EVERYTHING-AS-A-SERVICE XAAS

HOW BUSINESSES CAN THRIVE IN THE AGE OF CLIMATE CHANGE AND DIGITALIZATION

Conducted by

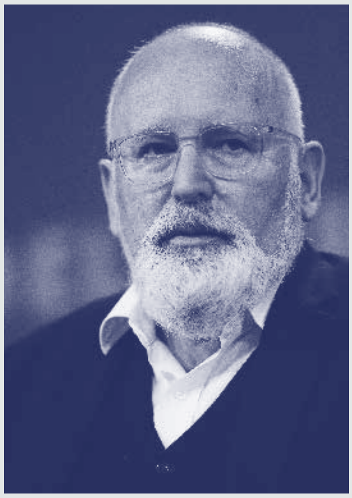
SYSTEMIQ

On behalf of

SUN Institute
Environment & Sustainability
Initiated by Deutsche Post Foundation

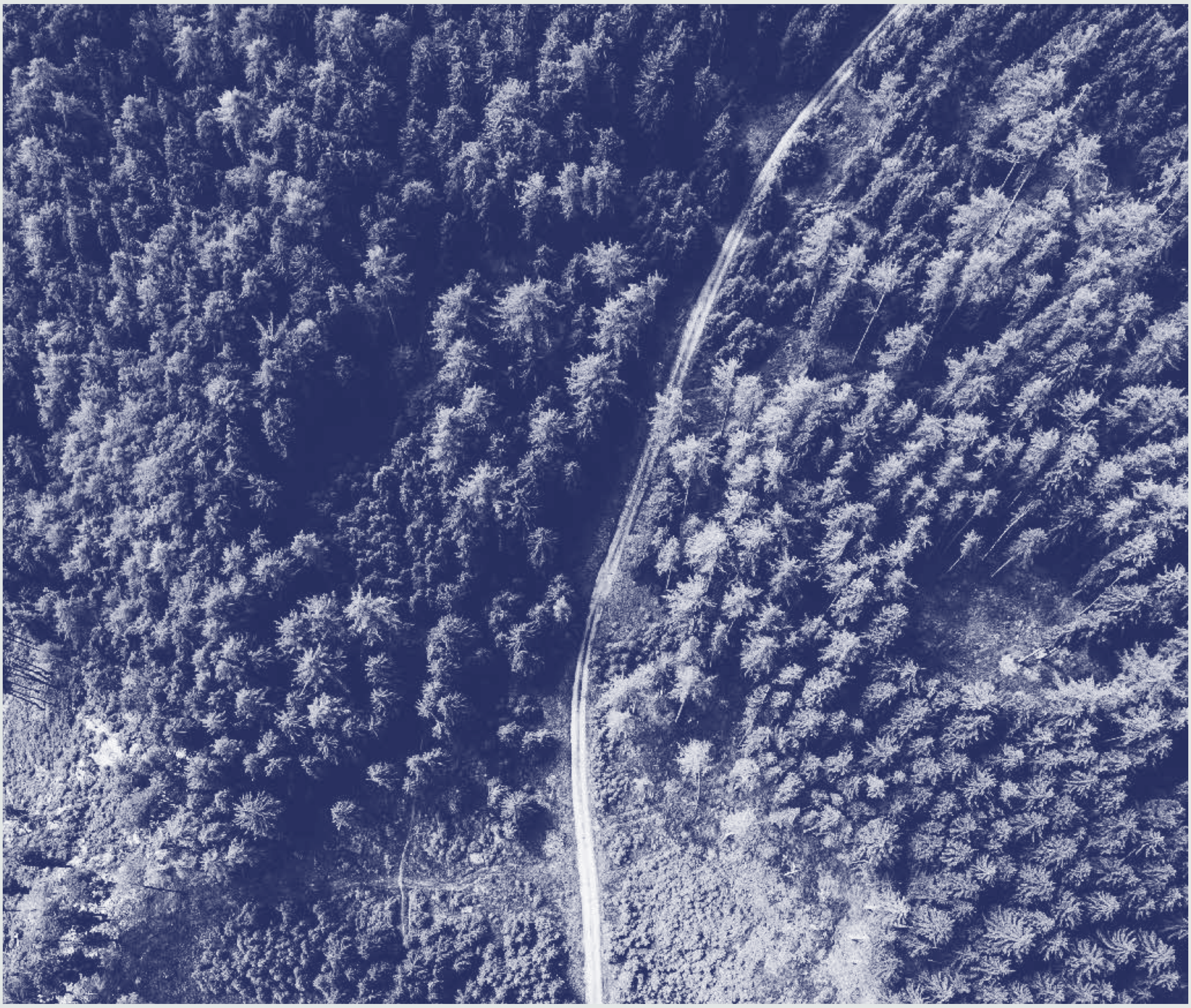
ENDORSEMENTS

“To reverse the climate and biodiversity crises and build a climate neutral economy by 2050, we must accelerate the decoupling of our economic growth from emissions and resource use. A simple replacement of fossil-based with bio-based will not be enough. We need innovative circular business models that are increasingly service-oriented and drastically reduce our dependency on primary resource extraction.



The Everything-as-a-Service report provides powerful and much-needed evidence on how such models work, and offers clear guidance to have them succeed on the ground. This report is therefore an important contribution to one of the key priorities of the European Green Deal and its Circular Economy Action Plan.”

Frans Timmermans,
Executive Vice-President of the European Commission



"Waste and disposability are woven into today's economy, fueling climate change and limiting opportunities for long-term economic prosperity. Everything-as-a-Service (XaaS) shows how – as part of a circular economy – we can change that, and harness the power of design and innovation to deliver better outcomes for businesses, their customers, and the environment."

Dame Ellen MacArthur,
Founder & Chair of Trustees, Ellen MacArthur Foundation

"Germany has set ambitious climate targets. To achieve climate neutrality by 2045, increasing the use of renewable energies is not enough. We need to manage our natural resources differently. For industrial nations, the transition towards a circular economy is an attractive opportunity to drive prosperity within ecological boundaries. As this report shows, demand-side innovations are both a critical and an attractive way to drive the transition: Germany can sell services, outcomes or results in the same successful way in which we have sold products in the past. The report describes a vision in which XaaS can grow into an essential driver of Germany's innovation, competitiveness and employment in Europe and beyond."

Elisabeth Winkelmeier-Becker,
Parliamentary State Secretary, Federal Ministry for Economic Affairs and Energy, Germany

"Sustainability is an integrative part of our corporate strategy. Implementing measures inspired by the circular economy makes an important contribution – ranging from product design for sustainability to circular and service-based business models. We all need to seize the opportunity to accelerate the transition towards more resource-productive and sustainable industrial systems."

Carla Kriwet,
Chief Executive Officer, BSH Home Appliances Group

"Business success tomorrow means creating value for environment, society, and business. This requires pioneering research and development, but also new business models that can essentially decouple CO_2 emissions from business growth. Scaling XaaS systems that embrace circular economy principles will be important for generating sustainable growth – and calls for a collaborative and focussed effort across industries."

Saori Dubourg,
Member of the Executive Board, BASF

“Moving to a circular economy will require fundamental change, such as a shift to producer ownership, where producers take ownership and responsibility for their product over the full lifecycle. This could generate incentives for new XaaS business models to gain a competitive edge through the design of products for durability, dematerialisation, re-use and high-value recycling.”

Paul Ekins,
Professor of Resources and Environmental Policy, UCL Institute for Sustainable Resources

“As markets tumbled in early 2020, many of us expected that the pandemic would slow global action on climate change, but the opposite happened. The pandemic forced society as a whole to remember the fragility of our planet. The 2021 XaaS Everything-as-a-Service report splendidly raises the importance of climate risks and outlines holistic strategies as we face issues relating to climate change. For us as an investment firm, climate risks are investment risks and we therefore see sustainable circular economy strategies, that aim to reduce carbon emissions, as becoming increasingly important.”

Mirjam Staub-Bisang,
Country Manager Switzerland and member of the ExCo EMEA, BlackRock,
Senior Advisor BlackRock Sustainable Investing

“Services that unlock value by helping us to better utilise, circulate and improve products and materials are critically enabling first layers of the circular economy. They represent exciting ways in which innovators and designers can begin their journey and apply society’s well developed skills in service design.”

Tim Brown,
Executive Chair, IDEO, and Vice Chair, kyu Collective

“Equipment-as-a-Service offers industrial companies entirely new and disruptive business and production opportunities. By essentially focusing on performance, flexibility and convenience, this allows customers to focus and grow. Beyond that, EaaS is the path to a business model based on circular economy principles. As this report outlines, implementing such models at scale will require collective action within and across industries.”

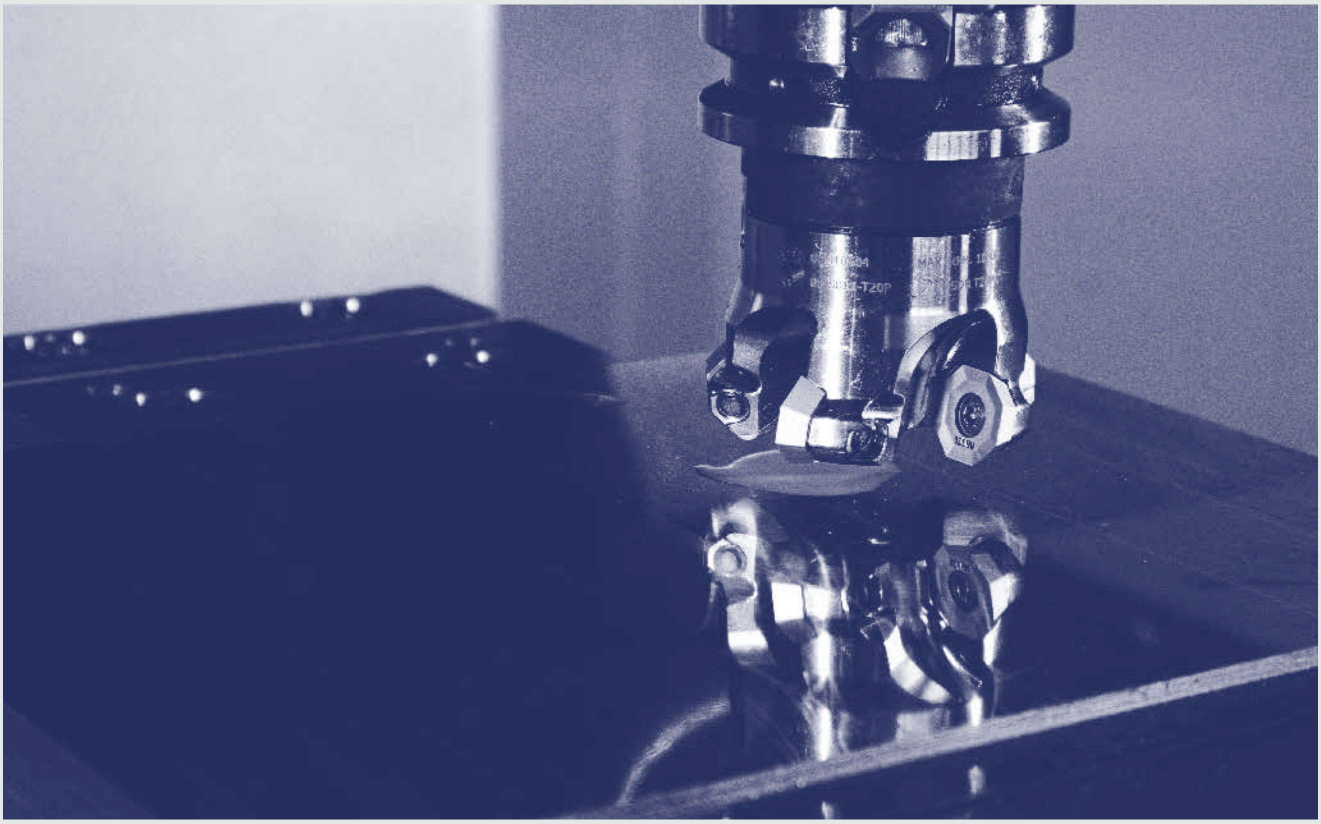
Peter Leibinger,
Chief Technology Officer and Vice Chairman of the Group Management Board, TRUMPF

“*Objects as a service* have existed for a long time, offered by hotel owners, ferrymen, taxi drivers. They were classified as ‘services’ integrated in the tertiary sector, which hundred years ago became dominant in the US economy but which continued to focus its attention on production and productive jobs.

In the 20th century, pioneering manufacturers emerged such as Eastman Kodak selling camera use as a system, MEWA cleaning towels as a service and equipment manufacturer Xerox customer satisfaction instead of photocopiers. In the 1980s, the concept of XaaS emerged in research papers, and in January 1994, The Harvard Business Review published its first case study on XaaS under the title *Xerox: Design for the Environment*.

The full potential of XaaS was first structured and described in my 2006 book The Performance Economy (English 2006, Simplified Mandarin 2008). The concept has since been accepted by an increasing number of companies, and presented in a growing number of publications, the latest being XaaS in your hands.”

Walter R. Stahel,
Founder-Director of The Product-Life Institute, Geneva
Visiting Professor at the Faculty of Engineering and Physical Sciences, University of Surrey



SYSTEMIQ TEAM, CONTRIBUTORS AND ACKNOWLEDGMENTS

THIS REPORT HAS BEEN CONDUCTED BY SYSTEMIQ ON BEHALF OF THE SUN INSTITUTE ENVIRONMENT & SUSTAINABILITY.

SYSTEMIQ team

Manuel Braun, Sophie Herrmann, Marlene Kick, Jörn Kobus, Martin R. Stuchtey, Achim Teuber.

Contributors

We would like to thank the following individuals for their input and expertise: Matthias Ballweg, Felix Cornehl, Ben Dixon, Bertram Kloss, Carl Kühl, Tim Langendörfer, Benjamin Neves, Julia Okatz, Louise Patzdorf, Janez Potočnik, Yoni Shiran, Tilmann Vahle, and Marie Wehinger.

