'No Time to E-Waste: The Critical Role for a Circular Economy in Enterprise Technology'. https://view.publitas.com/p222-16229/no-time-to-ewaste/page/1 *

Applia, DigitalEurope, LightingEurope, EurcoLight, Orgalim, and WEEE Forum. 2019. 'Joint Industry Comments on Modulating Producers' Financial Contributions for Waste Electrical and Electronic Equipment', 25 July 2019. https://weee-forum.org/wp-content/uploads/2019/07/Joint-industry-comments-modulation-of-producers%E2%80%99-financial-contributions-for-WEEE_2019_07_25_final.pdf. *

Atea Sustainability Focus. 2019. 'Circular Economy, The Foundation of a Sustainable IT Industry'. https://www.atea.dk/media/7058/asf-report-2019_circular-economy.pdf *

Atea Sustainability Focus. 2020. 'Closing the Loop on Materials'. https://www.atea.se/media/9067/asf_report-2020-closing-the-loop.pdf. *

Baldé, C.P., V. Forti, V. Gray, R. Kuehr, and P. Stegmann. 2017. 'The Global E-Waste Monitor 2017: Quantities, Flows, and Resources'. United Nations University, International Telecommunication Union, International Solid Waste Association. https://www.relec.es/relecv3/images/GESTI%C3%93N%20DE%20RAEE/Global-E-waste_Monitor_2017__electronic_single_pages_.pdf *

Best, A., L. Duin, and M. Chelminska. 2018. 'Macroeconomic and Societal Impacts of Mainstreaming the Circular Economy'. https://circular-impacts.eu/sites/default/files/D5.3_Macroeconomic-and%20societal-impacts_FINALv2.pdf.

California Code of Regulations. Title 22. Social Security. Division 4.5 Environmental Health Standards for the Management of Hazardous Waste. §66273.73 Authorization for Treatment (Processing) Activities, (C) (2).

CalRecycle. 2018. 'The Future of Electronic Waste Management in California, Project Summary and Recommendations'. https://www2.calrecycle.ca.gov/Docs/Web/112362. *

Casey, K., M. Lichrou, and C. Fitzpatrick. 2019. 'Treasured Trash? A Consumer Perspective on Small Waste Electrical and Electronic Equipment (WEEE) Divestment in Ireland'. *Resources, Conservation and Recycling* 145: 179–89. doi:10.1016/j.resconrec.2019.02.015. *

Circle Economy. 2018. 'The Circular Phone: Legal, Operational and Financial Solutions to Unlock the Potential of the Fairphone as a Service Model.' https://assets.website-files.com/5d26d80e8836af2d12ed1269/5dea57f99d58652614589821_26616471-0-The-Circular-Phone.pdf. *

Circle Economy. 2020a. 'Exploring the Global Environmental and Socio-Economic Effects of Pursuing a Circular Economy, Case Studies on Denim Jeans and Mobile Phones'. https://www.circle-economy.com/resources/exploring-the-global-environmental-and-socio-economic-effects-of-pursuing-a-circular-economy.

Circle Economy. 2020b. 'The Circularity Gap Report 2019'. https://assets.website-files.com/5d26d80e8836af2d12ed1269/5dea43f562f8ac3e3113fe51_ad6e59_ba1e4d16c64f44fa94fbd8708eae8e34_compressed.pdf.

Circular Electronics Partnership. 2021. 'Circular electronics roadmap: an industry strategy towards circularity'.

Clément, L., Q.E.S. Jacquemotte, and L.M. Hilty. 2020. 'Sources of Variation in Life Cycle Assessments of Smartphones and Tablet Computers'. *Environmental Impact Assessment Review* 84 (September): 106416. doi:10.1016/j.eiar.2020.106416.

Ellen MacArthur Foundation. 2018a. 'Circular Consumer Electronics, An Initial Exploration.' https://www.ellenmacarthurfoundation.org/assets/downloads/Circular-Consumer-Electronics-FV.pdf. *

Ellen MacArthur Foundation. 2018b. 'Remanufactured & Refurbished Parts: Busting Myths Surrounding Their Impact on New Product Sales.' 2018. https://emf-assets.s3.amazonaws.com/media/18/CoreCentric_White_Paper_Co.Project.pdf.

European Commission. 2020. 'A New Circular Economy Action Plan, For a Cleaner and More Competitive Europe'. Brussels. https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF. *

European Commission. Directorate General for Internal Market, Industry, Entrepreneurship and SMEs, TNO, Deloitte Sustainability, Bureau de Recherches Géologiques et Minières, and British Geological Survey. 2017. 'Study on the Review of the List of Critical Raw Materials, Final Report'. Website. Luxembourg: European Commission. http://op.europa.eu/en/publication-detail/-/publication/08fdab5f-9766-11e7-b92d-01aa75ed71a1/language-en.

