PACE
Platform for Accelerating the Circular Economy

Circular Economy Action Agenda
WORKING PAPER

CAPITAL EQUIPMENT

In partnership with

accenture

CIRCLE ECONOMY

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

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The Circular Economy Action Agenda for Capital Equipment has drawn insights from existing reports from Circle Economy and the Capital Equipment Coalitions in Europe and North America, complemented by discussions with and review by the following organizations and experts:

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The views and opinions expressed in this working paper are synthesized by the authors based on literature and consultations, and therefore do not necessarily reflect the official positions of the PACE Secretariat, Accenture, Circle Economy, or the individual company and government involved. As each organization has unique circumstances, recommendations in this working paper are not intended to replace professional advice tailored to individual organizations.

The Action Agenda for Capital Equipment is a Working Paper, which contains preliminary research, analysis, findings, and recommendations. It is circulated to stimulation timely discussion and critical feedback, and to influence ongoing debate on emerging issues. A working paper may eventually be published in another form and its content may be revised.

IN SUPPORT OF THE CIRCULAR ECONOMY ACTION AGENDA

MARTIJN BOELENS | CTO, Lely

"Working on circular business models with the aim of improving the circularity of companies, asks for collaboration throughout the supply chain. Clear action is needed, to be taken together with suppliers and customers. The Circular Economy Action Agenda sets direction with concrete actions for all companies to make the next step. It gave Lely insights on why and how to work on circularity within our own operations and processes, alongside our commitments to improve on-farm circularity."

MARTIJN LOPES CARDOZO | CEO, Circle Economy

"The Circular Economy Action Agenda delivers the necessary insights and a strong narrative for action within five 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."

JEROEN COX | Senior Manager Energy & Environment, KPN

"Over the past several years, KPN has built a strong track record in doing business in a sustainable manner. We firmly believe that this is vital if we are to preserve our competitive advantage and secure the long-term interests of all our stakeholders. With our services we intend to also contribute to solving societal issues, like reducing waste and promoting circular solutions. Knowing that cooperation is key to realizing our circular ambitions, we welcome the PACE Action Agenda and hope it will align the capital equipment sector behind shared goals."

ARNOUT DAMEN | CEO, Damen Shipyards Group

"The PACE Action Agenda addresses the necessity of change and opportunities for new business models, as well as the many hurdles that need to be overcome to make the transition towards a circular economy in capital equipment. We foresee major improvements in the coming years on three aspects of our business; sustainability, servitization supported by digitalization, and operational excellence. Rather than distinct strategic spearheads, these are strongly interconnected. The report clearly shows circularity goals aligning with all three objectives, and I therefore wholeheartedly support its calls to action."

FRANK VAN DIJCK | CTO, Vanderlande

"The development of a sustainable society is one of the greatest challenges facing us in the 21st century, which is why Vanderlande's belief is that now—more than ever—is the time to act and collaborate. We know that accelerating the circular economy requires a depth of knowledge and the participation of stakeholders across all sectors. This is why we are pleased with the guidance the PACE Action Agenda provides, and the direction the calls-to-action gives us all."

FRANS VAN HOUTEN | CEO, Philips

"Like all major transitions in human history, the shift from a linear to a circular economy will be a tumultuous one. It will feature heroes and pioneers, naysayers and obstacles, and moments of victory and doubt. If we persevere, however, we will put our economy back on a path of growth and sustainability. Perhaps five hundred years from now, people will look back and say it was the Circular Economy Revolution that ushered in a new era of wisdom and prosperity."

LUCA MEINI | Head of Circular Economy, Enel Holding

"For Enel, the circular economy is a strategic driver to further improve the sustainability and competitiveness of the business model through continuous innovation and open collaboration. We consider decarbonization and circular economy strongly interconnected, and to be pursued in an integrated way to positively contribute to the planet's environmental challenges."

JAMES SULLIVAN | Global Lead Circular Economy, SAP

"Technologies such as cloud, big data management, artificial intelligence, and geospatial analytics can accelerate our progress towards a truly inclusive, circular economy. Through the Circular Economy Action Agenda, we can collectively deliver real impact by providing powerful new tools to businesses, governments, and civil society for integrated decision-making that will help drive a better and faster transformation."

MARIJN VERVOORN | Director Sustainability Strategy, ASML

"At ASML, we believe the circular economy is vital to ensure the future success and competitiveness of the semiconductor equipment industry. With an emphasis on modular design and innovation we aim to extend our products' lifetime through upgrades and refurbishment. By highlighting the most urgent actions needed to further advance circularity in the field, the CE Action Agenda provides a clear way forward."

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.

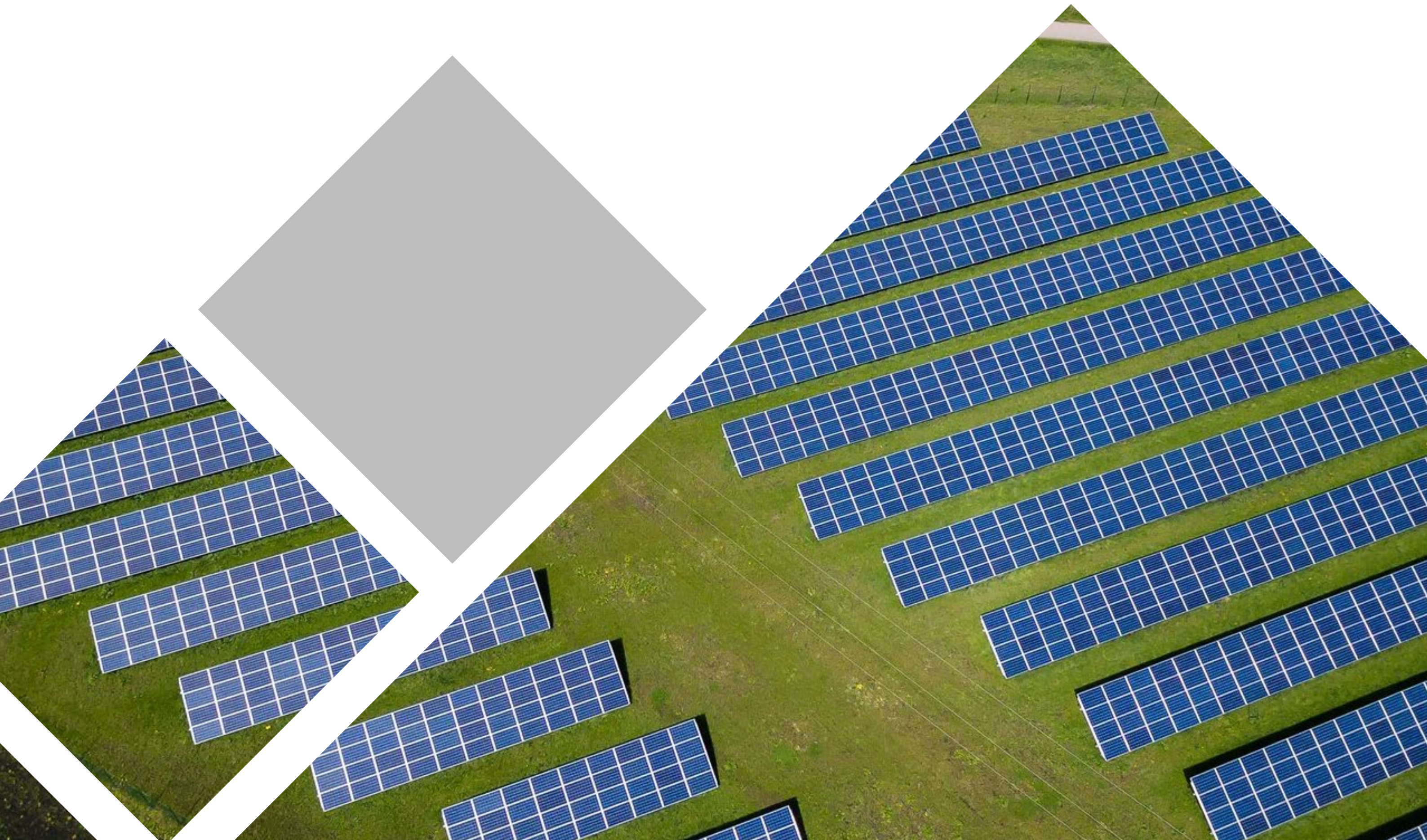
There is another way. By working towards a circular economy we can transition to a system that is designed to prevent waste and pollution, keep products and materials in use, and regenerate natural systems—leading to a more resilient economy.