We would like to express our gratitude to the following individuals and organizations for the collaboration, many inspiring discussions, and contributing partner features to this report: Chris Grantham (IDEO), Jan-Christoph von der Lancken (EPEA), Benedikt Braig (TRUMPF), Thomas Schneider (TRUMPF), Simon Widmer (Ellen MacArthur Foundation).

ACKNOWLEDGEMENTS

The project team is deeply grateful to a large number of individuals and institutions who have generously contributed their time and energy to inform the report. We wish to thank the following people: Josef Brunner (relayr), Jamie Butterworth (Circularity Capital), William Godfrey (Twist), Tobias Huber (Siemens Smart Infrastructure), Patrick Hypscher (BSH/BlueMovement), Titus Kehrmann (ConnectedValue), Jan Konietzko (Circular X), Stef Kranendijk, Nabil Nasr (REMADE Institute), William Neale (European Commission), Sabine Oberhuber (Turntoo), Maren Otte (CWS), Lothar Pauly, Daniela Pigosso (DTU), Andreas Schröder (Aston Business School), Christian Spengler (Siemens Smart Infrastructure), Hugo Spowers (Riversimple), Caroline Stern (Hilti), Harald Tepper (Philips), Arnold Tukker (Leiden University and TNO), and Tamara Veldboer (Circle Economy).

Our sincere gratitude goes to Walter Stahel (Product Life Institute) for laying the academic foundation of XaaS through his pioneering work on the performance economy and beyond.

Contributors and their respective organizations do not necessarily endorse all findings or recommendations of this report. The project team would like to thank Regency Creative for designing and producing the report. All remaining errors and omissions are the responsibility of the authors. Our appreciation extends to the photographers on Unsplash and Pixabay for the permission to use their photos.

ABOUT THIS REPORT

In the age of climate change and digitization, we have to rethink prosperity altogether: Our focus must shift from the products we manufacture to the benefit they generate for the user. Everything we produce can be thought and commercialized as a service. This report aims to make a new action-focused contribution to the growing field of practice and analysis around XaaS (Everything-as-a-Service) in two ways:

First, by presenting the positive economic, environmental and social case for this way of doing business, with a focus on the manufacturing sector. XaaS business and operating models can be a critical enabler for the circular economy transition, especially by incentivizing producers to optimize for resource productivity and taking responsibility over the product lifetime. The report quantifies the respective material and CO_2 impacts as well as total cost of ownership for three XaaS use cases to demonstrate the economic and ecological potential of such business models.

Second, by providing comprehensive insights on the design configurations and enabling factors that will drive successful strategies for companies innovating and scaling XaaS models. This is important not only to create the enabling environment for XaaS business models to work, but also to avoid potential rebound effects. These can diminish the positive societal impact of business model-driven efforts to decouple natural resource use from economic growth and well-being.

ABOUT THE SUN INSTITUTE ENVIRONMENT & SUSTAINABILITY

The SUN Institute Environment & Sustainability is a non-profit organisation established in Germany by the Deutsche Post Foundation in 2014. It supports institutions, programs and projects dealing with the environmental challenges and opportunities of globalization and enhanced cross-border activities.

Learn more at www.sun-institute.org

ABOUT SYSTEMIQ

SYSTEMIQ was founded in 2016 to drive the achievement of the Paris Agreement and the UN Sustainable Development Goals by transforming markets and business models in three key economic systems: regenerative land use, circular materials, and clean energy. A certified B-Corp, SYSTEMIQ combines purpose-driven consultancy with high-impact, solution development and for-purpose investment and partners with business, finance, policymakers and civil society to deliver transformative change. SYSTEMIQ has offices in Brazil, Germany, Indonesia, the Netherlands and the United Kingdom.

Learn more at www.systemiq.earth

TABLE OF CONTENTS

WHAT IS XAAS?

Everything-as-a-Service (XaaS) models combine tangible products and intangible services so that they are jointly capable of satisfying final user needs. In XaaS models, producers typically maintain product ownership and lifecycle responsibility and are consequently incentivized towards adopting circular economy strategies (long-lasting and circular design, use phase intensification, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling). Moving to XaaS models at scale promotes the shift to a performance economy – as outlined by the seminal academic work of Walter Stahel. XaaS examples include access/outcome/performance-focused models, such as turbine power-by-the-hour (Rolls-Royce), Tires-as-a-Service (Michelin), carsharing (ShareNow), Pay-per-Part (TRUMPF), or Lighting-as-a-Service (Signify).[1–4]

XAAS FAST FACTS

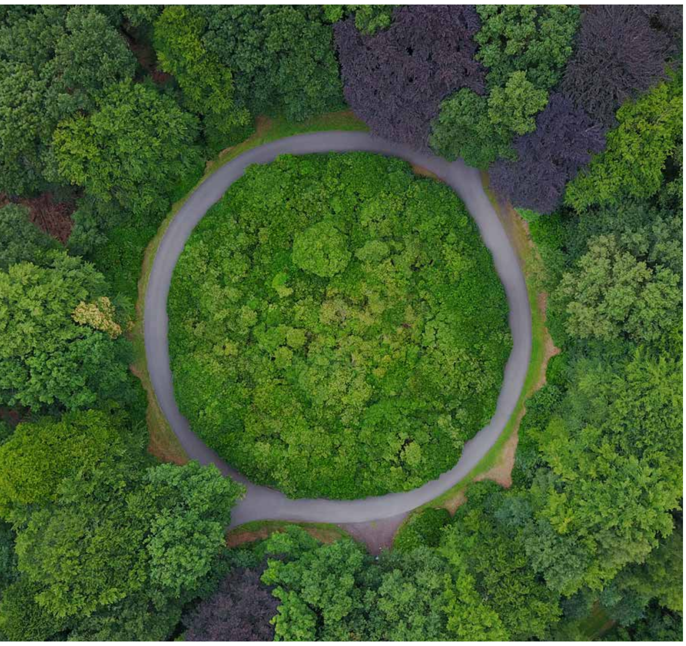
	CAR-AS-A-SERVICE (CAAS)	EQUIPMENT-AS-A-SERVICE (EAAS)	WHITE GOODS-AS-A-SERVICE (WGAAS)
SCALE OF THE PROBLEM	**570 MILLION TONNES** of total carbon emissions in Europe from passenger vehicles	**>90%** of machinery and equipment CO_2 footprint from indirect emissions (upstream and downstream Scope 3)	**5.5%** of total consumer expenditure for furniture, household appliances and maintenance
SCALE OF THE PROBLEM	**33%** increase of transport-related emissions since 1990	**21.8 MILLION TONNES** of ferrous metal scrap in the EU-27 manufacturing sector in 2018	**24.2 TWH ELECTRICITY** **1.5 BILLION LITRES OF WATER** annual consumption from residential laundry
XAAS IMPACT POTENTIAL (EU)	**70.9 MILLION TONNES** CO_2 reduction until 2030 through avoided BEVs and additional BEV-related improvements	**1-2 MILLION TONNES** of ferrous scrap decrease and related Scope 3 emissions in the manufacturing sector if XaaS resource efficiency can be applied	**43-76 EUR** potential savings for a typical household per year by improving lifecycle resource efficiency
XAAS IMPACT POTENTIAL (EU)	**up to 39%** TCO reduction potential from carsharing optimized for circularity	**37-65%** CO_2 savings from EaaS optimized for circularity and resource efficiency	**1.3 MILLION TONNES** of CO_2 emissions reduction through adoption of WGaaS until 2030

Source: SYSTEMIQ analysis, ICCT (2021), IEA (2021), Meinrenken et al. (2020), Wasserbaur et al. (2020), and Eurostat (2021).

EXECUTIVE SUMMARY

Climate change and digitalization are tectonic shifts that will require and reward the transition towards resource-productive industrial systems and dematerialized consumption. This fundamental transition is not only defining the political debate about green growth and the circular economy, but also reshaping the opportunity space for industrial companies. In this transforming landscape circular business and operating model innovation moves centre stage. XaaS (Everything-as-a-Service) models describe core green, digital economy models and can create significant value – if well designed with a view to the key parameters that lead to more sustainable outcomes. This report aims to make an action-focused contribution to the growing field of practice and analysis around XaaS in two ways: first, by presenting the positive economic, environmental and social case for this way of doing business, with a focus on the manufacturing sector. Second, by providing comprehensive insights on the design configurations and enabling factors that will drive successful strategies for companies innovating and scaling XaaS models.

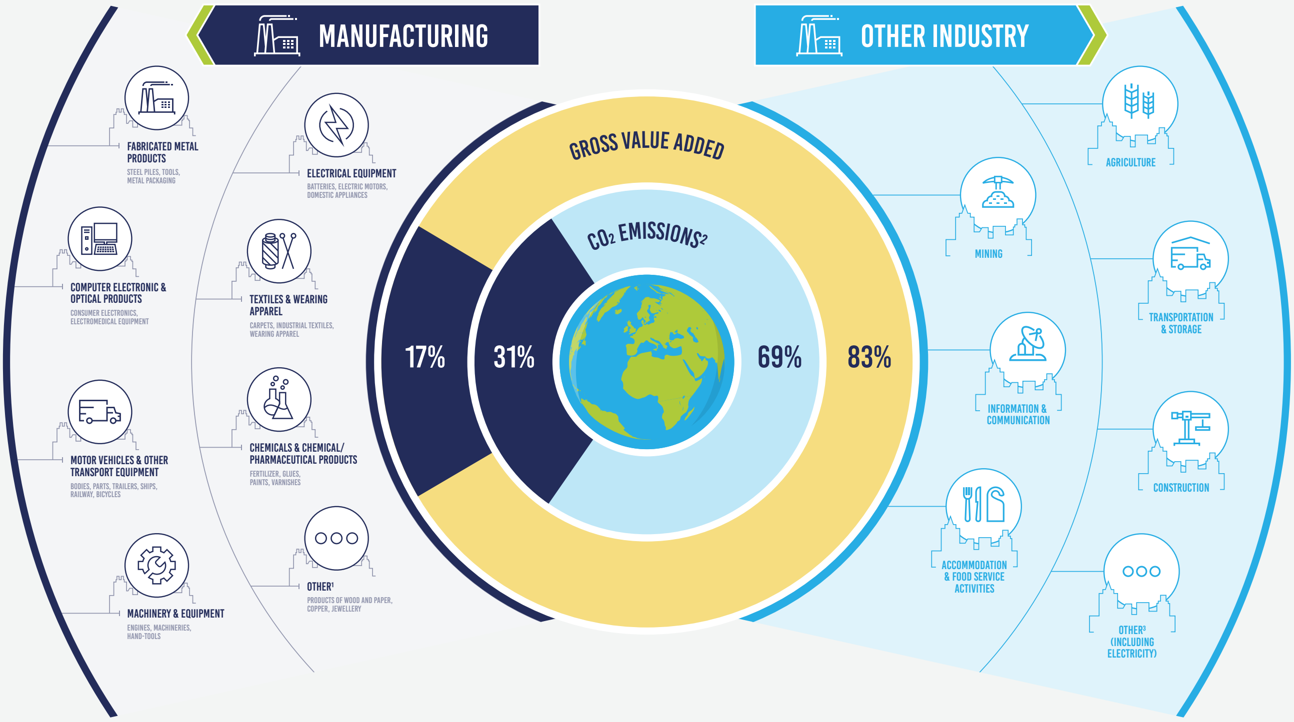
Climate action has become a strategic priority across industrial sectors and requires carbon reductions that go beyond Scope 1-2 improvements of conventional production systems. Recognizing that emissions have risen from 53 billion tonnes (Gt) CO_2e in 2015 to almost 60 Gt globally,[5] many of Europe's leading economies and companies have developed ambitious decarbonization plans and are actively exploring the opportunity space towards sustainability impact. To achieve net zero in 2050, massive reductions are needed until 2030 which have now been politically endorsed in Europe (minus 55%), the US (minus 50-52%), and many other countries (e.g. Norway, minus 50-55%).[6–8] Since the Paris Agreement, progress on low-carbon solutions and markets has been much faster than many anticipated, yet at the same time, global material extraction is still increasing and, if trends continue, will double by 2060.[9] According to the International Resource Panel, more than 50% of emissions are caused by resource extraction and processing.[10] Required carbon reductions by industry companies are too large to be delivered by Scope 1-2 improvements only. These emissions are already high (see Exhibit 1) but represent a small share of overall industrial emissions. On average, only 1/4 of a product's lifecycle emissions result from a company's direct operation.[11] Progressive companies have to reach beyond the product build phase to measure their footprint. They have to manage their Scope 3 emissions along the full value chain and lifecycle including emissions embedded in materials, components (upstream) and those in the use phase (downstream).[12,13]



Achieving Paris-compliant impact requires decoupling economic prosperity from resource consumption – it demands a focus on resource productivity and service systems as means to achieve a circular economy. Circular systems focus not only on designing out waste and managing a material resource base, but also keeping products and materials in use, driving better utilization of resources. This has high potential to reduce product lifecycle CO_2 emissions. As stated, in many cases the use phase emissions make up the majority of the product lifecycle footprint (e.g. ~50% for computer equipment, ~60% for capital goods, ~80% for cars).[11] The decarbonization potential achieved by a circular economy is further leveraged by supporting the conservation and restoration of biodiversity and

EXHIBIT 1

Overview of European manufacturing industry (subsectors), related CO_2 emissions and gross value added.