European Environment Agency. 2017. 'Circular by Design, Products in the Circular Economy'. Luxembourg. https://www.eea.europa.eu/publications/circular-by-design. *

European Parliament, and European Council. 2012. 'Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE)'. *Official Journal of the European Union* (197/38). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019.

Fairphone, and Dragonfly Initiative. 2017. 'Smartphone Material Profiles: Opportunities for Improvement in Ten Supply Chains'. https://www.fairphone.com/wp-content/uploads/2017/05/SmartphoneMaterialProfiles_May2017.pdf.

Forti, V., C.P. Baldé, R. Kuehr, and G. Bel. 2020. 'The Global E-Waste Monitor 2020: Quantities, Flows and the Circular Economy Potential'. Bonn, Geneva and Rotterdam: United Nations University/United Nations Institute for Training and Research, International Telecommunication Union, and International Solid Waste Association. https://collections.unu.edu/view/UNU:7737.

Friends of the Earth. 2010. 'More Jobs, Less Waste: Potential for Job Creation Through Higher Rates of Recycling in the UK and EU'. https://www.foeeurope.org/sites/default/files/publications/foee_more_jobs_less_waste_0910.pdf

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit. 2017. 'Global Roadmap on ODS Bank Management'. Eschborn. https://www.giz.de/en/downloads/giz2017-en-global-roadmap.pdf.

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit. 2020. 'Incentive Based Collection of E-Waste in Ghana'. Accra. https://www.giz.de/en/downloads/giz2020_en_incentive_based_collection_e_waste%20_ghana.pdf.

Gurita, N., M. Fröhling, and J. Bongaerts. 2018. 'Assessing Potentials for Mobile/Smartphone Reuse/Remanufacture and Recycling in Germany for a Closed Loop of Secondary Precious and Critical Metals'. *Journal of Remanufacturing* 8: 1–22. doi:10.1007/s13243-018-0042-1.

Holgate, P. 2018. 'How Do We Tackle the Fastest Growing Waste Stream on the Planet?' *World Economic Forum* (blog). 9 February 2018. https://www.weforum.org/agenda/2018/02/how-do-we-tackle-the-fastest-growing-waste-stream-on-the-planet/. *

ILO: International Labour Organization. 2014. 'An Enabling Environment for Sustainable Enterprises'. Fact sheet. Geneva: International Labour Organization, Small and Medium Enterprises Unit (SME) Enterprises Department. http://www.ilo.org/empent/Publications/WCMS_175476/lang--en/index.htm

ILO: International Labour Organization. 2015. 'Guidelines for a Just Transition towards Environmentally Sustainable Economies and Societies for All'. Geneva. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf.

ILO: International Labour Organization. 2018. 'World Employment and Social Outlook 2018: Greening with Jobs'. https://www.ilo.org/global/publications/books/WCMS_628654/lang--en/index.htm

ILO: International Labour Organization. 2019. 'Decent Work in the Management of Electrical and Electronic Waste (e-Waste)'. Geneva: International Labour Organization, Sectoral Policies Department. https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_673662.pdf *

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF). 2017. 'Global Trends in Artisanal and Small-Scale Mining (ASM): A Review of Key Numbers and Issues'. Winnipeg: IISD. https://www.iisd.org/system/files/publications/igf-asm-global-trends.pdf

Lacy, P., W. Spindler, and J. Long. 2020. 'The Circular Economy Handbook'. Accenture. https://www.accenture.com/us-en/about/events/the-circular-economy-handbook.

Laubinger, F., E. Lanzi, and J. Chateau. 2020. 'Labour Market Consequences of a Transition to a Circular Economy: A Review Paper'. 162. OECD Environment Working Papers. Paris: OECD. http://www.nowpublishers.com/article/Details/IRERE-0120. *

Laurenti, R., Å. Moberg, and Å. Stenmarck. 2017. 'Calculating the Pre-Consumer Waste Footprint: A Screening Study of 10 Selected Products'. *Waste Management & Research: The Journal of the International Solid Wastes and Public Cleansing Association, ISWA* 35 (1): 65–78. doi:10.1177/0734242X16675686.

Life Cycle Initiative. 2020. 'Using Life Cycle Assessments to Achieve a Circular Economy'. https://www.lifecycleinitiative.org/wp-content/uploads/2020/07/Using-LCA-to-achieve-circular-economy-LCI-July-2020.pdf.