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 publications 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.

Capital equipment incorporates a vast range of physical hardware, from data servers to medical scanners, power plants to ships. These products are essential for serving society's needs around the world, while enabling opportunities for industries such as ICT, energy, healthcare, and logistics. Yet, capital equipment manufacturing consumes 7.2 billion tons of raw materials globally each year (Circle Economy, 2019). It is critical that we optimize the inventory of capital equipment and its uses through circular strategies to reduce and minimize environmental impact, address resource scarcity, increase market resilience, and develop value chain sustainability (Circle Economy and PACE, 2020).

How can circular strategies contribute? Three objectives have been formulated by applying circular economy principles to capital equipment: products and components follow circular and digitization principles for minimal resource consumption and increased reuse strategies; value retention is maximized by optimizing the product and component utilization rate and use life, with the help of servitization and digitalization; end-of-use equipment and components are returned for reuse via efficient reverse logistics.

Despite the important opportunities, a circular transition for the capital equipment industry faces many barriers beyond the control of any individual stakeholder. From literature study and workshops carried out for this working paper, 16 key barriers have been identified that work collectively to slow progress towards a circular economy for capital equipment.

Building on the 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 of the transition:

1. Provide Incentives and Guidance for Product Design for Circularity
2. Transform Customer Perception and Procurement Models to Increase Market Demand for Circular Products and Services
3. Leveraging Servitization, Guide and Support Product Use Rates and Use Life Extension
4. Increase End-of-Use Product Return
5. Enable Efficiency and Transparency in Compliant and Responsible Reverse Logistics
6. Collaborate across Value Chain and Sectors to Strategically Plan Reuse Operations
7. Increase Incentives for Investment in Reuse Technologies and Facilities
8. Enable Manufacturers to Increase Sourcing of Secondary Components
9. Leverage Digital Technologies for the Circular Transition
10. Evaluate the Contribution of Circular Capital Equipment to the Sustainable Development Goals

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.

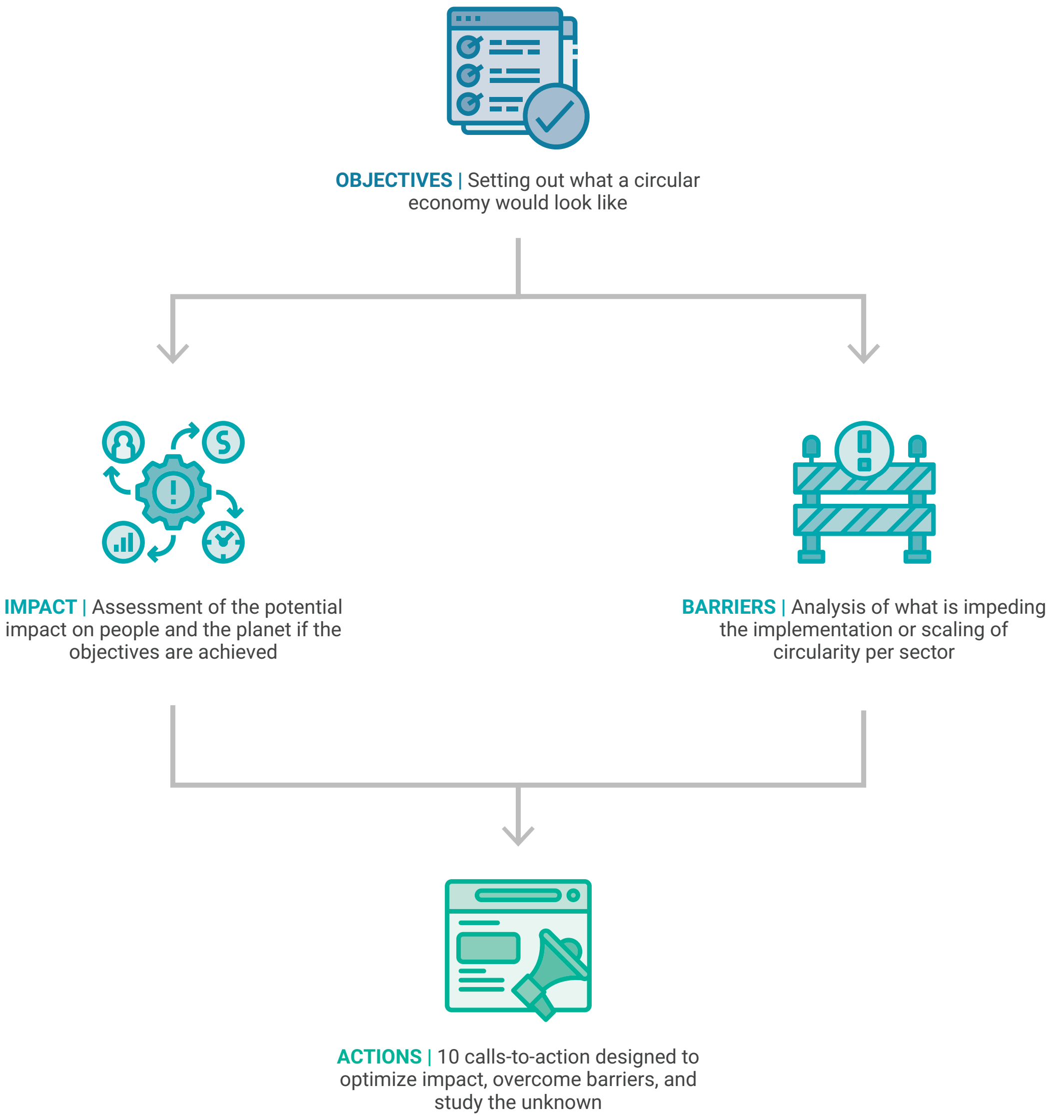
ABOUT THE ACTION AGENDA

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.

The Action Agenda builds on the existing literature and insights to identify actions needed for a better and faster transition to a circular economy. 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 for Capital Equipment

This working paper builds on the existing research of Circle Economy and the Capital Equipment Coalition Europe, with additional insights from consultations with the organizations and experts mentioned above. In total, experts from 14 organizations have contributed via phone interviews, group discussions and substantial written inputs for this Action Agenda, in addition to those contributing to the materials referenced herein. The working paper tries 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, and more consultations with public, private, and civil society partners will further enhance this Action Agenda as the work moves forward.

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

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 capital equipment, and sets out three objectives.

Capital equipment is in use for long periods of time

Capital equipment is designed, built, and acquired to last. Together with buildings and infrastructure, it encompasses a group of products that are key components of the economic stock (meaning materials in long-term use, also known as "products that last"). Their use life can span decades: a car has a typical use life of 15-20 years (Circular Car Initiative and World Economic Forum, 2020); an elevator or a train can last for over 30 years (Swedish Environmental Research Institute, 2010; Global Railway Review, 2018); 95% of lithographic printing machines manufactured since 1984 by ASML are still in use today (Circle Economy and PACE, 2020).

The combined volume of global economic stock accumulated since 1900 is 10 times larger than the annual consumption of disposable materials (Circle Economy, 2019), and the demolition of long-lived assets represents 23% of global waste being produced every year (Circle Economy, 2019). Capital equipment, despite being only a share of the global economic stock, has a massive material impact. It represents only 6.5% of global annual material consumption and more than half (56%) of global ore consumption (Circle Economy, 2019).

Capital equipment has a strong potential for resource-efficient value creation

Circular strategies applicable to "products that flow" (consumables that typically reach their end-of-use within a year) might not be effective and/or suitable for capital equipment. Capital equipment deserves a specific approach, recognizing that inherently long lifetimes can be extended even further, be shared in use, and that slowing down their degradation could deliver major waste avoidance, given the extensive size of the existing economic stock of equipment.

Retired aircraft treatment showcases the potential of circularity. When aircraft are retired, 85%-90% of the content is reused or recycled, with around 40%-50% redistributed as useable components. Any unserviceable materials are recycled and fed back into the supply chain as raw materials (ICAO, 2019).

This highlights the effectiveness of resource-efficient solutions such as remote and predictive maintenance, remote and on-site upgrades, software solutions that improve use rates of hardware, and also those that can replace hardware (e.g. an app on a mobile, instead of a dedicated screen). Since capital equipment generally has a high intrinsic value and long useful lifetime, these approaches contain a promising business case that will benefit both manufacturers and users.