[1] Other Manufacturing categories, e.g. Furniture, Paper, Basic Metals

[2] CO_2 emissions accounts by NACE activity in 2019

[3] Other NACE Rev.2 codes, e.g. Financial and Insurance Activities, Education, Real estate activities

Source: Eurostat.(2021). Data available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_ainah_r2&lang=en

the minimization of pollution. The circular economy lens, a regenerative economic model by design, describes pathways and new business models for economic growth opportunities and value creation from fewer resources. Circular business models play a crucial role to increase customer utility as well as decrease resource consumption and the full scope of CO_2 emissions. Digitalization builds a new foundation and offers unprecedented opportunities for such new, dematerialized, circular business models. Leading companies are shaping the cutting edge of innovation – product innovation, service innovation, and system innovation.

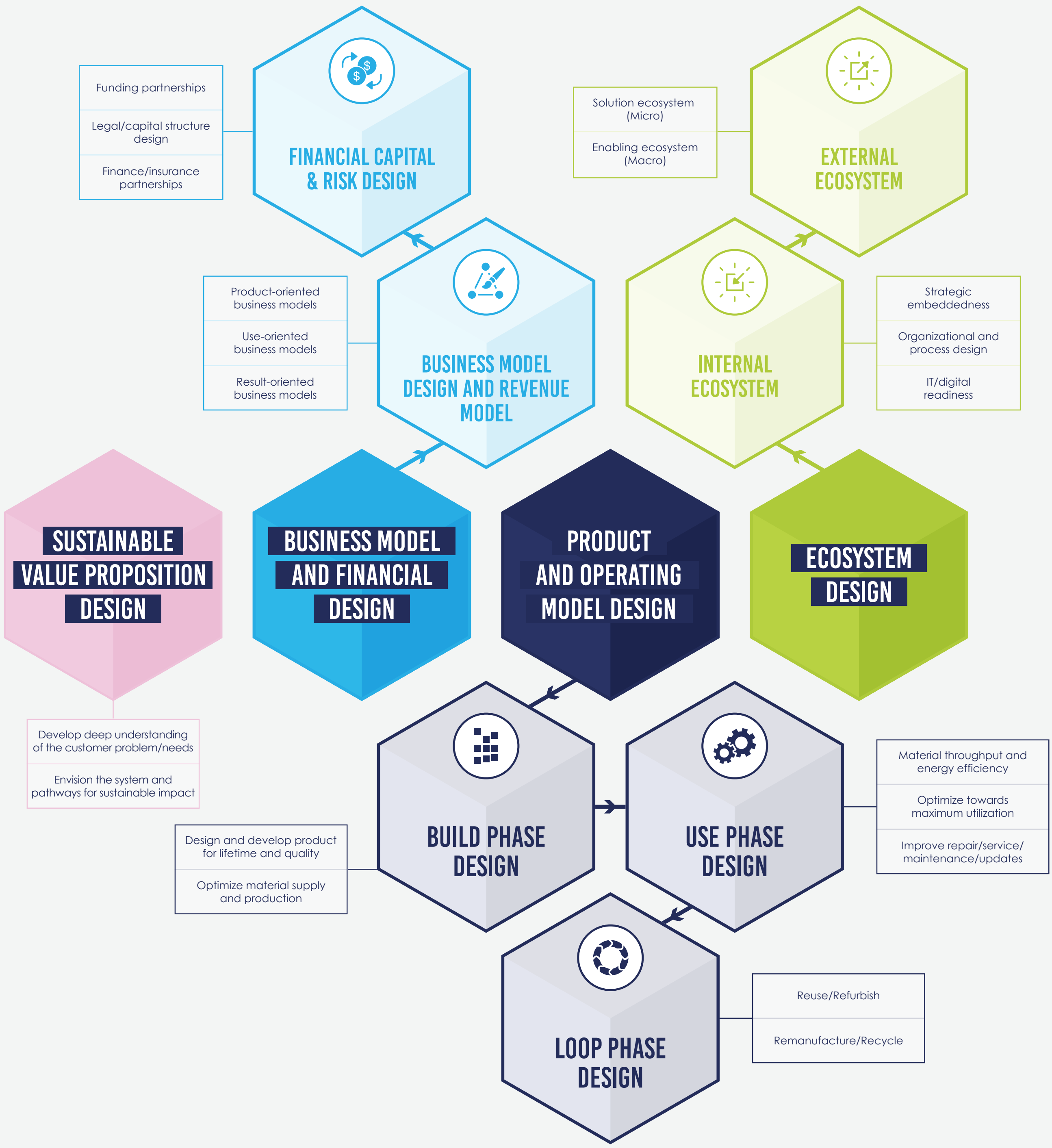
Global market dynamics and increasing competitive pressure reinforce the need for many organizations to design more productive and service-oriented systems. New sources of growth and differentiation are needed in many sectors. As markets mature and penalties for resource-intensive products increase, companies are looking out for new business opportunities. Supply chains need to strengthen their resilience and transparency. Winning new talent still represents one of the main managerial challenges. In recent years digitalization and Industry 4.0 have transformed operations substantially – especially with respect to data analytics and intelligence, connectivity, and computational power, as well as robotics and human-machine interaction. During the COVID-19 pandemic alone, the adoption of digital technologies in companies has increased significantly by up to seven years.[14] Industry operates in a new normal: faced with a complexity of internal and external challenges, but equipped with a technology stack and momentum that enables sustainable economic value creation.

XaaS models are a powerful climate-compatible solution that can deliver both environmental benefits and more economic value. Offering Everything-as-a-Service (XaaS) follows the idea to enable access instead of ownership, selling utility or services instead of products: people don't need cars, but mobility; they don't need washing machines, but clean clothes; they don't need pesticides, but plant protection or yield. Delivering utility/outcomes/performance changes everything. For society, XaaS models can democratize consumption, strengthen regional value creation and decent employment, and can entail positive health impacts. For customers/consumers, XaaS models can provide a better way to achieve their needs. For producers, XaaS models have the potential to strengthen deep customer relationships and to increase (and capture) value pools. By shifting ownership, control and responsibility to producers (producer ownership), XaaS models are naturally incentivized towards maximizing resource productivity and lifetime value. Selling outcomes (e.g. mobility, yield) goes with the incentive to achieve this by using less material, waste and operating cost. At the end of the use cycle, retained ownership enables remanufacturing and recycling of valuable raw materials. In doing so, such business and operating models are a critical enabler of the circular economy. From a systemic perspective, producer ownership is one of the most elegant ways to drive sustainable product design choices.[15] The degree of potential sustainability impact is massive but will depend on the ambition level of the producer when designing an XaaS model.

To deliver both economic and environmental benefits, XaaS systems must be designed along four critical design parameters. Currently, strategic shifts to XaaS models can be observed across manufacturing sectors and a vast diversity of products.[16,17] This trend tends to hold across a broad range of company sizes, development stages and geographies. Think of famous product service examples such as Rolls-Royce's power-by-the-hour, Michelin's Tires-as-a-Service or ShareNow's carsharing model and less known examples such as Signify's Lighting-as-a-Service, CWS's Workwear-as-a-Service and TRUMPF's Equipment-as-a-Service (EaaS) model. In the machinery and equipment sector, EaaS models are expected to grow by 35% annually until 2025.[18] The case of mobility illustrates that Car-as-a-Service (CaaS) and shared mobility becomes more and more acceptable and a norm, for instance within companies (e.g. Siemens' new car policy), cities with high population density (e.g. Helsinki), or consumers.[19–21] The market for alternative vehicle ownership models for smart and flexible mobility is projected to grow by a factor of 4 (to 463 billion EUR) until 2035.[22] However, many producers are stalled by the complexity of design choices and neglect the environmental potential of XaaS models – much of the time this is due to lack of awareness of the enormous potential, and in the worst case results in rebound effects. The design and optimization process requires decision-makers to understand the complexity of design choices and their environmental implications – to eventually be able to advance both the economic and environmental potentials at the same time. Configuring a coherent XaaS model on this basis should address four critical design blocks (Exhibit 2). The complexity of configurations as well as the pathway to take design choices depends on individual organizational characteristics:

EXHIBIT 2

Four building blocks to configure XaaS models.



Source: SYSTEMIQ.

- **Sustainable value proposition design: developing a clear value proposition and impact ambition early on.** Companies should identify and define the basic human or societal needs their offering is trying to meet with the XaaS model. For example, a car manufacturer has to decide how to sell mobility (e.g. car usage, passenger kilometres). In the end, customer utility counts and is the ultimate measure of customer value. Beyond that, understanding the wider system (e.g. for a car maker the mobility system) is key to deriving pathways to maximize sustainability impact (e.g. addressing systemic inefficiencies, anticipating rebound effects). Together, a sustainable impact ambition and a customer-centric value proposition are the foundation for configuring the XaaS model.

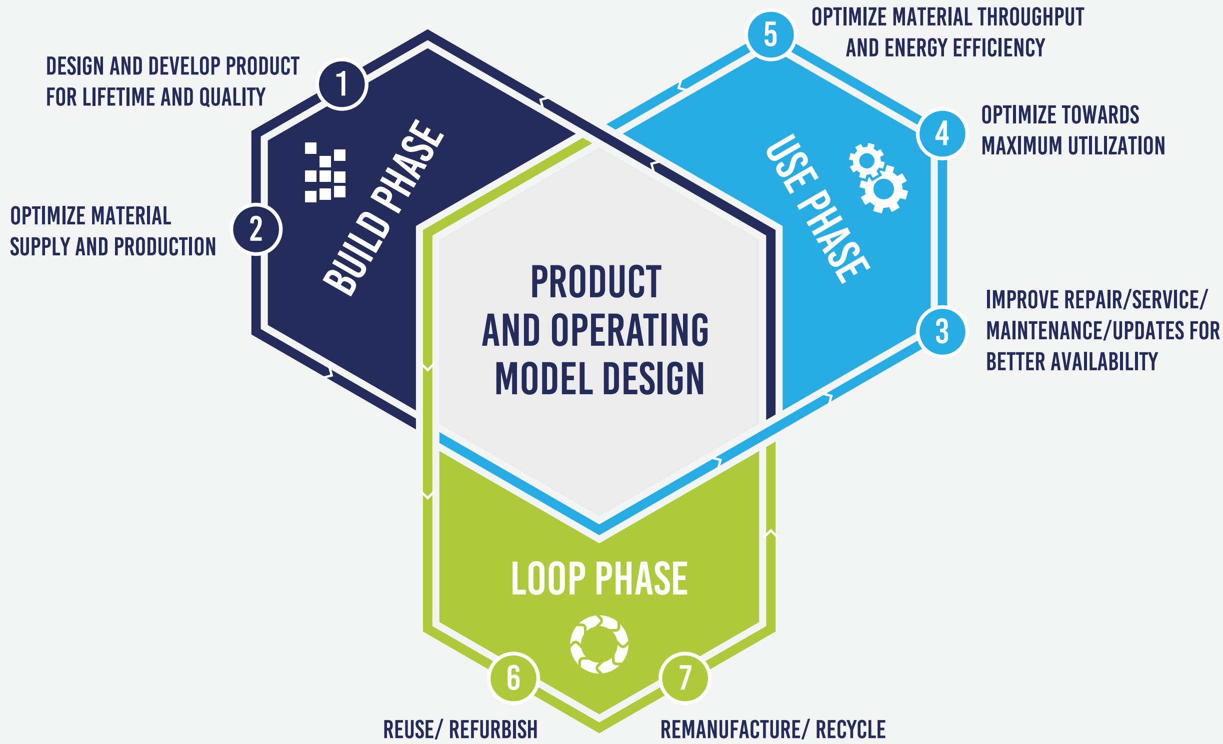
- **Business model and financial design: configuring the fundamental business model orientation as well as financial set-up and risk management**. There are four main archetypes available to identify suitable XaaS business models. Those include use-based business models or result-oriented schemes, where ownership is kept at the producer/provider level. Another option are product-oriented models, where product ownership is still transferred to customers but value creation is deeply linked to service/performance contracts. Finally, there are sharing platforms, which go beyond the use-/result-oriented models by single producers/providers and typically offer multiple products. There is no silver bullet answer to business model design and many feasible combinations exist between models, yet the design choice strongly influences the requirements regarding funding and financial design. Thereby companies developing XaaS models need to specifically design mitigation strategies to manage financing risks, operating risks and commodity risks, as well as information risks.

- **Product and operating model design: "simply" switching the business model is not enough – unleashing full economic and environmental benefits requires addressing product and operating model design levers (Exhibit 3)**. To optimize total cost of ownership (TCO) and decarbonization potential, a circular product and operating model needs to be implemented in the XaaS model. Key circular value levers address the full product lifecycle in terms of (a) build phase (e.g. develop product for quality and lifetime, optimize material supply and production), (b) use phase (e.g. improve repair/maintenance for better availability, increase utilization, optimize material throughput and energy efficiency), as well as (c) loop phase (e.g. reuse/refurbishment, remanufacturing/recycling). To effectively reduce the environmental impact of products through XaaS models combining the key levers, it is required to understand where these impacts (e.g. CO_2 emissions) occur along the lifecycle.

- **Ecosystem design: optimizing the internal organizational set-up and finding the right partners for implementation to manage resource/service flows, financial flows, and information flows.** On an (a) intra-organizational level, it is critical for companies to consider that XaaS models typically require more interdisciplinarity and an agile/collaborative approach between R&D, Operations, Sales/Customer Service departments. Furthermore, XaaS projects benefit substantially from strategic embeddedness and strong senior management and shareholder support. Decision-makers have to be aware that XaaS models may require building new capabilities (e.g. with respect to data/digital, agile/SCRUM, sustainability/LCA). Proactively addressing change management aspects (mindset, purpose, structures, etc.) is therefore particularly relevant for established

EXHIBIT 3

Seven circularity levers address all three lifecycle phases of the product.