Magalini, F., and J. Huisman. 2018. 'WEEE Recycling Economics, The Shortcomings of the Current Business Model'. UNU: United Nations University, Vie Scycle. https://asegre.com/wp-content/uploads/2018/10/UNU-EERA-brochure-Online-FINAL.pdf *

Material Economics. 2018. 'The Circular Economy: A Powerful Force for Climate Mitigation, Transformative Innovation for Prosperous and Low-Carbon Industry'. https://materialeconomics.com/publications/the-circular-economy.

McCarthy, A., and P. Börkey. 2018. 'Extended Producer Responsibility (EPR) and the Impact of Online Sales'. OECD Environment Working Papers. Paris: OECD. https://www.oecd.org/environment/waste/policy-highlights-extended-producer-responsibility-and-the-impact-of-online-sales.pdf. *

Miliute-Plepiene, J., and L. Youhanan. 2019. 'E-Waste and Raw Materials: From Environmental Issues to Business Models'. IVL: Swedish Environmental Research Institute. http://ewaste.education/pdf/E-M@S_IVL_eminingbook_English.pdf

Montalvo, C., D. Peck, and E. Rietveld. 2016. 'A Longer Lifetime for Products: Benefits for Consumers and Companies'. European Parliament. Directorate General for Internal Policies. https://www.europarl.europa.eu/RegData/etudes/STUD/2016/579000/IPOL_STU(2016)579000_EN.pdf.

Montt, G., F. Fraga, and M. Harsdorff. 2018. 'The Future of Work in a Changing Natural Environment: Climate Change, Degradation and Sustainability'. Geneva: International Labour Organization. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---cabinet/documents/publication/wcms_644145.pdf.

Needhidasan, S., M. Samuel and R. Chidambaram 2014. 'Electronic waste – an emerging threat to the environment of urban India'. *Journal of Environmental Health Science & Engineering*. doi:10.1186/2052-336X-12-36.

OECD. 2012. 'Case Study on Critical Metals in Mobile Phones'. https://www.oecd.org/environment/waste/Case%20Study%20on%20Critical%20Metals%20in%20Mobile%20Phones.pdf.

OECD. 2017. 'Mapping Support for Primary and Secondary Metal Production'. Vol. 135. OECD Environment Working Papers. Organisation for Economic Co-operation and Development. doi:10.1787/4eaa61d4-en.

PACE, and World Economic Forum. 2019. 'A New Circular Vision for Electronics, Time for a Global Reboot'. Geneva: World Economic Forum. https://pacecircular.org/sites/default/files/2019-03/New%2BVision%2Bfor%2BElectronics-%2BFinal%20%281%29.pdf. *

PACE, World Economic Forum, and Accenture. 2019. 'Harnessing the Fourth Industrial Revolution for the Circular Economy, Consumer Electronics and Plastics Packaging'. Geneva: World Economic Forum. https://www.weforum.org/whitepapers/harnessing-the-fourth-industrial-revolution-for-the-circular-economy-consumer-electronics-and-plastics-packaging/. *

PACE. 2019. 'Circular Value Creation, Lessons from the Capital Equipment Coalition'. Davos. https://pacecircular.org/sites/default/files/2019-03/Circular_value_creation_2019_v7_WEB.pdf. *

Parajuly, K., R. Kuehr, A.K. Awasthi, C. Fitzpatrick, J. Lepawsky, E. Smith, R. Widmer, and X. Zeng. 2019. 'Future E-Waste Scenarios'. Bonn and Osaka: StEP, UNU ViE-SCYCLE and UNEP IETC. https://www.step-initiative.org/files/_documents/publications/FUTURE%20E-WASTE%20SCENARIOS_UNU_190829_low_screen.pdf.

Pouikli, K. 2020. 'Concretising the Role of Extended Producer Responsibility in European Union Waste Law and Policy through the Lens of the Circular Economy'. *ERA Forum* 20 (4): 491–508. doi:10.1007/s12027-020-00596-9. *

Proske, M., C. Clemm, and N. Richter. 2016. 'Life Cycle Assessment of the Fairphone 2'. Berlin: Fraunhofer IZM. https://www.fairphone.com/wp-content/uploads/2016/11/Fairphone_2_LCA_Final_20161122.pdf.

Ranta, V., L. Aarikka-Stenroos, P. Ritala, and S.J. Mäkinen. 2018. 'Exploring Institutional Drivers and Barriers of the Circular Economy: A Cross-Regional Comparison of China, the US, and Europe'. *Resources, Conservation and Recycling* 135 (August): 70–82. doi:10.1016/j.resconrec.2017.08.017. *

Secretariat of the Basel Convention. n.d. 'Overview'. Accessed 1 December 2020a. http://www.basel.int/Implementation/Ewaste/Overview/tabid/4063/Default.aspx.