Capital equipment has its own front-running trajectory towards circularity

In advancing a circular economy for capital equipment, the priority should be on reusing—which includes repurpose, refurbish, and remanufacture—rather than recycling, with the aim of retaining the highest possible value of the equipment. While recycling remains the final solution when the technology or condition makes the equipment no longer viable, there is a need to improve the economics of reusing.

In the capital equipment sector, the financial capital invested and at stake is relatively high. Because of this, customers are already more used to keeping their investment through service models, making it easier to arrange new business models, such as 'product-as-a-service', with stakeholders in a B2B setting compared to B2C. For these reasons—and from a historic perspective in which circular economy strategies such as maintenance and refurbishment have been applied as common practice—the capital equipment sector is a circular economy frontrunner in some respects, and has best practices and learnings to share with other sectors.

Leaders from the public and private sectors and civil society are increasingly recognizing the need for system transformation, in order to reduce waste and material inputs. This working paper supports the need for collaborative action by presenting an Action Agenda for governments, businesses, financial institutions, NGOs, international organizations, and research organizations to take the next steps in the transition to a circular economy for capital equipment.

While we aim to build a unified and global perspective on capital equipment designed for the circular economy, we recognize a wide variety of issues, maturity level, and priorities for circularity across different parts of the world. Nevertheless, three objectives have been formulated based on the PACE Circular Economy Action Agenda (for Electronics and for Plastics), World Economic Forum Circular Cars Initiative Policy Workstream 2020, and PACE Capital Equipment Coalition publications, in line with the circular economy principles:[1]

11. Products and components follow circular and digitization principles for minimal resource consumption and increased reuse strategies
12. Value retention is maximized by optimizing the product and component utilization rate and use life, with the help of servitization and digitalization
13. End-of-use equipment and components are returned for reuse via efficient reverse logistics

In this working paper,, "reuse" is defined as a broad set of strategies that retain the value of used products and components through resale, refurbishment, remanufacture, repurpose, and parts harvesting.

1: PRODUCTS AND COMPONENTS FOLLOW CIRCULAR AND DIGITIZATION PRINCIPLES FOR MINIMAL RESOURCE CONSUMPTION AND INCREASED REUSE STRATEGIES

This objective is focused on designing products with circularity and digital technology in mind: using fewer resources, especially non-renewable resources, and more refurbished or reused components and recycled/renewable materials, as well as materials that can be economically recycled. Importantly, it requires embedding digital technology in the design phase to enable remote monitoring and easy disassembly at end-of-use. Collaborative methods for specification, design, and procurement are applied, i.e. circular requirements are discussed with customers, suppliers, operators, maintainers, and recyclers.

2: VALUE RETENTION IS MAXIMIZED BY OPTIMIZING THE PRODUCT AND COMPONENT UTILIZATION RATE AND USE LIFE, WITH THE HELP OF SERVITIZATION AND DIGITALIZATION

This objective aims to reduce the environmental impacts of production and reduce waste flows, by increasing the use life of products and components. In a circular future, the technical life of a product or component is extended, and the use life and utilization rate is extended by digitally-enabled maintenance and shared access. Business models are reshaped by servitization: offering services beyond one-off sales, focusing on delivering functionality instead of material goods. Lifetime extension is achieved through software and hardware upgrades, Internet-of-Things-based condition monitoring, proactive maintenance strategies, repair, refurbishment, remanufacturing, and component harvesting.

3: END-OF-USE EQUIPMENT AND COMPONENTS ARE RETURNED FOR REUSE VIA EFFICIENT REVERSE LOGISTICS

Products that are no longer suitable for use are returned through reverse logistics. Instead of being sent to landfill or uncontrolled incineration, they are refurbished, remanufactured, or repurposed; or used for parts harvesting, which in turn allows for lifetime extension of other products which are still in use. This way, the current stock of equipment can be retained to their highest possible value.

PRODUCT SCOPE

The Circular Economy Action Agenda for Capital Equipment includes a diverse set of equipment broadly defined by the following criteria:

- Long-lived and high-value assets accounted for in balance sheets
- Equipment critical to the production of goods or services

Characterized by a large amount of capital involved over relatively long product lifespans, this category plays an integral role in meeting and improving on society’s needs such as mobility, healthcare, and housing. This specifically includes devices and equipment from seven product categories:

- Motor vehicles
- Machinery and equipment
- Electrical machinery (e.g. elevators)
- Other transport equipment (e.g. trains)
- ICT equipment (e.g. antennas, data center equipment)
- Medical and precision instruments (e.g. Magnetic Resonance Imaging)
- Office machinery and computers

From a segmentation perspective, capital equipment predominantly addresses the need of the business-to-government (“B2G”) and business-to-business (“B2B”) markets, although some specific products such as “motor vehicles” or “photovoltaic panels” belong also to the business-to-consumer (“B2C”) segment.

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

This chapter explains why assessing the potential environmental and socio-economic impact of circular strategies applied to capital equipment is important.

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 2015 Paris Agreement. It is crucial to keep this north star in focus, and to steer the circular transition accordingly for a balanced, positive outcome.

While capital equipment represents only 6.5% of global annual material consumption (by mass), it represents more than half (56%) of global ore consumption (Circle Economy, 2019). This heavy consumption includes precious metals and rare earth, the future availability of which could be threatened within the next 30-50 years—estimates are highly debated amongst researchers (Jowitt, Mudd and Thompson, 2020; Britannica, 2021). The critical scarcity of these metals could stop the progress of low-carbon technologies such as solar energy or electric mobility.

Capital equipment's carbon footprint is commensurate with its material footprint: it accounts for 6.5% of total global greenhouse gas emissions. However, economically, it contributes 13% of value added to the global economy. This very distinct mass-value-carbon profile[2] of capital equipment resonates well with the true premise of a circular economy—to create more value with less resource use. However, it also raises questions, such as, if circular strategies are applied, how will the mass-value-carbon profile evolve? Is it possible to reduce the mass impact, while also reducing the carbon impact and better sharing and increasing the economic value of capital equipment?

While a circular economy is increasingly recognized as an essential component to achieving greenhouse gas reduction targets (Ellen MacArthur Foundation and Material Economics, 2019), the environmental and socio-economic impacts of a circular transition for the capital equipment sector need to be explored and researched. 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. The three objectives defined in the previous chapter need to be assessed by scientific experts along five impact categories:

- **Resource use**: use of virgin 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. Soil health and nutrition are also considered.
- **Economic wellbeing**: a broad category covering income, wealth, value-added, and their distribution; trade, productivity, competitiveness, entrepreneurship, resilience and investment.
- **Decent work**:[3] 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.

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

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

Cross-Cutting Barriers

Nascent industry-wide agreed standards and definitions for circularity – international standards for what constitutes products or services designed for circularity are still in the making.

- Digital and bio-based sources are not yet standard ingredients for defining circular designs.
- Various terms relating to circular product design, e.g. repairable or durable, are not yet defined at industry level.
- The terms reuse/refurbish/remanufacture do not yet have industry-specific definitions.
- Current circularity metrics do not explicitly reflect or emphasize value retention and the impact on business model design, which is at the core of circularity objectives for capital equipment.

A common vocabulary is needed to support harmonization efforts in related government policies, procurement practices, and certification schemes. Furthermore, being able to report on and measure circularity in a standardized way would allow supplier benchmarking.

Limited guidance to balance business model requirements with equipment design and sustainability objectives – designing a complex product for circularity requires designers to evaluate and balance requirements relating to for example, usability, longevity, repairability, modularity, backward compatibility, standardization, data security, product safety, production cost, and technical performance. All of these derive from the chosen business model, since they relate to the affordability and value-added provided to the customer. The priority of requirements depends on the product category and specific market characteristics. To date, the evaluation of circularity criteria is rarely a structural part of the design process.

Another barrier is that 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. In other words, there is no level playing field between linear and circular products. For example, sharing the design of some components can create an intellectual property risk, while uncontrolled trade of potentially hazardous components can create a legal risk. At the same time, benefits from circular products and services, e.g. 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 prioritized by many corporate decision-makers, and designers lack a clear mandate for prioritizing circularity criteria (PACE, World Economic Forum, and Accenture Strategy 2019).

Insufficient integration of circular economy principles in organizational procurement and end-of-use management – organizational procurement plays a significant role in decision-making for capital equipment investments. However, circular economy principles and criteria are currently insufficiently integrated in procurement processes and decisions. This results, for example, in tenders being limited specifically to new equipment. Organizational end-of-life management guidelines can also be a barrier to circularity, demanding destruction of devices and equipment at the end of their use cycles.