Source: SYSTEMIQ.

organizations. Beyond that, it is essential to assess whether the IT/technology stack is ready to manage XaaS processes (e.g. ERP system, predictive analytics). On the level of the (b) solution ecosystem (micro) an organization may not be able (or may not want) to cover all activities needed to deliver the XaaS solution internally. Choosing and orchestrating the right ecosystem design (partners) along the value chain and across industrial borders from the start is essential to deliver complex XaaS models. Finally, the level of the (c) enabling ecosystem focuses on creating supporting structures and collaboration beyond the boundaries of the solution ecosystem to drive innovation or to represent common interests. This typically requires defining a clear goal (e.g. scaling the XaaS model, regional value creation, industry sector decarbonization) and may include further relevant parties from politics (e.g. communities, municipalities, nations), society (consumer associations and NGOs), business/industry (e.g. associations, standard setting bodies) and research (e.g. universities, research institutions, innovation hubs).

Three quantified case examples demonstrate that XaaS models could create impact ranging from minus 24 to 65% in CO_2 emissions and 2 to 39% in terms of final TCO reduction. These cases illustrate the impact of ambitiously designed XaaS models in terms of providing utility, while decreasing resource intensity and increasing profit pools. Each time, we present impacts of less and more optimized XaaS models to show how the level of ambition influences results (Exhibit 4). For all cases modelled and presented in the report, reductions in CO_2 and TCO are not a given but depend on (a) designing product and operating model for maximum circularity, (b) pricing, i.e. the potential capturing of TCO effects by the provider, and (c) the enabling ecosystem for the XaaS model and its benefits, including avoidance of rebound effects. Today, there is high risk in failing in some of these dimensions, as many XaaS examples show.

EXAMPLE 1

Shifting to Cars-as-a-Service (CaaS) – an important element for shaping the future of sustainable mobility. The uptake in electrification of passenger road transport (switch from ICE to BEV) powered by more and more renewable energy will eliminate tailpipe emissions in the long run (minus ~30-65%)[i]. But in the mid-term, irrespective of the powertrain electrification, decarbonizing the build phase will become crucial to reach climate neutrality for the automotive value chain. A circular CaaS product and operating model could complete the transformation towards sustainable passenger transport and decarbonize the CO_2 emissions caused by a BEV by ~25% in a car subscription model (Scenario 1) and by ~45% in a free float carsharing model (Scenario 2). An initial analysis indicates that a free float carsharing model could achieve TCO benefits of up to ~39% for consumers.

From an aggregated CaaS perspective, this could lead to a reduced European BEV stock[ii] of 17% (ca. 5.8 million vehicles) providing the required mobility demand, translating into CO_2 savings from avoided production of 70.9 million tonnes (Mt) CO_2 until 2030 and additional annual BEV-related savings of 8.3 Mt CO_2. Beyond that, from a systemic perspective, it is critical to emphasize that CaaS models should be seamlessly integrated with other even more sustainable modes of transportation (e.g. walking and bike riding for short distances, public transportation and railways) to maximize the overall environmental benefits.

EXAMPLE 2

Machinery and Equipment-as-a-Service (EaaS) – enabling a resource-efficient manufacturing industry. The CO_2 footprint of a typical machine in the use phase often exceeds that of its build phase by a factor of 20. Capitalizing on Industry 4.0 investments and capabilities, EaaS models have the potential to decarbonize the full lifecycle emissions, including the production process. The case in this report builds on the reference example of a state-of-the-art metal laser cutting machine. The analysis reveals that CO_2 emissions can be reduced by ~37% when the machine is offered in a result-oriented Pay-per-Part model (Scenario 1). Extending Scenario 1 to a demand-pooling marketplace production platform (Scenario 2) decreases emissions by up to ~65%. The decarbonization potential mainly stems from the use phase resource efficiency: optimization for lifecycle efficiency per design, increased production capacity (utilization) combined with improved results with less scrap in terms of metal sheets processed into functional parts. Due to the increased capacity and improved material throughput, TCO can be reduced by ~16–24%, depending on the EaaS scenario (Exhibit 4), while CapEx switches to OpEx for the customer.

An aggregated lens to EaaS shows that this model can play a crucial role in decarbonizing machinery and metal processing overall. To illustrate, if 30% of newly installed laser cutting machines until 2030 were offered in comparable EaaS models (20% EaaS 1.0; 10% EaaS 2.0), then 6.3 Mt CO_2 could be saved through improved machine lifecycle

i Minus 30% with European electricity mix 2019 to 65% with entirely renewable energy.

ii Assuming the European BEV fleet in 2030 (according to the IEA Sustainable Development Scenario) would adopt 20% subscription-based models and 20% carsharing.

footprints. From a systemic perspective, a deeper value chain integration and ecosystem cooperation can potentially lead to further optimization of resource flows. Implementing XaaS logics along the supply chain (e.g. Metals-as-a-Service, Components-as-a-Service and Product-as-a-Service) is the logical next step in creating functionally connected, outcome- and utility-focused systems.

EXAMPLE 3

White Goods-as-a-service (WGaaS) – a driver for resource productivity of domestic household appliances. This case explores the example of washing machines (WMs), which are the most resource-intensive domestic appliance consuming 1.4 Mt of materials, 24.2 TWh of electricity, and 1.5 billion litres of water in Europe per year. Offering WGaaS can be a critical enabler for optimizing associated environmental build and use phase impacts. Offering WMs in subscription models (Scenario 1) can enable the widespread instalment of top-of-the-line WMs with higher lifetime and resource productivity through maintenance, increased efficiency and material recovery. The CO_2 footprint could be decreased by ~24% compared to an average WM. Operating a pooled Pay-per-Wash model (Scenario 2) could decrease emissions from laundry washing by ~35% through additional effects such as higher load utilization. WGaaS shifts upfront costs over the use phase, making high-quality WMs accessible to more customers. The resulting lifecycle resource efficiency entails a TCO reduction potential of between ~18% (Scenario 1) to ~24% (Scenario 2).

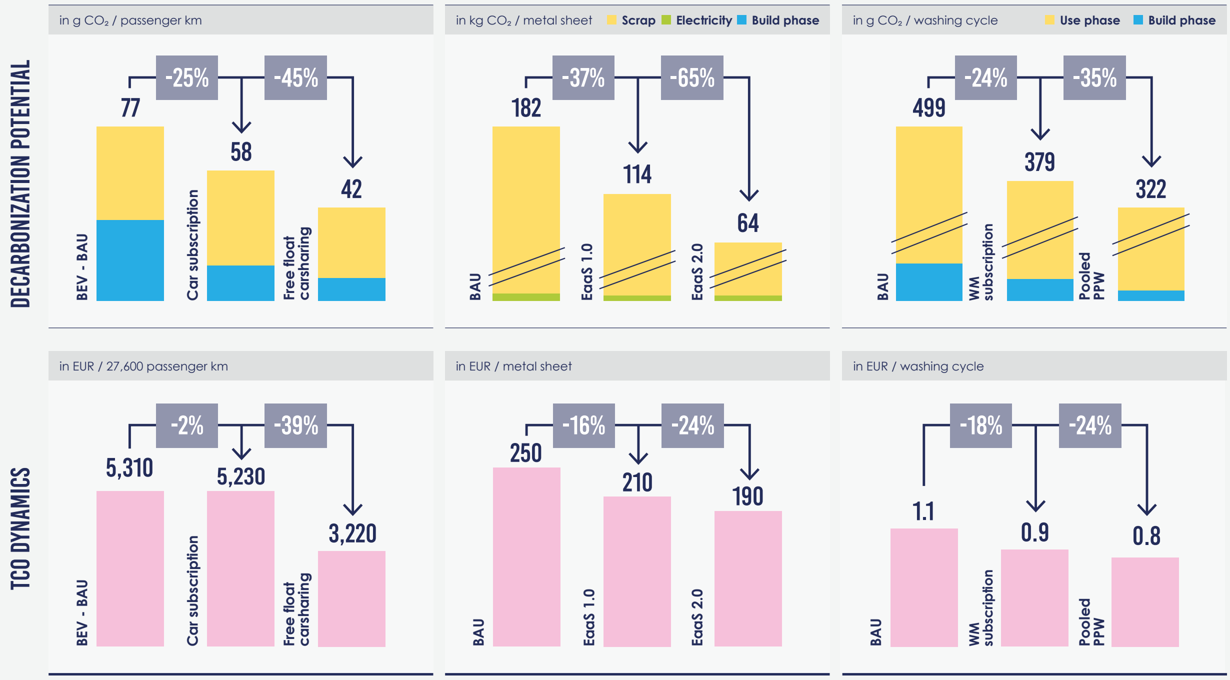
Overall, WGaaS can have an aggregated impact for reducing residential resource consumption and CO_2 footprint. Assuming that 20% of WMs sold in the EU until 2030 would be provided via circular subscription models and 10% by pooled Pay-per-Wash solutions, 49 million m³ water and 1.2 TWh electricity can be saved. Together with reducing the impact of materials embedded in WMs, this translates into savings of 1.3 Mt CO_2 emissions. At the same time, households could save between 43-76 EUR per year (in total ~2.2 billion EUR until 2030). Taking a long-term outlook, from a systemic perspective beyond the scope of this case, the next evolution of WGaaS could develop into full-service schemes, building on a high degree of automation and value chain integration (e.g. automated ironing) or at-scale (last mile) logistics.

© TRUMPF Group

EXHIBIT 4

Transitioning to XaaS: Measuring the ecological and economic effects of three use cases optimized for circularity.

THE POWER OF XAAS	CAR-AS-A-SERVICE (CAAS)[1]	EQUIPMENT-AS-A-SERVICE (EAAS)[2]	WHITE GOODS-AS-A-SERVICE (WGAAS)[3]
	CaaS can maximize utilization and vehicle lifetime and enhance the productivity of resources in use.	**EaaS can optimize lifetime capacity and material throughput**, addressing structural inefficiencies.	**WGaaS can enhance resource efficiency** in the build and use phase and lifetime functionality.
	Decarbonization is driven by a higher utilization, smart servicing and design for extended lifetime.	**Decarbonization is driven** by optimizing the cutting process and lifecycle smart support services.	**Decarbonization is driven** via longer lasting, more efficient appliances and optimized user behaviour.
	TCO improvement as customers only pay for utility, but depends on the pricing strategy of producers.	**TCO improvement** due to increased capacity and decreased waste, shifting CapEx to OpEx.	**TCO can be decreased** through higher utilization, but depend on the pricing strategy of the producer.
	Seamless integration of CaaS into intermodal transport towards future of sustainable mobility.	**Optimizing material flows and utilization in closed value networks** for a sustainable manufacturing.	**Leveraging efficient domestic appliances** to reduce residential resource consumption.
	Battery electric vehicle as case example.	**Metal laser cutting machine** as case example.	**Washing machine (WM)** as case example.



Source: SYSTEMIQ analysis based on multiple sources.
[1] SYSTEMIQ analysis based on OECD and ITF (2020), IRP (2020), Ecoinvent (2020), Volkswagen AG (2021a, 2021b, 2021c), Schwacke (2020), expert interviews.
[2] SYSTEMIQ analysis based on data provided by TRUMPF Group (2021).
[3] SYSTEMIQ analysis based on Sigüenza et al. (2021), Bocken et al. (2018), Homie (2021), BlueMovement (2021), EcoTopTen (2021), expert interviews.

The shift to XaaS is a pro-market, pro-growth and pro-technology agenda. Scaling XaaS as a basis for the circular industry transformation at the required pace requires a strong digital infrastructure, new forms of collaboration and a set of (market-oriented) policy interventions. This study explores the role of these enablers to accelerate and bring the XaaS models to their full potential.

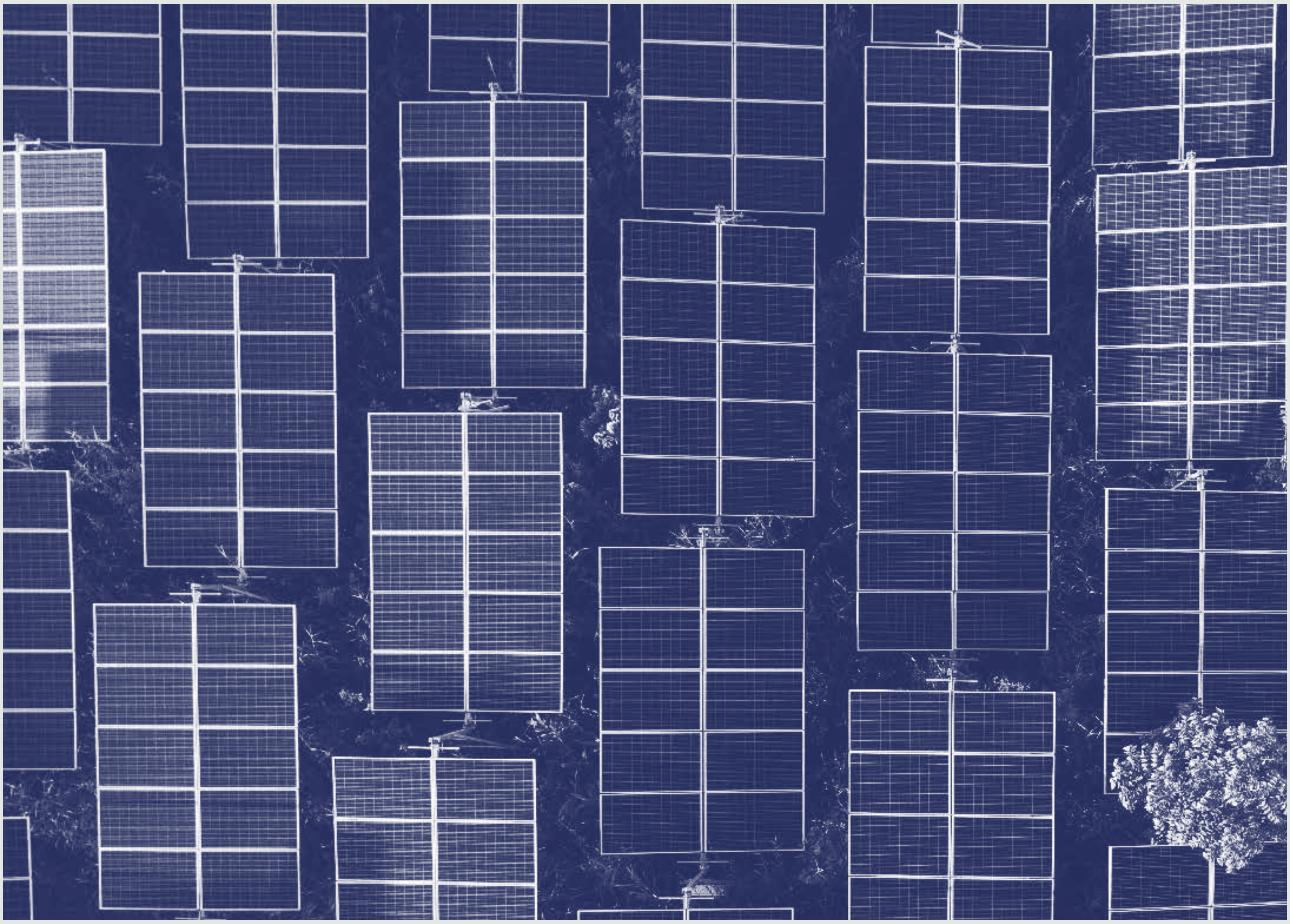
- **First, the technology stack of companies and sectors will be critical to manage XaaS data/ information flows – open architectures will be**

needed to enable circular production systems. On the one hand, the digitalized Industry 4.0 builds the foundation from which XaaS models emerge, and on the other hand, IT/digital capabilities will play the key role in satisfying additional increasing data needs driven by economic and ecological requirements (e.g. carbon accounting). A company's readiness for XaaS implementation will be dependent on IT/digital (e.g. data capturing and analytical capability), and drive the overall digital transformation.