Secretariat of the Basel Convention. n.d. 'Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal'. Accessed 1 December 2020b. http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx#enote1.

Sprecher, B., Y. Xiao, A. Walton, J. Speight, R. Harris, R. Kleijn, G. Visser, and G.J. Kramer. 2014. 'Life Cycle Inventory of the Production of Rare Earths and the Subsequent Production of NdFeB Rare Earth Permanent Magnets'. *Environmental Science & Technology* 48 (7): 3951–58. doi:10.1021/es404596q.

STEP. 2020. 'Case studies and approaches to building partnerships between the informal and the formal sector for sustainable e-waste management'. https://step-initiative.org/files/_documents/publications/Partnerships-between-the-informal-and-the-formal-sector-for-sustainable-e-waste-management.pdf.

UNIDO: United Nations Industrial Development Organization. 2020. Proyecto Residuos Electrónicos América Latina. Quiénes Somos. https://residuoselectronicosal.org/quienes-somos/.

UNIDO: United Nations Industrial Development Organization. n.d. 'Regional Cooperation on E-Waste Management in Latin American Countries'. Accessed 1 December 2020. https://www.unido.org/ewastelac.

United Nations Global Compact, and Accenture. 2019. 'The Decade to Deliver: A Call to Business Action'. CEO Study on Sustainability. https://www.accenture.com/_acnmedia/PDF-109/Accenture-UNGC-CEO-Study.pdf#zoom=40.

United Nations. 2015. Transforming Our World. The 2030 Agenda for Sustainable Development. A/RES/70/1. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

Velden, M. van der, and M.B. Taylor. 2017. 'Sustainability Hotspots Analysis of the Mobile Phone Lifecycle'. Oslo: University of Oslo/SMART. https://zenodo.org/record/1146844/preview/Sustainability%20Hotspots%20Analysis%20of%20the%20Mobile%20Phone%20Lifecycle.pdf.

WEEE Forum. 2018. 'Implications of the (New) Open Scope of Directive 2012/19/EU on Meeting the WEEE Targets'. http://weee-forum.org/wp-content/uploads/2019/06/open_scope_issue_paper_final-1.pdf. *

WEEE Forum. 2019. 'Successfully Countering Online Free-Riders'. http://weee-forum.org/wp-content/uploads/2019/06/countering_online_free-riders_consultation_issue_paper-2.pdf. *

WHO: World Health Organization. n.d. 'E-Waste on Children's Health'. Accessed 20 December 2020. https://www.who.int/teams/environment-climate-change-and-health/settings-populations/children/e-waste.

Wilburn, D.R. 2012. 'Byproduct Metals and Rare-Earth Elements Used In the Production of Light-Emitting Diodes, Overview of Principal Sources of Supply and Material Requirements for Selected Markets'. Scientific Investigations Report 2012–5215. U.S. Geological Survey. https://pubs.usgs.gov/sir/2012/5215/pdf/sir2012-5215.pdf.

World Economic Forum. 2020. Global Battery Alliance. Action. https://www.weforum.org/global-battery-alliance/action.

WRAP. 2017. 'Switched on to Value: Powering business change'. https://www.wrap.org.uk/sites/files/wrap/Switched%20on%20to%20value%20-%20Powering%20business%20change_0.pdf.

Wu, W., P. Wu, F. Yang, D. Sun, D.-X. Zhang, and Y.-K. Zhou. 2018. 'Assessment of Heavy Metal Pollution and Human Health Risks in Urban Soils around an Electronics Manufacturing Facility'. *Science of The Total Environment* 630 (July): 53–61. doi:10.1016/j.scitotenv.2018.02.183.

Zeng, X., R. Gong, W.-Q. Chen, and J. Li. 2016. 'Uncovering the Recycling Potential of "New" WEEE in China'. *Environmental Science & Technology* 50 (3): 1347–58. doi:10.1021/acs.est.5b05446.

PHOTOS

Cover, Chris Ried/Unsplash; Contents, Thisisengineering/Unsplash; 9, Hector Martinez/Unsplash; 11, Thisisengineering/Unsplash; 13, Shane McLendon/Unsplash; 19, Danny Feng/Unsplash; 23, Laura Ockel/Unsplash; 26, Science in HD/Unsplash; 29, Ilya Pavlov/Unsplash; 45, Myriam Jessier/Unsplash; 47, Ashkan Forouzani/Unsplash; 51, Thisisengineering/Unsplash.

PACE
Platform for Accelerating the Circular Economy

Bezuidenhoutseweg 105
2594AC The Hague
The Netherlands
www.pacecircular.org

February 2021