Furthermore, although some customers have started to lean towards buying or prioritizing circular products or services, it is not widespread or at the level needed to support transformation. Second-hand equipment is often perceived as inferior. Circularity criteria are not included in purchasing decisions, partly due to a lack of awareness or understanding. Public tenders even often exclude refurbished equipment by specifying that only "new" systems can be purchased.

Barriers to Following Circular Design Principles

Limited collaboration across the value chain – recyclers are seldom involved in material selection processes and have little insight into the design process, while designers often lack insight into the lifecycle thinking and recovery strategies for products. In addition, there is a lack of feedback loops from operations to design. This leads to a deficiency of innovation regarding coherent design strategies for disassembly, safe disposal, and high-quality component recovery, as well as a lack of effective refurbishing/remanufacturing technologies and processes that complement design for recycling through e.g. reduced shredding of end-of-life products. To implement closed loop recycling (e.g. for plastics), even closer collaboration between designers, material engineers, procurement, raw material suppliers, recyclers, and potentially marketing specialists is required. There is limited experience on how this collaboration should look, and how to encourage collaboration across the value chain inside and between sectors.

Lack of transparency on origin, quality, and content of secondary components and materials – secondary resources often pass through multiple traders, which prevents transparency on origin, chain of custody, or method of collection. For example, storage systems using second life electric vehicle batteries need to know the technical and usage characteristics of a used battery. The quality of the secondary component/material is currently often unknown due to inconsistent labeling, tracking, and transparency. The absence or 'immaturity' of certification processes leads to secondary component suppliers and recyclers struggling to provide the same level of quality and environmental, health and safety assurance for secondary components and materials as other suppliers can for new components/virgin materials. For some manufacturers, this is a key barrier for secondary component or material sourcing.

Nascent markets for used components and secondary or bio-based materials – manufacturers who plan to increase reused or recycled content in new product manufacturing face barriers to planning procurement decisions on a material and component level. There is currently a lack of transparency on demand for components that have reached end-of-use. As a consequence of low demand, supply through component harvesting is also limited.

Where secondary component/material markets are less robust and not commingled with new component/primary material markets (e.g. steel), recyclers can often not guarantee long-term supply, e.g. due to complex supply chains compounded by shifting waste shipment regulations or their interpretation (see related barriers).

The medium- and long-term volumes, qualities, and prices of secondary component/recycled materials are rather uncertain.This puts secondary materials/components at a disadvantage compared to today's flexible supply chain for virgin materials/components.

One additional drawback for bio-based materials specifically is the underdeveloped recycling infrastructure for these materials, e.g. external body of medical imaging devices. However, according to WBCSD (2020), the transformation to a so-called circular bioeconomy[4] demonstrates a business opportunity of around US$7.7 trillion. The capital equipment industry can also benefit from this opportunity.

Barriers to Maximizing Value Retention

Short innovation cycles that invalidate technical longevity – short innovation cycles may offset the benefits of longer technical lifespan. In many cases product and single component functions, i.e. performance, become obsolete way before they reach their technical end-of-life. For example, a solar panel can last 25-40 years (NREL, 2021), however, efficiency is improving so quickly that there would be no economic incentive to buy a 10-year old panel. These issues need to be embraced during the design phase—designing for e.g. modularity and upgradability.

Challenging business case for product use extension – business models to extend product use (e.g. as-a-service) often have higher operational costs in monitoring, maintenance, repair/refurbishment, testing, and logistics (Circle Economy, 2018). Some business models require larger upfront investment with longer payback time, adding to financing challenges. To be able to actually offer product life extension services, manufacturers need to have sufficient supply of secondary components. Otherwise, equipment cannot be maintained and is doomed to end life early.

In addition, the value of circular propositions is unclear and therefore diminishes the appeal for customers, for example why and when it would be more beneficial to upgrade versus replacing a product. All new value propositions need explanation to stimulate market adoption. 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 to innovate in this space (Ellen MacArthur Foundation 2018).

Data inconsistency and siloes – sharing equipment implies having access to usage data. To do so, additional monitoring investment is needed, and customers might be reluctant not only to invest, but also to share their actual usage data and store it in the cloud. When data is there, it can be incomplete and siloed, which hinders lifecycle monitoring and traceability.

Regulatory disincentives to product use extension

- Current accounting rules for depreciation favor new products, thereby incentivizing businesses to regularly replace used with new products.
- Emerging Right-to-Repair regulations are not suitable for B2B equipment. The right to uncertified repair creates safety, reliability, performance, and warranty issues especially for capital equipment.
- Regulation can inadvertently create obstacles for product reuse. Chemical regulations, for example the EU's Chemical Strategy, EU REACH, and EU POP—in place to achieve a toxic-free environment—can hinder reuse of systems, products, or components that contain restricted chemicals or whose full material composition cannot be known. This especially affects products with long lifecycles such as capital equipment, which can be manufactured before the regulations were in place. On the other hand, a shift towards circularity must not come at the cost of weakening the protection of human health and the environment from the impacts of hazardous chemicals. These regulations serve as strong enablers for phasing out hazardous materials, which is a crucial aspect of a circular economy.
- Current standards, as opposed to standards at time or market introduction, can hinder the reuse of components. For example, rising energy efficiency requirements hinder the development of PaaS (Product-as-a-Service) models, so that the actual economic life cannot match the potential technical life, and the overall energetic balance of an early replacement can be counterproductive.

Barriers to Returning End-of-Use Equipment and Components

Regulatory obstacles to returning end-of-use equipment or components

- Some national rules require the certified destruction of used systems, or prevent the purchase of refurbished equipment.
- Some public organizations are not allowed to trade with private parties, which prevents capital equipment being returned to the manufacturer for refurbishing.
- In many countries it is not possible to put a buy-back clause in the tender for sales of new equipment. In addition, it is sometimes illegal for a manufacturer to buy back equipment, or for owners to return the equipment to the manufacturer or recycler. For example, trade with private parties may not be allowed.

Limited incentives for capital equipment owners to return equipment at end-of-use – capital equipment users may not be aware that they can return products at end-of-use. Data security concerns or data privacy law compliance pose disincentives, and ultimately prevent potential component reuse and material recycling (Circle Economy and PACE, 2020). There is currently no shared platform for tracing equipment over its lifecycle and different ownerships. Furthermore, the costs of returning equipment to the manufacturers can be much higher than sending it to landfill or other collection channels.

Complex and inconsistent waste regulations for products classified as electronics – international reverse logistics processes for end-of-use electronics-related products are highly dependent on two classifications: 1) is the product classified as "used EEE" or as "WEEE"?, 2) is it classified as "non-hazardous waste" or as "hazardous waste"? 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. The complex and inconsistently applied classification of electronics and the effects for reverse logistics are a barrier for a circular economy for decommissioned material (Forti et al. 2020; World Economic Forum, 2019; Circle Economy and PACE, 2020).

Complex regulatory processes and high transaction costs for reverse logistics with circular objectives – the objective of the Basel Convention[5] is to avoid the environmentally and socially detrimental trading of hazardous waste. Under the Convention, certain transboundary movements of components that incorporate hazardous materials 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 (Secretariat of the Basel Convention, 1992). Currently, PIC processes are manual and can be cumbersome, taking up to two years. Besides, they involve high transaction costs and add operational constraints for shipping/reselling abroad. Lack of training of for example, trade officials is part of the cause. Digitizing PIC processes would be one part of the solution.

Regulatory obstacles to the reuse and refurbishment of components – since capital equipment is long-lived, there are clear examples of refurbished parts (even of a complete product) being compliant with legislation (e.g. energy efficiency, hazardous substance) at the time of introduction, but not in a few years' time. Science-based assessment needs to be performed to evaluate whether it is better for planet, health, and economy to scrap a component and make new, versus keeping the old component in use when safety standards are in place.

Underdevelopment of "second life" enabling technologies – in the current market, a variety of factors are limiting the economic viability of value retention (such as under-developed reverse logistics, too little value chain collaboration, and increasing technical complexity), therefore limiting incentives for investment in technological innovation in refurbishing, remanufacturing and repurposing processes.

In addition, sorting, pre-processing and recycling technologies are also underdeveloped, especially for material streams which are more complex (e.g. electronics or composites), of lower economic value (e.g. plastics), or still emerging (e.g. bio-based materials) (CEC, 2021; PACE, 2021). As a result, a significant portion of these materials are not recycled or are downcycled to lower-value applications.