- **Second, policymakers can apply demand-side instruments to strengthen ownership of producers and to create a level playing field for all actors.** Regulation can be powerful to accelerate and provide stimuli, but also plays a pivotal role to adjust for systemic rebound effects. Overall, policymakers should address three key policy instruments and evaluate cross-sectoral measures to foster the shift towards sustainable XaaS models that fulfil circular economy principles and reward access over ownership. In particular, (a) economic and market instruments should create strong fiscal incentives, such as carbon pricing, to encourage resource efficiency or discourage consumption patterns with negative footprints.[23] Economic instruments should essentially incentivize producers to retain value of products by taking responsibility over the product lifetime and keeping ownership. Funding support or access to capital/grants can be important to enable the uptake of circular XaaS models. In addition, since public authorities are responsible for spending over 14% of the GDP per country in the EU, procurement rules should be evaluated towards applying guidelines for Green Public Procurement including rules for XaaS models as soon as possible.[24] Second, (b) regulatory instruments and standards should connect products to producers to facilitate a lifecycle perspective and producer ownership responsibility, but also evaluate the effectiveness of Ecodesign and waste regulations for XaaS models. In addition, standards are a verifiable way to control socially and environmentally acceptable business practices, unify terminology and facilitate necessary interfaces for the exchange of information. Finally, (c) empowering public and private institutions as well as consumers will be critical. This should include information and awareness campaigns to educate organizational actors (e.g. key decision-makers and institutional investors) as well as consumers about both the economic and environmental impact potential of XaaS models.[25]

- **Third, mobilizing industry action and adoption of XaaS models would benefit from facilitating exchange and collaboration among the emerging ecosystem of pioneers.** Owing to the complexity of the outlined design decisions, networking, exchange and best-practice sharing in the precompetitive space is necessary to enable organizations to continuously optimize their XaaS model configuration. Furthermore, in order to foster specific regional value creation (e.g. specific industrial clusters) or integrated XaaS models (e.g. alignment of XaaS models across value chain steps) stronger collaboration and systemic partnerships will be essential. In this context, entrepreneurial innovation will be vital to address many of the emerging challenges with novel solutions, help incumbents to transform to sustainable XaaS models quickly, and thereby accelerate the wider industry transformation towards sustainability and resource productivity.

Combining climate neutrality and digitalization into XaaS is an attractive vision for Europe. XaaS can provide better ways for consumers and society to fulfil their needs. Industrial companies may drive decarbonization and unleash innovation and competitive differentiation. By strengthening the ownership of producers, XaaS presents a first-best solution, addressing the full scope of emissions, creating a level playing field for all actors. Consequently, countries, companies and investors now have a once-in-a-generation opportunity to decouple economic prosperity from natural resource use and environmental impact, creating millions of jobs and more resilient economies.[26]



1

THE INDUSTRIAL LANDSCAPE IS TRANSFORMING – COMPLEX CHALLENGES AND NEW GROWTH OPPORTUNITIES ARE RESHAPING THE COMPETITIVE AGENDA

1.1 GLOBAL MARKET DYNAMICS AND COMPETITIONREQUIRE MORE PRODUCTIVE AND SERVICE-ORIENTED SYSTEMS

Value chains are under pressure as globalization is losing momentum and resilience is becoming a priority.[1] European industry is deeply integrated into international value chains. In Germany for example, over 40% of net exports are made possible by participation in global value chains.[2] However, since 2008 world trade has been losing relative importance for the world economy. Trade in goods and services in relation to GDP has been stagnating.[2] Reasons include the increasing technological self-sufficiency of large emerging economies, a focus on local production, the shrinking trade in physical products, and the increase of trade-restrictive, protectionist measures.

The COVID-19 pandemic shifted the focus on making supply chains more resilient. In the event of a crisis, globally ramified supply chains can quickly lead to production downtimes, sales slumps, and a threat to a company's existence. In view of these risks, the localization versus globalization debate has entered a new era.[3] For example, shortages of intermediate products have become a serious problem for German industry. According to the German ifo Institute, 45% of industrial firms surveyed in a recent study reported supply bottlenecks, reaching by far the highest value since January 1991.[4]

Fluctuating resource prices lead to cost volatilities and affect product-based companies.[5] As businesses exploit ever more diffuse sources of raw materials, prices for new supplies of raw materials rise and fluctuate. Since production is often tied to many limited resources, each of which faces supply constraints, this leads to more volatility.[6] Many companies are already preparing for higher prices and raw materials shortages by starting to use secondary materials, improving material efficiency, and switching to more resource-productive business and operating models.

Customers increasingly demand deep relationships and customized, performance-focused business models responding to their needs. Customers are looking for ways to increase convenience and flexibility, share risks and secure product uptime and availability. In the B2C industry they increasingly value access instead of ownership (e.g. as is the case for carsharing). B2B customers seek opportunities to shift from capital expenditures (CapEx) to operational expenditures (OpEx) to stabilize their cash flows. Given ever shorter innovation cycles, customers are looking for models that allow for high flexibility and updates of their assets in use. Producer-customer relationships shift from transactional sales to performance- and outcome-oriented partnerships.

The competitive pressure on company levels is increasing. High-value products and services translate to more than 20% of the EU's total value added and provide more than 35 million jobs.[7] However, in many industries, rising market concentration (often outside the EU) is increasing competitive pressure.[8] In addition, price-competitive Asian-Pacific companies are growing and positioning the region as the "new global industry powerhouse".[9] Instead of competing on price and production margins, many European companies need to find new areas of competitive edge.

Value creation is increasingly shifting from physical products to dematerialized, digital business models.[10] Some of the highest valued companies are dematerialized (such as Netflix or Facebook) and a lot of value in physical goods industries comes from their (dematerialized) service-based activities (such as Philips or Rolls-Royce). Hence, the rapidly increasing importance of data and services for value creation is driving companies to rethink their traditional business models.

Industry companies are on the hunt for talent with emerging skills, such as data and analytics, cybersecurity, UX design, or environmental science. The next generation of employees are much more aware of climate change and better equipped with digital skills. They recognize the importance of new service-based and data-driven business models to address the environmental and economic challenges associated with current business practices. Overall, these developments and trends described above are challenging industrial actors to reinvent themselves for the future, while at the same time providing unique business opportunities that require new competencies: value generation driven by dematerialization and digitalization.

1.2 INDUSTRIAL DIGITALIZATION IS RESHAPING OPPORTUNITIES FOR BUSINESS MODEL INNOVATION

In recent years digitalization and Industry 4.0 have transformed operations substantially. This has led industrial systems to operate in the new normal of digitally enabled products and processes. Data analytics and intelligence, connectivity, and computational power, as well as robotics and human-machine interaction have become important success factors for companies. These technological trends have significantly increased data availability in companies and along the supply chain. For example, today over 39% of companies are using digital technologies to improve end-to-end supply chain transparency.[11] A range of industrial Internet of things (IIoT) solutions enable products to share performance data and provide insights on product usage. In this way, manufacturing companies optimize production and processes.

Digital adoption is further gaining momentum and will be at the core of future industrial competitiveness, where service effectiveness and creating new business models will be key. During the COVID-19 pandemic, the adoption of digital technologies has accelerated by up to seven years on previous forecasts.[12] Investments in digital capabilities and applications are key themes for corporate decision-makers.[11] Digital transformations are pursued as unique opportunities for companies to rethink their strategy, value chain, creation and operations, as well as their sales channels and customer engagement.

Digitalization is the spark for transforming industrial systems towards sustainability by creating a circular economy. Data and digital technology can enable dematerialized product offerings, for example by virtualizing formerly physical goods, affecting related CO_2 emissions. Tracking and tracing technologies provide information on the condition and performance of products. Machine learning improves production processes and minimizes waste, leading to less resource demand. Ultimately, digitalization brings about new business models where companies can charge customers based on actual usage or product performance, eventually increasing product utilization or reducing overall resource consumption.[13]

1.3 INCREASING DECARBONIZATION PRESSURE REQUIRES COMPANIES TO TAKE FULL SCOPE RESPONSIBILITY

Climate change is accelerating and the coming decade is crucial to take immediate and collective action. Global CO_2 emissions are rising. Even a severe COVID-driven contraction of the economy has barely changed this trajectory with CO_2 emissions projected to rebound in 2021 to pre-pandemic levels.[14] In the coming decade (until 2030), society needs to reduce CO_2 emissions by 45% compared to 2010 levels and reach net-zero emissions by 2050 to limit warming to 1.5 °C as aspired to in the Paris Agreement. Next to decarbonizing the energy sector, efficient resource use and waste management are key strategies to achieving this goal, alongside conserving and restoring biodiversity, and minimizing pollution.[15] Environmental sustainability and economic growth is no longer a trade-off, but rather the foundation of a new, green growth paradigm.

As part of the solution, the massive reductions that are needed until 2030 have now been politically endorsed in Europe (minus 55%), the US (minus 50-52%), and many other countries (e.g. Norway, minus 50-55%).[16–18] Powerful policy signals are being introduced to achieve the European climate neutrality target by 2050. The Circular Economy Action Plan of 2015 has enabled the adoption of additional policies, such as the European Green Deal and the new Circular Economy Action Plan of 2020, but also product- and sector-specific regulations putting sustainable production and consumption high on the political agenda.

The manufacturing sector is a substantial driver of European emissions and material use and urgently needs to decarbonize and dematerialize to reach climate goals. The European manufacturing industry consists of a large variety of subsectors including plastics, electronics, textiles, machinery and equipment, among others. With its intense material use, the manufacturing sector accounted for ~1/3 of CO_2 emissions from industry in Europe, outweighing gross value added in 2019 (see Exhibit 5).[19] Direct emissions of European manufacturing industry are particularly related to three materials: steel, aluminium, and chemicals, including plastics. The demand for these materials is notably driven by the motor vehicle, the machinery and equipment, packaging, and consumer goods industries.[i,20]

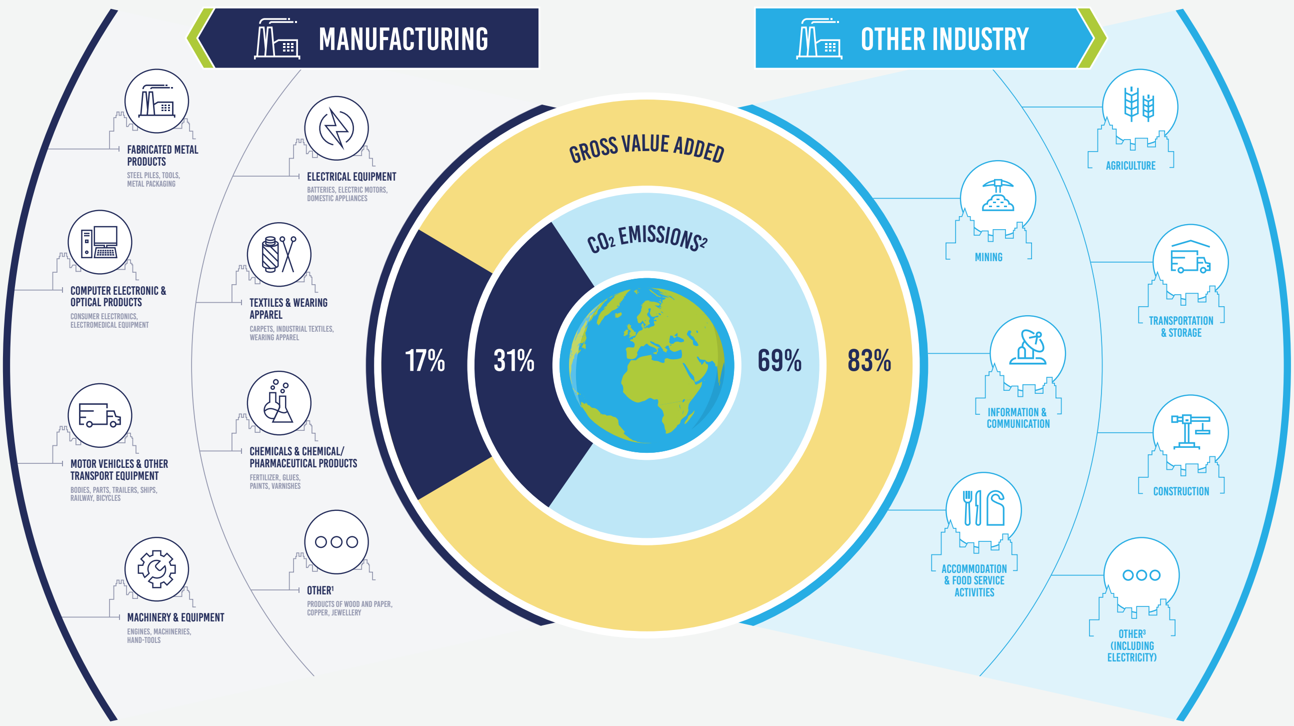
In most cases, CO_2 emissions along the value chain – especially emissions embedded in materials and components and in the product use phase – represent the largest impact. In fact, accounting for indirect emissions including upstream and downstream emissions (Scope 3)[ii] would reveal that the footprint of the manufacturing sector over product lifecycles is much higher (than the Scope 1 and 2 emissions typically reported).[21] On average, only 1/4 of the product lifecycle CO_2 emissions result from a company's direct operations (Scope 1 and 2).[22] To focus industry efforts on reducing carbon emissions and becoming carbon-neutral, it can be expected that nations will in future set new policies to decrease full lifecycle impacts, too.[23] Required reductions are too large to be delivered by Scope 1 and 2 improvements of conventional production systems.

i Industry classification taken from The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE.

ii For a detailed explanation of Scope 1-3 emissions, please refer to the Glossary.