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

Findings from the barrier analysis are synthesized into 10 calls-to-action towards a circular economy for capital equipment.

Building on the barrier assessment presented in previous chapters, we put forward 10 calls-to-action for a faster transition to a circular economy for capital equipment. 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 the transition. Under each call-to-action, a variety of actions can be taken up by different stakeholders. Some examples are given in this working paper, 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.

In this working paper, a "business" is any company involved in the capital equipment value chain: raw material or component supplier, manufacturer, brand owner, distributor, retailer, service provider, operator, or recycler.

CALL-TO-ACTION 1 |

Provide Incentives and Guidance for Product Design for Circularity

More than 80% of a product's ecological impact is shaped in the design (European Commission, 2012). Product design for circularity in capital equipment aims for [1] minimal material inputs, [2] longevity, [3] reusing, [4] refurbishing, [5] remanufacturing, and [6] recycling. These are especially relevant, as capital equipment is already durable and high value. The aim is a design that maximizes not only material retention but also economic *value retention* (measured in monetary units), i.e. delivering the service and outcome expected by the end-user.

A key driver of circularity is platform-based design. This is "an integration-oriented design approach emphasizing systematic reuse, for developing complex products based on platforms and compatible hardware and software virtual components," (Bailey, Martin and Anderson, 2005). Besides circular benefits such as easier reuse of design and components, platform design enables a fast time-to-market, reduced development risk, reduced components and products obsolescence, increased backward and forward compatibility, and an ongoing response to customer needs.

Another priority for capital equipment is "circular-ready design" requirements, that is, a product design compatible with and optimized for a circular business model. As part of the physical and business model design, digitization is a key aspect that needs to be taken "natively" into account from the design phase. See call-to-action 9 for more information on digital innovation. When applied in unison, a manufacturer optimizes the economics of products and components during their lifetime .

Often circularity is not prioritized in the development phase, because it is associated with higher costs (Ranta et al. 2018). However, this does not have to be the case. A study showed that refurbishment costs for network routers can be cut by 50% with only small design alterations, such as using scratch-resistant materials (Accenture Strategy and Rat für Nachhaltige Entwicklung, 2017). To tackle this perception, governments can increase incentives for companies to invest in circular design. Nevertheless, the main responsibility is directed toward suppliers and manufacturers.

WHERE CAN WE START:

- **International standards institutions, in collaboration with manufacturers, can define circular product design standards**, including clear definitions and measurement methods for priority aspects such as longevity, digitally-enabled maintenance, and reuse.
- **Manufacturers can commit to circularity at the leadership level**, integrating product circularity in their sustainability strategies, identifying focus areas, and setting measurable targets.
- **Manufacturers can equip product developers and procurers with the supportive tools and knowledge** needed to assess their suppliers and the impact of certain components, e.g. offering lifecycle assessment training.[6]
- **Manufacturers and product designers can consider other steps within the value chain** while designing products, such as backward and forward compatibility. They can create a habit of taking a systemic viewpoint, which can be leveraged through collaboration along the supply chain, co-designing innovative solutions and understanding for the individual processes.
- **Businesses can implement 'circular-ready design' and circular design requirements**, which serve as guidance to ensure product design enables circular business models and value retention through e.g. modularity, dematerialization, renewable content, and being fit for reuse strategies.
- **Researchers can explore customer needs, experiences, and incentives as well as marketing strategies** to ensure that product design and appearance is not outdated before the end of its long use life. Servitization business models make this aspect highly relevant.
- **Businesses can exploit extended sales opportunities** based on circularity as a design principle, such as offering customized circular design products. Collaboration with suppliers can be vital to create a shared business case.

CALL-TO-ACTION 2 |
Transform Customer Perception and Procurement Models to Increase Demand for Circular Products and Services

Capital equipment, because of its high purchase price, is subject to advanced and competitive procurement practices, whether in the B2B or B2G segments. However, there is a lack of demand in both market segments for circular products and services (Capital Equipment Coalition, 2021). In organizational procurement, circular economy criteria are often not integrated in high-value equipment procurement and end-of-use management processes. Advancing awareness, offering training, and introducing scoring tools for suppliers can equip procurers to expand their decision-making and better assess circularity-related requirements, such as environmental and societal impact of components, and supplier performance (PACE, 2019).

Nevertheless, requirements in tenders, e.g. public tenders for medical equipment, often prohibit circular solutions by specifying that only new systems can be purchased. It is also not uncommon for organizational guidelines to demand the destruction of used equipment due to the fear of intellectual property loss (Capital Equipment Coalition, 2021). The lack of demand for circular products and solutions, from both public and private buyers, keeps the industry from scaling the design and production of circular products such as medical scanners and wind turbines made from reused or refurbished components.

There is a need for increased market demand to kick-start the transition to a circular economy for capital equipment. Large buyers such as governments and business—which are the primary consumers of capital equipment—have the power to shift the market towards more circularity.

WHERE CAN WE START:

- **Governments and businesses can revisit organizational procurement guidelines**, reconsidering specifications that prevent circularity and integrating tender instruments to reward circular solutions, as well as circularity criteria that need to be tracked by value-based metrics.
- **Governments and businesses can commit to a percentage of total yearly component category spend that includes a preference for circular products and services**—without waiting for the market to offer perfectly circular products.
- **Manufacturers can consider labeling reused and refurbished products** to inform and build trust with customers. With the help of government and industry guidance, creating transparency about circular content will increase customers' trust in "second life" equipment, thus avoiding greenwashing.
- **Civil society and manufacturers can raise awareness and encourage the adoption of "total cost of ownership" models over list price models.** Striving for maintaining current equipment over buying new can represent an economic benefit (e.g. avoiding downtimes and commissioning costs).
- **Manufacturers and distributors can incorporate circular economy in discussions with large-scale buyers,** highlighting the environmental and financial benefits for customers, testing the appeal of different circular products and services, and implementing collaborative projects.
- **Research and circular economy organizations, together with businesses and their customers, can discover and match customer needs to circular opportunities.** Marketing and sales employees need to be integrated into this process.
- **Manufacturers and businesses can define strategies to increase customer awareness and responsibility**, making them more receptive to reused and refurbished components/products and service-based business models.

CALL-TO-ACTION 3 |
Leveraging Servitization, Guide and Support Product Use Rates and Use Life Extension

A high product use rate and use life extension are relevant for the capital equipment industry, due to products' long lifecycles and high-value components. For example, professional refurbishment can enable up to 10 use cycles for equipment such as MRI machines.

Servitization is the main way to accelerate product life extension and use intensification for capital equipment. Servitization can be defined as, "the innovation of an organization's capabilities and processes to shift from selling products to selling integrated products and services that deliver value in use," (Baines, Lightfoot, Benedettini, Kay, 2009). Business models such as product-as-a-service, components-as-a-service and maintenance/upgrade services, open up the benefits of design for longevity and repairability, and develop stronger customer relationships (Lacy, Spindler, and Long 2020).

There are clear success stories where—in combination with sophisticated circular design—as-a-service models significantly cut costs and material losses. For example, in the automotive industry a transition from a classic transaction-based sales model to a service-based sales model (e.g. subscriptions), vehicles remain with the OEMs, or another service provider. In keeping ownership, manufacturers/OEMs enable closed loop reuse, a simplified reverse logistics, making recycling economically more attractive (Circular Car Initiative, World Economic Forum, Accenture Strategy, 2020).Another opportunity is asset sharing (i.e. equipment sharing), which focuses on access rather than ownership, and thus increases use rates. In such a setting, the costs of equipment can be shared across users (see also call-to-action 9). Increasing use rates is not only linked to asset sharing. It can also be induced through services that help customers optimize existing equipment, therefore avoiding the need to buy additional products.

Active and remote monitoring and maintenance, allowing upgrades and diverting downtimes, lead the way to a circular economy. This helps to maintain vulnerable components before they create harm, such as equipment downtimes and maintenance costs. Thus, it allows for efficient, low-carbon, qualitative, and safe equipment maintenance. An important requisite is access and approval to collect relevant data.

WHERE CAN WE START:

- **Manufacturers and businesses can explore servitization business models**, including product-as-a-service, components-as-a-service, and asset sharing.
- **Research organizations, in collaboration with manufacturers and their customers, can improve knowledge** about the combined business/environmental/social performance of as-a-service business models.
- **Manufacturers and businesses can explore product life extension pathways** such as:
  - scaling training and certification for repair and refurbishment to independent service providers
  - remote maintenance technologies incorporated into products
  - standardization of components to facilitate repair services
  - offering options for upgrade (software and hardware)
- **Manufacturers can make long-term agreements with secondary component suppliers** to guarantee extended lifetime of equipment.
- **Financial institutions can improve access to capital** for product use extension business models that require additional capital expenditure.