EXHIBIT 5

Overview of European manufacturing industry (subsectors), related CO_2 emissions and gross value added.



[1] Other Manufacturing categories, e.g. Furniture, Paper, Basic Metals
[2] CO_2 emissions accounts by NACE activity in 2019
[3] Other NACE Rev.2 codes, e.g. Financial and Insurance Activities, Education, Real estate activities

Source: Eurostat.(2021). Data available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_ainah_r2&lang=en

To close the emissions reduction gap, decarbonization measures must go beyond increasing the share of renewable energy and production efficiency. For example, due to increasing product demand, these measures will quickly be overtaken by emissions resulting from increased material production. Circular economy business practices, such as the maximization of product utilization and the decrease of total material used, help to further reduce the emissions along the product lifecycle especially if utility-oriented emissions are considered (e.g. CO_2 per part produced and not only CO_2 per machine). To meet the targets, material consumption needs to be decoupled from industrial economic value creation through new business models.[24]

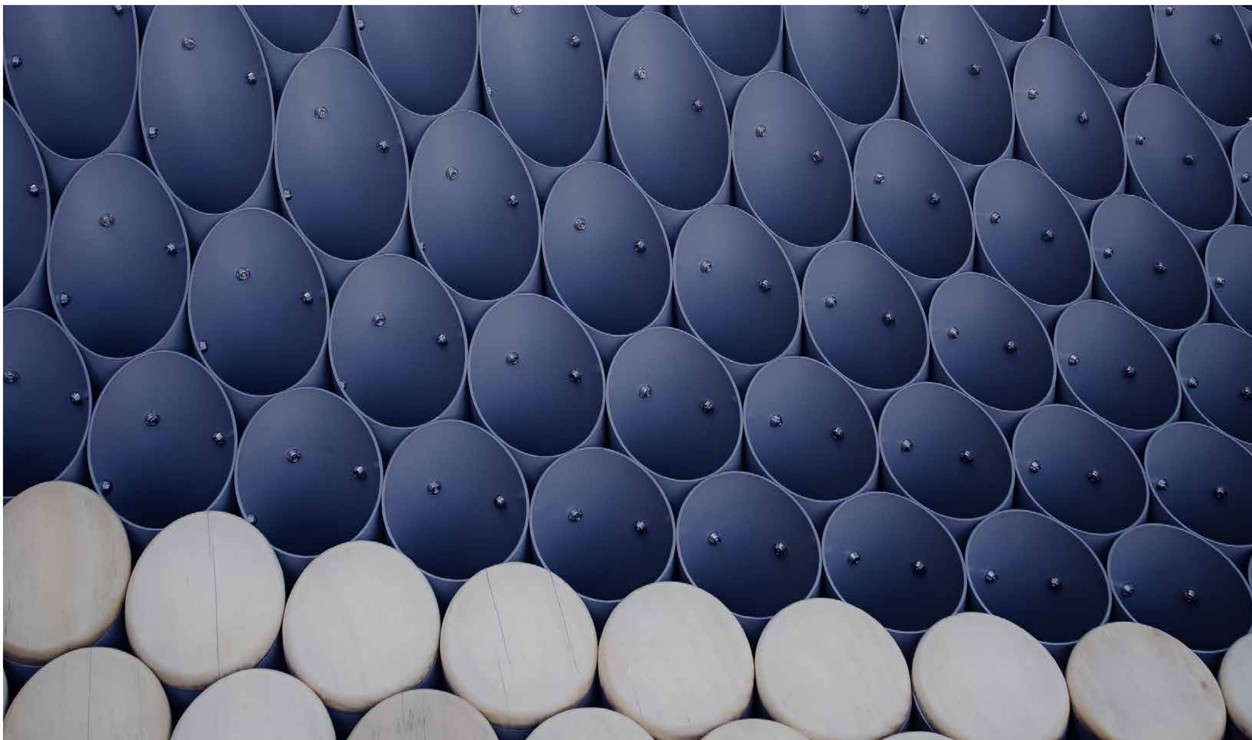
Highly resource-productive systems offer a path for industry to back out of a dead end. Over the last decades, economic activity and growth was significantly tied to an increase in resource consumption. Increased resource consumption, however, causes environmental harm. Global resource extraction and processing accounts for 90% of biodiversity loss and 50% of global GHG emissions.[5] According to the International Resource Panel (IRP), global material extraction continues to grow; the global demand for materials in a business-as-usual scenario (BAU) is projected to double by 2060.[25] Materials lie at the core of industrial value creation and industry has manoeuvred itself into a dead end where economic growth means more production (and more resource consumption). Degrowth and sufficiency – required if current production patterns remain – represent a threat to industry. Highly resource-productive systems offer a new growth paradigm for industry that combines economic growth with environmental benefits instead of putting them at opposite ends.

1.4 SERVICE-ORIENTED BUSINESS MODELS ARE CRITICAL ENABLERS OF A CIRCULAR INDUSTRIAL SYSTEM

By changing the way we produce and consume through new technologies and business models, the circular economy can help to reduce emissions, resource consumption and waste. The circular economy can be described as the operating system for building a thriving, sustainable and resilient economy. Underlying circularity principles encourage radical changes to (a) keep products and materials in use, (b) design out waste and pollution, and (c) regenerate natural systems. This entails new product design, revised supply chains, business models and consumption patterns.[26] For example the circular economy tackles the wasteful underutilization of products and strategies for the entire lifecycle – from long-lasting and circular design, to repair and recycling (see partner feature of the Ellen MacArthur Foundation).

Circular business models including Everything-as-a-service (XaaS) enable companies to identify and scale growth opportunities. XaaS models can operationalize the principles of the circular economy – by combining tangible products and intangible services so that they are jointly capable of satisfying final user needs. In XaaS models, producers typically maintain product ownership and lifecycle responsibility. This ensures that business activities, processes, products, and resource flows are aligned to keep their value over time – from selling product volumes to selling product performance or outcomes. Hence, XaaS can create circular material flows if the business model, operating model, and ecosystems are designed accordingly.

XaaS models represent a significant opportunity for companies to navigate the transforming industry landscape and anticipate the developments towards servitization, digitalization and decarbonization (see Exhibit 6). Enabled through digitalization, XaaS models ensure that economic value creation and environmental impact minimization go hand in hand. They provide a systemic innovation to business activities, processes and incentive structures that optimize output per unit of input for a maximized utilization of resources, while providing the demanded utility.



Digitally enabled XaaS models can combine environmental and economic value creation.

Source: SYSTEMIQ.

THE CIRCULAR ECONOMY IS BASED ON THE PRINCIPLES OF ELIMINATING WASTE AND POLLUTION, KEEPING PRODUCTS AND MATERIALS IN USE, AND REGENERATING NATURAL SYSTEMS, ALL DRIVEN BY DESIGN.

It offers us a vision of an economic model through which business, society, and the environment can thrive in the long term, addressing global challenges such as climate change, biodiversity loss, waste, and pollution at their root. The circular economy sees growth decoupled from the extraction of finite resources, moving away from linear take-make-waste material flows that are dominant in systems today. It is an economy that creatively meets our needs in a system where everything is food for something else. Just like in nature.

Everything-as-a-Service models can play an important role in the circular economy transition.

In the linear take-make-waste model, products are often designed to be used for only a short amount of time before being discarded. Those that are designed to last for longer but are needed infrequently by individuals find themselves stored away in the cupboards of homes and businesses, underused. In addition, planned obsolescence is often designed into products as a way to secure revenue streams, meaning that items need to be replaced more regularly. This results in a large amount of material waste and significant loss of value, embedded energy, and labour. It raises the question: How can we eliminate waste and make good quality solutions accessible for everyone?

Structural waste, particularly relating to underutilised assets, can be countered by new business models that focus on access rather than ownership. Moving towards Everything-as-a-Service (XaaS) models enables a shift from customer ownership to access, where products are provided as a service when needed and businesses retain ownership. This builds on the understanding that customers often only require access to a product for a limited period of time or defined use phase, after which they can return it to the service provider. A host of new businesses built on this model have emerged in recent years offering a wide range of products to their customers on a short-term basis (through rental, subscription, sharing or leasing) rather than selling them.

WHAT IS CIRCULAR DESIGN?

LOOK AROUND YOU

Almost everything you see has been designed by someone.

JUST LIKE IN NATURE,

all flows from one form to another. We can't reverse the impacts of design decisions.

CIRCULAR DESIGN

applies circular economy principles at the design stage of everything.

DESIGN ENDLESS POSSIBILITIES INTO THE FUTURE.

XaaS models can realign incentives between companies and customers and lead to better designs and solutions. For example, design choices such as repairability, modularity, and remote monitoring can become more relevant or appealing for manufacturers offering a service model. However, switching to an XaaS model alone doesn't necessarily mean that the new solution is fit for a circular economy. The outcomes need to be purposefully thought through when designing the service.

ELLEN MACARTHUR FOUNDATION

Join the circular design movement and learn more at:

ellenmacarthurfoundation.org
#CircularDesignNow

Circular design can help to create XaaS models that are fit for a circular economy.

Circular design is designing with the principles of circular economy in mind. It is a practice that embraces systems thinking to meet user needs while navigating some of the biggest interconnected global challenges we are facing today. The circular economy principles can serve as an inspiration for a non-exhaustive list of considerations in the design stage:

01

ELIMINATE WASTE AND POLLUTION.

Develop a deeper understanding of underlying user needs and question if physical products and materials are needed in the first place. What can be designed out?

Zoom out to take a systems perspective. Understand the flow of materials and information to eliminate structural waste. Design solutions in which value is retained and redistributed.

Establish the necessary reverse logistics alone or in collaboration. Make it easy and irresistible for users to participate in circular economy models.

02

KEEP PRODUCTS AND MATERIALS IN USE AND AT THE HIGHEST VALUE.

Make sure the products that are part of your service are designed for longevity. Besides designing for physical durability, consider emotional durability across multiple use phases (e.g. timeless design, emotional connection) and user groups (e.g. tailoring the experience to different groups that are using the service).

Prioritise inner loops: Designing for reuse, repair, remanufacturing and refurbishment retains more value, embedded energy, and labour than recycling. This is enabled by strategies such as safe and circular material choices, design for disassembly, and modularity.

Measure your progress when it comes to circularity, for example, with tools such as Circulytics.

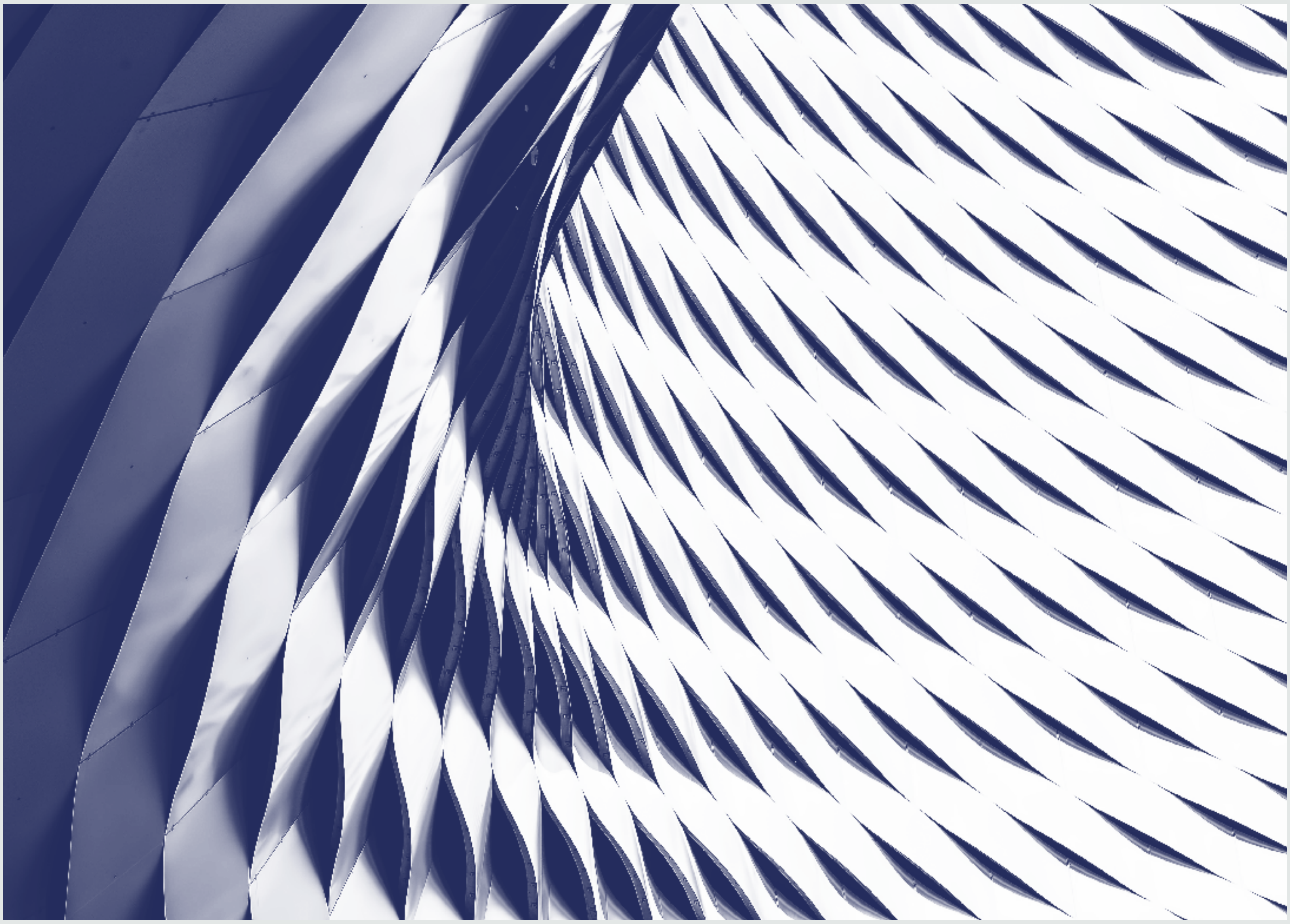
03

REGENERATE NATURAL SYSTEMS.