- **Research organizations and policymakers can analyze global and local barriers** towards enabling connectivity of products and sharing of product data.
- **Equipment owners can put in place sustainable evaluation criteria** to assess whether to intensify, extend or end the use of a product or component. This includes for example, to support the decision whether it is environmentally more favorable to replace products/components of lower energy efficiency with new ones or keep them in use.
- **Accountants, business consultants, and companies can propose specific changes for adapting accounting to a circular economy for capital equipment,** recognizing disincentives of current depreciation rules and considering key aspects of new business models, e.g. estimates of residual value of equipment in product-as-a-service business models.
- **Policymakers can evaluate and implement regulations in favor of product usage intensity and life extension**, such as end-of-life processing fees or extended life incentives.
- **Manufacturers and businesses can offer their customers opportunities for asset sharing**.

ONGOING ACTIONS

- Wärtsilä is a Finnish manufacturer for—amongst other things—power plants and marine engines, and a global leader in smart technologies and complete lifecycle solutions. Through using modular engine architecture, the company achieved a 45% reduction in production development expenses, 44% lower costs for continuous product care, and a 50% reduction in assembly time (Sitra, Technology Industries of Finland and Accenture, 2018).
- Rijkswaterstaat, part of the Dutch Ministry of Infrastructure and Water Management and the main client of construction and renovation contracts, promotes circular and sustainable public sector procurement principles for the construction industry. The idea is to increase public sector procurement to push demand for circular and sustainable requirements, and in doing so generate certainty for suppliers that the market is ready. This leads the way to kick-start the necessary supply-demand dynamics (RWS, 2021).
- NIO, a Chinese electric vehicle manufacturer, offers its batteries-as-a-service (BaaS)—meaning they can be contracted independent of ownership of the car.
- Faurecia Clarion Electronics is venturing into servitization by offering a multi-brand repair service within a couple of days for all electronics within a car.
- Philips' Smart Path program creates a new revenue stream for the company in offering upgrades to its customers. The program focuses on hardware and software updates, as well as product and component replacements and take-back.
- GE Digital is integrating predictive maintenance in several of its products, including healthcare and aviation equipment (GE Research, 2021) (see also call-to-action 9 for more on digital twin technology).

CALL-TO-ACTION 4 |
Increase End-of-Use Product Return

Returning end-of-use products and components back to the manufacturer for value retention can be restricted in some cases. For example, some public organizations are not allowed by law to trade with private parties (Capital Equipment Coalition, 2021). There is a need to make exemptions and/or to change regulations in a way that does not hinder end-of-use product return.

Consumers might understand the relevance of bring-back to “close the loop”, but understanding doesn’t necessarily lead to adequate action, due to complexity, missing standards for bring-back, and a lack of a financial case. In addition, data privacy concerns for end-users and intellectual property risk for some manufacturers are other disincentives that especially impede bring-back of capital equipment (Capital Equipment Coalition, 2021). An up-to-date inventory of equipment at the customers’ premises, as well as the lifecycle data of equipment, is often missing to plan and operate advanced take-back/bring-back programs.

Leveraging multiple customer relationship management over the entire lifecycle instils trust. Providing vigorous bring-back/take-back or buy-back programs brings additional security and assurance at the end of the equipment’s life. Likewise, once partnerships and trust increase, greater avenues open up for bilateral advantageous collaboration over a longer period of time (PACE, 2019).

Even though B2B and B2G customers are the primary consumers of capital equipment, B2C customers, for example those buying cars or solar cells, also need to be adequately addressed. Beyond voluntary bring/buy-back programs, compulsory schemes such as Extended Producer Responsibility (EPR) in the B2C market can be a mechanism for financing and executing reverse logistics. To design and implement EPR-similar schemes for B2B, public-private sector collaboration is needed. Governments, policymakers and manufacturers need to work together to develop and optimize reverse logistics across industries and countries, however these must still be tailored to the local context, e.g. consider other applicable regulations. Where these schemes may take time to be fully deployed, other financing mechanisms should be used in the interim.

This call-to-action is linked with call-to-action 2 on procurement models. Accelerating them in combination is key.

WHERE CAN WE START:

- **Businesses can understand customer barriers to bring-back**, since this is key to offering an appealing bring-back proposition that can further stimulate market demand.
- **Governments and policymakers, in cooperation with manufacturers and value retention service providers,[7] can establish and enforce take-back schemes** in line with environmental, labor, and security standards. Developing a convergence of national regulations should be explored.
- **Businesses and manufacturers can voluntarily establish reverse logistics, especially for B2B customers, without waiting for fully compulsory schemes,** e.g. by integrating take-back or buy-back programs into contracts.
- **Businesses and manufacturers can define reverse logistics objectives**, separately for products, components and/or materials, and set up tracking and monitoring mechanisms to check on progress.
- **Money lending institutions and manufacturers can collaborate to leverage long-term financing contracts to include a bring-back policy** at the end-of-use of equipment that has been financed by the lender.
- **Manufacturers can keep track of equipment installed at their customers’ facilities**, to know where to reach out to offer take-back opportunities when it was not agreed upon at the time of sale.
- **Manufacturers can guarantee safe data cleansing options and provide instructions for data purging to customers** for all equipment that stores personal and/or confidential data.
- **Manufacturers can guarantee compliance with health and safety policies** for extended repair, refurbishing, and remanufacturing services within their own company and/or within the contracted service provider.

CALL-TO-ACTION 5 | Enable Efficiency and Transparency in Compliant and Responsible Reverse Logistics

Global reverse logistics and related transboundary movement of used materials and components are pre-requisites for reuse and recycling at scale. The transboundary movement of end-of-use components 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 proper reuse, refurbishing, and remanufacturing. Key barriers include inconsistent classification and inefficiencies in approval processes (see the barriers chapter).

Efficient and transparent reverse logistics is a key enabler of subsequent value retention processes and associated new business models. Various large equipment manufacturers are already scaling their refurbishment programs (e.g. Diamond Select by Philips). Retaining the value of equipment can create new jobs along the entire reverse supply chain. Designing health and safety regulations that suit reusing components that incorporate potentially harmful substances, and ensure their compliance, can further contribute to safeguarding the quality of these new jobs.

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 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:

- **Stakeholders along the supply chain can jointly set up transparent traceability mechanisms for products and components** to guarantee efficient trading cross-border and cross-supply chain partners.
- **Trade ministries can team up with international organizations, the private sector, and standards institutions to elaborate on certification** for manufacturers and value retention service providers, to ease shipping of secondary products and components across borders.
- **Suppliers, manufacturers, and value retention service providers can commit to professional, safe, and responsible trading standards** around secondary components, in compliance with the Basel Convention and country-specific regulations.
- **Industry experts, in collaboration with competent authorities to the Basel Convention, can reevaluate the classification and treatment of used products, components, and materials** to avoid counter-productive hurdles for a circular economy.
- **Governments and policymakers can consider developing green product passports that certify compliance with trade regulations**; see call-to-action 8 for more information on product passports.

CALL-TO-ACTION 6 |
Collaborate Across Value Chain and Sectors to Strategically Plan Reuse Operations

Refurbish and remanufacture facilities are long-term investments and require specialized skills, know-how, intellectual property, and economy of scale. Therefore, they need to be planned carefully with key considerations such as location, capacity, and specialization. Will there be a stable and sufficient inflow of used components? 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 recovered components? How can the carbon footprint of the reverse logistics be reduced?

To answer these questions there is a need to increase public-private dialogue, as well as inter- and intra-industry communication, to develop viable solutions that are supported by all stakeholders. Additionally, geography-specific collaboration can further account for regional specifications. An important basis for these discussions and the transition towards a circular economy is a better understanding and the incorporation of more information about the social, environmental, and economic consequences of different global or local value retention models. This information can be fed back into the design process, the transition to servitization, and the crafting of new business models, as well as used to measure partner performance and evaluate component flows.

Building a systemic view through cross-value chain collaboration also helps to discover optimization opportunities. Manufacturers need to define and subsequently publicly commit to quantitative strategic targets on their route to going circular. This also incentivizes material and component suppliers to increase their investment to help manufacturers achieve their goals.

WHERE CAN WE START:

- **Businesses and governments can work together to scope regional collaborations** to develop sophisticated reuse ecosystems, balancing economy of scale with value sharing and local expertise.
- **Businesses can define specific targets** for value retention operations and who is responsible for achieving the targets within operations.
- **Research organizations can develop data and knowledge about the economic, environmental, and social impacts of different value retention models** to inform strategic decision-making for setting up reuse facilities.
- **Governments can create favorable investment conditions for experienced value retention service providers** to bring the technical expertise required to the country or region.
- **Governments can foster an enabling environment for a new generation of sustainable enterprises** in value retention and processing services, and create an ecosystem to promote collaboration.
- **Manufacturers and value retention service providers can initially conduct a circularity and climate impact assessment of returned equipment** to identify the best option for end-of-use treatment.

ONGOING ACTIONS

- Over the last decade Royal Philips, a leading health technology company, has reintroduced 7,000 tons of refurbished medical imaging equipment to the market, and infused 6,000 tons of recycled plastics into its new consumer products. It further aims to trade-in ever more equipment, such as cardiovascular systems, and take responsibility that all returned materials are responsibly repurposed (Circle Economy and PACE, 2020).
- Damen, a Dutch shipbuilding company, works together with an industrial auctioneer to sell surplus material such as pumps and helidecks. It offers them to customers at a decent price, and at the same time gives these items a second life (PACE, 2019).
- In the automotive industry, OEMs, suppliers, and recyclers collaborate to professionalize reverse logistics and disassembly processes, enhancing efficiency and maximizing recovery value. Components and materials are passed on to specialized facilities for remanufacturing and recycling (Circular Car Initiative, World Economic Forum, Accenture Strategy, 2020).
- Many of the Capital Equipment Coalition members have publicly committed to ambitious targets (Circle Economy and PACE, 2020):
  - KPN set and achieved its target to reuse and recycle 75% of its outflow weight by 2018.
  - Lely aims to cover 100% of its capital equipment returned through reuse, refurbishing, repurposing, or recycling by 2025.
  - Cisco strives to deliver on its customer promise of 100% return of equipment at zero cost.
  - Enel aims to achieve a 70% share of renewables on total capacity by 2023.
  - Dell targets 100% of its packaging content to be made from recycled or renewable materials, and over 50% of its product content to be made from recycled or renewable materials by 2030.

CALL-TO-ACTION 7 | Increase Incentives for Investment in Reuse Technologies and Facilities

Value retention economics depend largely on the amount of stable component inflow, reverse logistics costs and compliance costs, as well as the competitiveness of manufacturing or buying new components instead (Capital Equipment Coalition, 2021). In the current market, a variety of factors is limiting the economic viability of value retention, and so also limiting incentives for investment in infrastructure and technological innovation. These factors include for example, under-developed reverse logistics, too little value chain collaboration, and increasing technical complexity.

There are success stories of the economic benefits of properly utilizing value retention technologies. Nokia, for example, attained a revenue increase of around 50% from selling second-hand products. Another is Caterpillar, which gained a 50% increase in gross profits by offering remanufactured products at a 20% discount rate (Sitra, Technology Industries of Finland and Accenture Strategy, 2018).

Reflecting the true costs—including environmental and social externalities—in the price of products would trigger change in procurement in favor of secondary components and products. At the same time, it would increase incentives to optimize value retention technologies. To realize this, there is a need for governments and policymakers to step in and introduce regulations, as businesses will not reflect these true costs voluntarily due to the competitive disadvantage for those who do. One example of incentive mechanisms for investment in value retention technologies and facilities can be carbon pricing. This can increase the competitiveness of reused, refurbished, and remanufactured products/components, as they usually have a much lower carbon footprint compared to new ones.

Governments can play a vital role in stimulating the development of secondary component markets. In collaboration with financial institutions and manufacturers, they can support investment in reuse technologies and facilities through innovation funds, sales incentives, take-back schemes (see call-to-action 4), and commitments to increasing sourcing of second-life products.

WHERE CAN WE START:

- **Governments and financial institutions can set up funds for value retention technology innovation and infrastructure investment**.
- **Suppliers, manufacturers, and businesses can join forces to explore opportunities to improve value retention technologies, ecosystems, and infrastructure in general** that lead to high-quality and efficient reuse, and thus better economic output.
- **Manufacturers can issue public commitments for increasing sourcing of used components in new product manufacturing**, as a powerful signal to bolster the secondary components supply chain.
- **Governments, in collaboration with policymakers and value retention service providers, can stimulate the secondary component market** by, for example, tax incentives, subsidies, carbon pricing, and targets for manufacturers, to steer the shift from new to reused component integration.
- **Research organizations can conduct studies on the local business environment for secondary components** (e.g. production costs compared to virgin materials), to inform policymakers on needed interventions.
- **Research organizations, together with manufacturers, can investigate customer needs** with regards to different circular products and services, which can help underpin where investments need to be made.

CALL-TO-ACTION 8 |
Enable Manufacturers to Increase Sourcing of Secondary Components

Increasing secondary components in capital equipment manufacturing is essential for slowing down virgin resource demand. However, two issues are making it difficult for manufacturers to increase sourcing of secondary components: first, used components often cannot compete with new components in terms of corporate social responsibility, legal, quality, safety or reliability assurance, due to a lack of transparency about their origin and usage history, and a lack of certification processes. This therefore creates a substantial business risk for buying secondary components. Second, unstable supply and lack of insight into supply forecasts discourage manufacturers from long-term sourcing decisions for secondary components (Capital Equipment Coalition, 2021).

Legislation that aims to achieve a toxic-free environment (such as the European Commission's recently reintroduced Chemicals Strategy for Sustainability), inadvertently sets further challenges for secondary component sourcing. For reused and refurbished components and products, it is often difficult to know if they contain newly-regulated substances, and if they do, it is often impossible to remove them. As a result, equipment with long lifecycles often cannot be repaired or refurbished with older components. Thus, there is an urgent need for dialogue between policymakers and the industry on how to create an enabling environment to achieve higher circularity in capital equipment without compromising health and safety.

Technology innovation is a complementary approach to address this challenge. For example, product passports can help share relevant information (e.g. origin, compliance, use-time, upgrades) across the value chain, and thus fast-tracks the adoption of secondary component use (see also call-to-action 9). New business models will be an additional strategy. In servitization models, customers are paying for access (i.e. outcome or functionality) instead of product ownership, thus whether or not the underlying product is virgin or in its second or third use cycle has little relevance (Capital Equipment Coalition, 2021).

WHERE CAN WE START:

- **Producers, manufacturers, value retention service providers and standards institutions can collaboratively develop traceability standards, certification processes, and product passports** to enable multiple use cycles for products and components.
- **Manufacturers, in collaboration with value retention service providers, can establish an industry platform for increased transparency about supply and demand** for secondary components. This can avoid production downtime and allow for long-term planning.
- **Manufacturers can integrate and decide how openly they label "as new" components in their products and offer extended guaranteed services** for these components. This can lower aversion to secondary components.
- **Governments, businesses and research organizations can collaborate to work out how health and safety regulations should be applied in product/component reuse**, to achieve optimal environmental outcome.
- **Governments can review regulations which inadvertently hinder the development of used component supply chains**, such as those that require certified destruction of used systems, prevent the purchase of refurbished equipment, or restrict buy-back of used equipment from public organizations.

CALL-TO-ACTION 9 |
Leverage Digital Technologies for the Circular Transition

Digital technologies can transform how components and products are designed and managed, and move businesses away from outdated "take-make-waste" systems. Digital technology solutions will not fix all challenges to transition to a circular economy, but they can facilitate the process. For capital equipment especially, a cost-effective and automated analysis of equipment status is a strong ingredient in the success of digital circular business models, and can benefit several steps of a product's lifecycle. Among others, *modularity* in the design phase and *servitization* in the use phase—two pillars of circularity applied to capital equipment—heavily leverage digital capabilities.

Manufacturers can utilize a digital twin (a digital replication of a physical asset, product, process, or system) to generate a deeper understanding of the specific asset, and consequently optimize its modularity, material use, and waste volumes during production. Digital twin technology not only allows the representation of single components, but also modeling of relationships among machines, workflows, and components.

Data collected by sensors that feed into a digital twin enable predictive maintenance services, as well as services for digital and physical upgrades. These services avoid downtime, increase utilization rates, and extend lifetimes.