Consider where the parts of your design come from and go to. Rethink how the parts of your design can be of value and contribute in a positive way to the larger ecosystem beyond a narrow view of end users.

Think about how your processes affect people and the environment. How can they be designed to have a positive, rather than negative impact?

Build horizontal and vertical collaborations across the value chain. Co-create with stakeholders and affected audiences (e.g. supply chain, logistics, after-use sector, people affected by your design) to ensure that your design is fit for context, and to increase resilience, diversity and distributed access.



2

XAAS MODELS HAVE THE POWER TO COMBINE ECONOMIC VALUE CREATION WITH ENVIRONMENTAL BENEFITS BY ENABLING RESOURCE PRODUCTIVITY AND CIRCULARITY

In service-oriented business models, producers move from a product- to an outcome-based and performance-oriented product-service-bundle to fulfil specific customer needs, while typically keeping ownership. Such models are also referred to as X-as-a-Service models (XaaS). X represents the specific product or service (e.g. Washing-Machine-as-a-Service) but also the functional need or utility it fulfils (e.g. Mobility-as-a-Service). XaaS providers take on product lifecycle responsibility to deliver product functionality and outcomes. Implementing XaaS models at scale presents a shift towards the performance economy.

XaaS business and operating models usually combine three different components: (a) tangible and physical products, (b) intangible services, and (c) digital ecosystem embeddedness. In XaaS business models, additional value is created through integrated services, which ensure product performance or fulfil advanced customer convenience. Digitally enabled technologies such as sensors and IIoT connectivity can further improve operations through performance data (e.g. flexible/usage-based billing, data transparency). In addition, digital platforms are increasingly adopted in the manufacturing industry to run XaaS models.

XaaS models have been found to work better for products that meet a combination of technical/ design criteria, financial/business criteria, and market/customer criteria (see Exhibit 25 in Appendix A.1). For example, this typically includes products that are rather investment-intensive (i.e. resulting in CapEx to OpEx shift advantages); technically advanced and require maintenance during lifetime (i.e. value creation potential in the use phase); are generally mobile to transport (i.e. allow second-life applications); or just infrequently used by the single customer (i.e. allow for utilization improvements).

2.1 XAAS MODELS CAN SIMULTANEOUSLY UNLEASH ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS

Economic value creation

The transition from product (volume-focused) sales to XaaS business models is becoming a strategic imperative for manufacturing companies due to some inherent advantages that are accelerated in the digital and green economy.

Producers can advance customer value and create better offerings by shifting from transactional sales to fulfilling specific customer needs based on functionality, enabled by digital technologies. For example, selling holes instead of drills, selling mobility instead of cars, selling crop protection instead of pesticides. Embedded hardware and software systems ensure connectivity between components and allow for data-driven business model innovation. XaaS models with a strong analytic backbone drive the next wave of servitization and become a new source of competitive advantage.

Offering XaaS models strengthens customer relationships towards partnerships. Due to the typically increased service quality throughout product use, XaaS models can outcompete traditional models on customer experience and loyalty.[27] The long-term nature of many XaaS models facilitates collaboration and joint value co-creation – eventually deepening partnerships. According to some producers, well designed XaaS models can increase customer satisfaction by 10-20% and reduce costs by 15-25%.[27]

XaaS models can improve financial economics and competitiveness. XaaS provides a way for companies to compete on value parameters other than production costs alone. Producers and service providers benefit from recurring revenues over the product lifetime. Shifting the business model to value-based sales (e.g. selling the performance of the machine rather than the machine itself) can improve total cost of ownership (TCO) and be more profitable. When choosing use- and result-oriented models as well as sharing platforms, the customer gains access at lower (upfront) cost, eventually further reducing TCO (described in Chapter 4).

Manufacturers offering XaaS are in a powerful position to continuously innovate, driving the next generation of product-service systems. Access to customer data allows organizations to capitalize on digital enablers.[28] The more service-oriented the business and operating model, the more connections and data exchange between producers, customers, and their products will be possible, which might in turn be monetized. An increasing number of producers are using digital systems to support their services, creating totally new service-oriented offerings, such as comprehensive remote services that bring digital and physical systems together.

Environmental benefits

Next to the economic benefits, XaaS models have the potential to improve resource productivity and decrease environmental impacts. In contrast to traditional sales, where producers mainly take responsibility for the build phase, XaaS models connect the producers more closely with their products in the use phase. Producers take more ownership and responsibility, which inherently incentivizes companies to improve the number and productivity of resources needed to deliver the service. For example, this can be achieved by applying circular economy principles (e.g. sustainable inputs, modular design, repair, maintenance and take-back). This ultimately leads to a total reduction of resources, while providing the same utility with fewer products. The shift from seeing product sales as value creation and societal progress (neoclassical economics view) to focusing on meeting customer and societal needs at lowest possible input and maximized efficiency (in terms of resource utilization) is key.

Firstly, XaaS models create incentives to design goods with longer durability and to extend product life through repair and remanufacturing. In XaaS models, goods are revenue-generating assets – hence a longer lifetime or higher uptime increases the utility of a product over its lifetime. This ensures the slowdown of resource loops since fewer products may be needed to serve the same utility, resulting in dematerialization.[29]

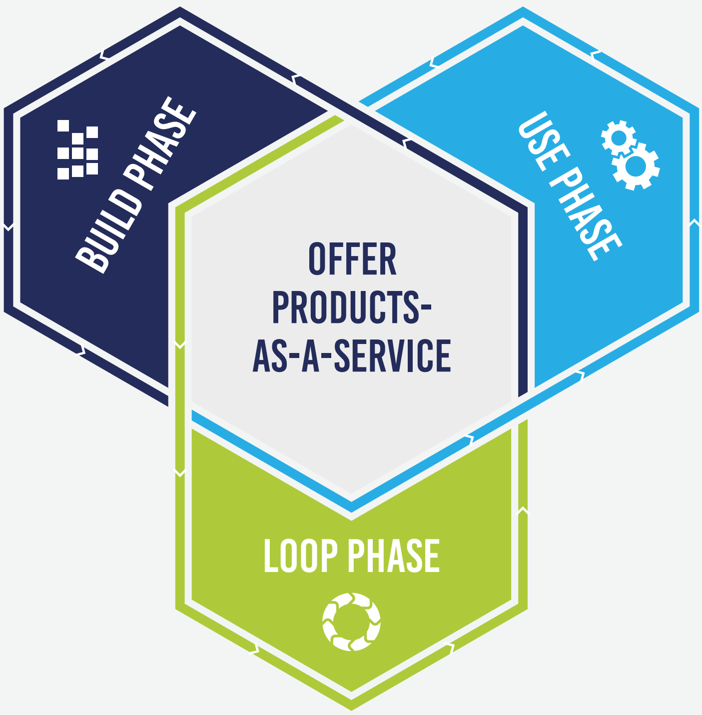
Secondly, producers who shift to producer ownership have the incentive to maximize value recovery at end-of-life which can ultimately involve the ambition to close material loops between post use and production.

Thirdly, offering XaaS models ideally incentivizes producers to optimize resource efficiency across the entire product lifecycle. Measures to reduce resources per product in the use phase include the reduction of waste. Therefore, considering circular principles in the product build phase (e.g. reduce, reuse, recycle) is critical.

To summarize, circular economy principles are operationalized through resource value retention activities across the entire product lifecycle which has three phases: (a) build phase, (b) use phase, and (c) loop phase (see Exhibit 7). Each phase provides different opportunities to decrease the environmental impacts of products, resulting in decarbonization and dematerialization. XaaS models considering circular principles are not only creating sustainable value through product design and operations, but also close, slow, and narrow overall resource loops.[30]

EXHIBIT 7

Three lifecycle phases of the product.



Source: SYSTEMIQ.

Social benefits

XaaS models encompass social benefits since they democratize access to high-quality products, strengthen regional employment, and can entail positive health impacts.

XaaS models can democratize consumption. In XaaS models, costly upfront investments are eliminated and shifted over the product lifecycle. Product utility can be consumed based on what is actually needed (e.g. pay for passenger kilometres travelled versus buying a car). XaaS can reduce household costs, if TCO reductions are not captured by producers. Depending on the XaaS configuration, Washing machines-as-a-Service, for example, could save consumers between 43-76 EUR per year (see Chapter 4). Since many companies take producer ownership in XaaS models, consumers are no longer responsible for dealing with waste materials at end-of-use or technical obsolescence. In sum, these effects make high-quality products more accessible and convenient for customers, both in the B2C and B2B sphere.[31]

Circular XaaS models can benefit regional value creation and employment. Circular product and operating models require local service activities, which cannot be easily substituted by imports. To avoid emissions and save costs, services are typically implemented where industrial products are located. Repair or refurbishment and other use-phase services are labour-intensive jobs and contribute to local employment.[32] In Europe alone, implementing circular strategies could create 2 million new jobs by 2030.[33] At the same time, advanced services and digital solutions are at the core of most XaaS models, further increasing demand for knowledge-intensive activities and jobs. XaaS models are well suited to strengthen localized value chains and onshoring of high-quality jobs.

The environmental potentials from circular XaaS models are interlinked with positive impacts on health. The IRP has shown that reducing environmental pressures through resource conservation has direct links to human health.[34] Resource extraction – from mining metals to land-use-related deforestation – impacts health, for example through direct air pollution.[31]

2.2 AN XAAS LANDSCAPE IS EMERGING ACROSS THE MANUFACTURING SECTOR

2.2.1 THE MANUFACTURING SECTOR OFFERS A DIVERSE PRODUCT LANDSCAPE SUITED FOR XAAS

The following overview and insights summarize a qualitative analysis of the vibrant, emerging XaaS landscape across the European manufacturing sector. Exhibit 8 provides an exemplary (not exhaustive) summary of this ecosystem. The overview is structured along all manufacturing subsectors and differentiates between the four main types of XaaS business models (for more information on the archetypes, see Chapter 3):

- **Product-oriented XaaS models** (where products are sold but entail additional services that ensure value retention for the producer during the use phase, e.g. maintenance contracts, recurring service fees, take-back schemes);

- **Use-oriented XaaS models** (where XaaS providers keep ownership and offer Products-as-a-Service – the customer pays according to its use, e.g. Pay-per-Use or time-oriented via regular instalments);

- **Result-oriented XaaS models** (where products are also offered as-a-service, but the customer pays per outcome, e.g. per printed page in the case of Printing-as-a-Service); and

- **Sharing platforms** (which can be offered by producers but also by non-producing third parties, and may offer products from different producers at the same time).

Generally, XaaS models exist in all manufacturing subsectors but with differing prevalence. Most XaaS models can be found in the machinery and equipment subsector, followed by motor vehicles and transport equipment; computer, electronic and optical products; electrical equipment; textiles and others – particularly for furniture and toys. Fewer XaaS models are found for fabricated metal products or for chemicals and pharmaceutical products.