Historical monitoring and lifecycle tracking gathered in product passports can also be leveraged to improve not only maintenance, but also equipment design and end-of-use by providing visibility on the equipment conditions and residual value. Digital twin technology can also use product passport data for assessments on reversible and circular design. Consequently, product passports and digital twin technology should be advanced as complementary technologies (Heinrich and Lang, 2020).

Another dimension to servitization is equipment sharing, powered by two-sided digital platforms on which algorithms match demand and supply. The better the platform, the higher the equipment use rate, which in turn reduces the amount of equipment dedicated to a service.

Digital opportunities can unleash their potential when both suppliers and customers have willingness to adopt the new digital environment.

WHERE CAN WE START:

- **Manufacturers can embrace digital twin technology as the foundation** for optimizing e.g. modularity in design, material usage, equipment performance, and maintenance services.
- **Manufacturers can ensure circular design standards include digital elements** such as remote sensing.
- **Businesses, in collaboration with research organizations, can pilot digital solutions for increased product traceability and transparency**, such as standardized indicators, passports that include location, ownership, and composition (see call-to-action 8), demand and supply of critical component.
- **Manufacturers can utilize data collection and analytics technologies** to offer predictive and remote maintenance services to customers.
- **Manufacturers can utilize digital platforms to fully embrace servitization as a new business model**, thus connecting with customers and selling value instead of physical equipment.
- **Manufacturers can facilitate digital solutions for reverse logistics**, such as hybrid bring-back and take-back models, allowing for fast communication and collaboration between customers and value chain partners.
- **Research organizations, in collaboration with businesses, can research and clarify the environmental benefits of their digital solutions** to increase customer adoption.

ONGOING ACTIONS

- GE creates digital twins of its gas turbines, steam turbines, and wind turbines, which brings productivity to a new level. The physical asset feeds its digital version with data that is used for example, to configure turbines (e.g. define real-life location), test different scenarios (e.g. high or low winds), and monitor its internal as well as external condition (e.g. temperature of motors). Relevant data can be directly accessed by on-site engineers, and acts as the foundation for decision-making (e.g. power level of wind turbine operations). GE's digital wind farm in California has increased energy production by 20%. This translates into a revenue increase of $100 million over its lifetime (GE Renewable Energy, 2021).
- Rolls-Royce's Intelligent Engine program has led to notable innovations such as its industry-leading aftermarket service: predictive maintenance. Rolls-Royce's engines designed for business aircraft are fitted with remote diagnostics and bidirectional communications that allow for remote reconfiguration of the engine-monitoring features. With this advancing technology, Rolls Royce aims for 100% averted missed trips in business aviation—achieving an average of 99% in 2019 (Rolls Royce, 2020).
- Access Material Exchange is a digital platform that matches supply and demand of used products and materials. It aims to demonstrate to businesses that a smaller ecological footprint (-60%) can come hand-in-hand with greater financial value (+110%). To realize this, the platform makes use of four tools: [1] digital passports, [2] tracking and tracing, using barcodes, QR codes, and chips, [3] valuation of the financial, environmental, and societal impact of products/materials through data analytics, and [4] matchmaking, creating new high-value reuse options across industries by utilizing artificial intelligence.

CALL-TO-ACTION 10 | Evaluate the Contribution of Circular Capital Equipment to the Sustainable Development Goals

This working paper documents the key barriers and action areas identified in a circular transition for capital equipment, primarily from a private sector perspective. However, a multi-sectoral approach will be essential for the transition. Strong collaboration with the governments, civil society and research organizations is necessary not only to take actions and overcome barriers, but also to ensure that the transition will contribute to the end goals in an optimal way.

As discussed in the Impact chapter, circularity is not the end goal, but 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 2015 Paris Agreement. A circular economy for capital equipment can have profound effects across resource use, climate change, human health, biodiversity, economic wellbeing, and decent work outcomes. Science-based, forward-looking impact assessment is needed to understand the environmental and socio-economic impacts of a circular transition for the capital equipment sector, where it can deliver benefits, as well as where trade-offs, risks, or points of attention exist. For example, how can a circular economy in capital equipment best contribute to climate goals and policies? How to ensure that increased reuse and recycling operations lead to not only more jobs, but also high-quality jobs with safe, healthy working conditions and decent income?

This call-to-action invites broader value chain stakeholders from all sectors—public, private and civil society—to participate in the design and realization of a circular economy for capital equipment, for a better, just and faster transition that helps us to achieve the Sustainable Development Goals together.

WHERE CAN WE START:

- **Civil society can convene cross-sectoral, multinational stakeholders** to develop and implement coordinated circular transition strategies and measures for capital equipment.
- **Research organizations and businesses can collect data** on capital equipment components and waste flows.
- **Research organizations, governments and civil society can advance understanding of the environmental and socio-economic impacts** of circular strategies in capital equipment, developing suitable metrics to measure impact and progress.
- **Governments and businesses can identify opportunities to integrate capital equipment circularity into their climate strategies.**

How Can I Drive the Change?

GOVERNMENTS

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

- Define a strategy for the circular economy with specific sector focus, as well as short-term and measurable objectives. Set up a governance model with a dedicated structure for the circular economy that involves all relevant structures and ministries.
- Create a level playing field, removing incentives for linear solutions (e.g. more tax on materials and less on labor).
- Adjust public procurement guidelines and processes to effectively integrate circularity.
- Review existing regulations for their impact on resource efficiency, and evaluate options for a more balanced outcome.
- Encourage the use of renewable materials and energy, e.g. through the remodeling of environmentally harmful subsidies and/or differentiated VAT.
- Provide policy incentives for the uptake of circular design and investment in refurbishment, remanufacturing, and sorting and pre-processing technologies.
- Support the creation of an ecosystem to implement circular and innovative solutions involving companies, start-ups, and universities etc (also creating digital platforms and networks for knowledge exchange and innovation).

BUSINESSES

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

- **Brand owners** can commit to circularity at the leadership level, understand customer's unmet needs, test new value propositions built around circular products and services, and activate conversations with the public sector and other value chain stakeholders to address the areas that need action most.
- **End-users** can integrate the circular economy in their procurement strategies and develop co-innovation projects with other actors in the value chain, including start-ups.
- **Manufacturers** can integrate circularity in design decisions, increase options for product repair and refurbishment, finance product return, increase sourcing of secondary materials, and **extend supply chain auditing to downstream partners to advance decent work.**
- Collaborating with other value chain actors, **component suppliers** can co-develop standards and certification for secondary components, helping product designers better understand how to design for repair.
- All businesses can develop financial instruments to support the implementation of circular economy initiatives e.g. buying back, keeping ownership of equipment, and presence on the balance sheet.

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.
- Elevate and connect circularity of capital equipment with broader transformations.

FINANCE

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

- Asset managers and impact investors can support access to capital for private sector investment 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 capital equipment, including:

- Collect data on capital equipment lifecycle flows.
- Advance understanding of the environmental and socio-economic 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 employee behavioral and organizational change on both the supply and demand side.
- Develop new technologies in areas such as automated remanufacturing, refurbishment, sorting, and pre-processing.

CONCLUSION

A circular economy is a key component of the transformation of the capital equipment sector towards sustainable development. In a circular economy for capital equipment, products and components follow circular and digitization principles for minimal resource consumption and increased reuse strategies; value retention is maximized by optimizing the product and component utilization rate and use life, with the help of servitization and digitalization; and end-of-use equipment and components are returned for reuse via efficient reverse logistics.

In the transition to a circular economy for capital equipment, **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 sustainable development in resource use, climate change, human health, biodiversity, economic wellbeing, and decent work. Actions are needed to remove barriers, as well as to increase our understanding on how the transition will contribute to our north stars. **Let's be guided by the 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, manufacturers, suppliers, civil society, finance institutions, research organizations, and NGOs—**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 capital equipment system change at scale.

Let's get to work!

ENDNOTES

1. Ellen MacArthur Foundation's three circular economy principles: design out waste and pollution; keep products/materials in use; regenerate natural systems.
2. As defined in Circle Economy's 2019 Circular Gap Report.
3. 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."
4. Bioeconomy can be described as an economic model that builds on biological resources to produce products, energy, food and feed (WBCSD and Boston Consulting Group, 2020).
5. 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.).
6. Life Cycle Initiative—hosted by UN Environmental Programme: https://www.lifecycleinitiative.org/
7. In this working paper we define 'value retention service providers' as service providers that offer to process components/products for reuse, refurbishing and remanufacturing, thus aiming to maintain the highest possible value of the object.

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