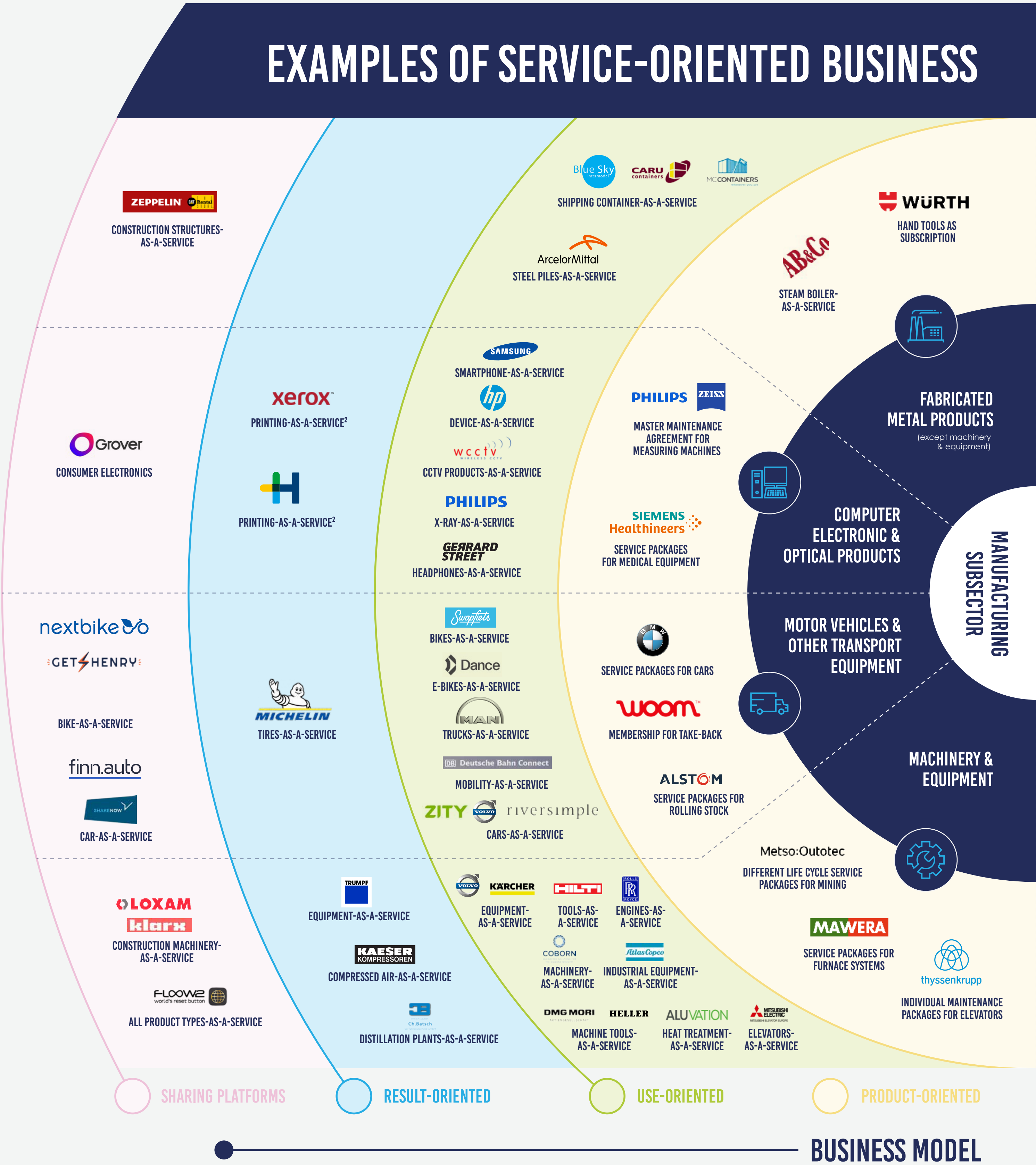
The four main XaaS business model archetypes are offered across all subsectors, but to different degrees. Product-oriented and use-oriented business models exist across all subsectors. Sharing platforms are found across all sectors as well but seem to be more frequent in motor vehicles and transport equipment as well as textiles. As a rough indication, product- and use-oriented business models including service contracts, leasing, sharing and renting have found more application in the industry sector than result-oriented business models.[35] Result-oriented business models are mostly found in the machinery and equipment subsector (e.g. TRUMPF, Heidelberger Druckmaschinen, Kaeser).

Companies seem to explore different XaaS business models, either sequentially or simultaneously. Manufacturers often start their service transformation with a product-oriented business model and over time increase the service intensity of their business models, culminating in a shift to a use- or result-oriented XaaS model. Several manufacturers such as Siemens and HILTI offer multiple XaaS business models next to traditional sales. Manufacturers with use-oriented and product-oriented XaaS models frequently offer a variety of customized XaaS models (e.g. different periods for subscription models or different service packages for products, depending on the customer needs).

The XaaS business models emerge across various company sizes from different motivations. Start-ups, SMEs and large incumbent corporations all implement XaaS models. Companies in younger, tech-enabled market segments often implement XaaS models to proactively push products into the market. Some SMEs seem to consider XaaS models particularly to create recurring value based on technological advantages (e.g. connectivity throughout the supply chain), mirroring practices from the Software-as-a-Service sphere. Companies in more mature or incumbent industries often seem to explore XaaS models rather as a defensive move with the aim to secure market shares and find a new competitive edge.

EXHIBIT 8

The emerging landscape of XaaS models in the European manufacturing industry – some examples.

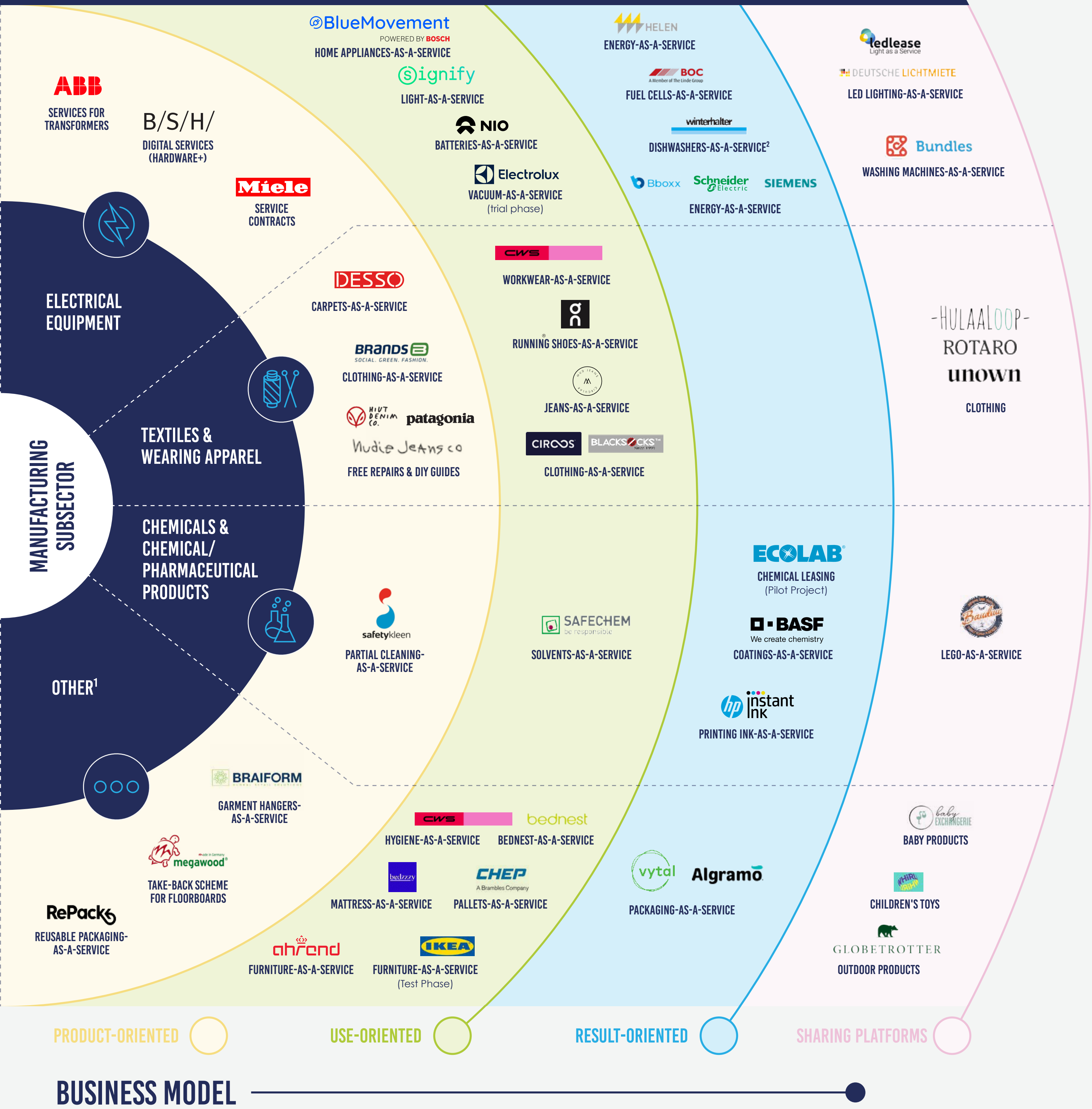


¹ Other Manufacturing categories, e.g. Furniture, Paper, Plastic products, Basic Metals
² Companies offering their product(s) in more than one business model

Source: SYSTEMIQ collation, company websites.

MODELS IN THE MANUFACTURING SECTOR

NOT EXHAUSTIVE



2.2.2 MANY COMPANIES DO NOT LEVERAGE THEIR FULL POTENTIAL WITH RESPECT TO ENVIRONMENTAL AND ECONOMIC IMPACT

There is growing recognition that XaaS models can improve resource utilization and environmental impact compared to traditional offers. Providing these environmental benefits is increasingly seen as a source of competitive advantage and used as a strategic element to address the environmental demands of customers.[36] International frontrunners such as Philips and Mitsubishi Elevator Europe are successfully pioneering XaaS models that follow circular economy principles. Another example is the Dutch semiconductor company ASML which is offering a reuse programme ("Return4Reuse") and refurbished machines ("As-New programme") for high-precision semiconductor printing machines.[37] By quantifying the environmental benefits of XaaS models and making them transparent and accessible, XaaS providers not only optimize their own footprint, but also help their customers to make more sustainable decisions.

The following points illustrate exemplary environmental benefits that pioneering companies currently combine in their XaaS narratives or strategies:

CASE BOX 1:
MITSUBISHI ELEVATOR EUROPE – OFFERING ELEVATORS IN A CIRCULAR, USE-ORIENTED XAAS MODEL.

With M-Use®, Mitsubishi Elevator Europe created a use-oriented business model for elevators that follows circular economy principles by combining the Pay-per-Use model with a circular use of materials and a sustainable approach to energy. The customer only pays for the operating hours of the elevator and gets compensated if contractual agreements are not fulfilled. Retaining ownership brings Mitsubishi Elevator Europe into a stronger commitment towards the customer and the products. Through effective lifetime maintenance, downtimes are reduced and life expectancy is increased. Upon end-of-use, components and materials are reused or recycled.[38]

Waste prevention/better recycling are most often applied across all XaaS model configurations. Companies with product-oriented XaaS models for example take products back, which results in waste prevention and increases recycling (especially in the textiles and consumer electronics industries). The business model of the sharing platform Grover, for example, aims to reduce electronic waste, a major environmental concern increasingly recognized by consumers. In terms of recycling, companies dealing with energy-intensive materials such as steel increase the amount of recycled steel by keeping ownership. ArcelorMittal, for example, established a Steel piles-as-a-Service model, enabling better recycling.

Reduced (primary) resource use is one of the environmental benefits often explained by companies with use-oriented XaaS models. On the one hand, this relates to more sustainable products that require less material throughput driven by technology innovations. BlueMovement, for example, offers highly efficient washing machines which save energy and resources as they need less detergent. On the other hand, companies with a use-oriented/platform-based XaaS model are maximizing the utility of their product by offering the service to many consumers (concurrently or subsequently), which can in turn avoid primary resource use. The start-up Vytal, for example, is offering Plastic packaging-as-a-Service models to many customers, which avoids single-use plastics to reduce overall plastic consumption.

Lifetime extension and reuse possibilities resulting in increased product utilization are becoming a selling proposition for high-value products. Some fashion companies are experimenting with new models and start-ups are emerging. Companies who offer workwear such as Lindstroem and CWS attract their customers with high-quality materials and textile services (e.g. full-service cleaning).

Improving energy efficiency is one of the well-established measures applied by companies to reduce environmental impact in the production phase. In XaaS models, manufacturers have increased incentives to further reduce emissions through energy efficiency savings in the use phase, because this becomes an element of the XaaS offering. Beyond that, energy efficiency can also be core to the value proposition of some specific XaaS models, such as Signify or Deutsche Lichtmiete.

However, many companies in the emerging XaaS landscape do not yet capture the environmental impact potential they could have via ambitious XaaS models. It seems that this is particularly due to not taking a holistic perspective on sustainability impact levers and integrating those drivers systematically into the operating model as well as customer narrative. To improve the environmental impact potential of XaaS models, a set of critical design configurations needs to be considered (see Chapter 3).

In addition, many companies seem not to be aware of potential rebound effects that might be triggered by their XaaS models. Rebound effects occur when actual impact improvements are less than expected because of behavioural or systemic responses to changes, resulting in negative, unintended environmental consequences. For example, XaaS models can result in the following rebound effects, which must be proactively addressed by the providers when designing the XaaS business and operating models:

- Improvements of TCO and accessibility for consumers could stimulate more demand for the same product and underlying utility than before (e.g. passenger kilometres travelled by car).

- More comfortable and cheaper services can replace a less competitive service that has less negative environmental impact (e.g. ride-hailing substituting public transport).

- Service-based usage models can lead to carefree consumption patterns (e.g. moral hazard leading to increased wear and tear).

- Transport demand may increase due to logistics needed for sharing and sequential product use (e.g. sharing platform; transport to repair and refurbishment centres).

- Ever-faster innovation cycles may create challenges for manufacturers to reuse the outdated technology or its continuous use might be less environmentally beneficial than using a new product (e.g. energy efficiency).

- IoT applications as enablers of XaaS models require additional material input and energy consumption outside the product scope (cloud solutions, data centres etc.).

3

TOOLKIT

CONFIGURING XAAS MODELS SHOULD BUILD ON FOUR CRITICAL DESIGN BLOCKS

XaaS models can achieve significant impact in terms of resource productivity and decarbonization, thus should be designed for their full impact potential. In practice, many producers are stalled by the complexity of design choices and often there seems to be a lack of awareness about the decarbonization potential. The following chapter introduces a comprehensive toolkit for XaaS model configuration – with the aim to support decision-makers who aspire to design circular XaaS models that leverage both the economic and environmental potentials. Configuring a coherent XaaS model on this basis should address four critical design blocks (Exhibit 9). The pathway to take design choices depends on the individual organizational context.

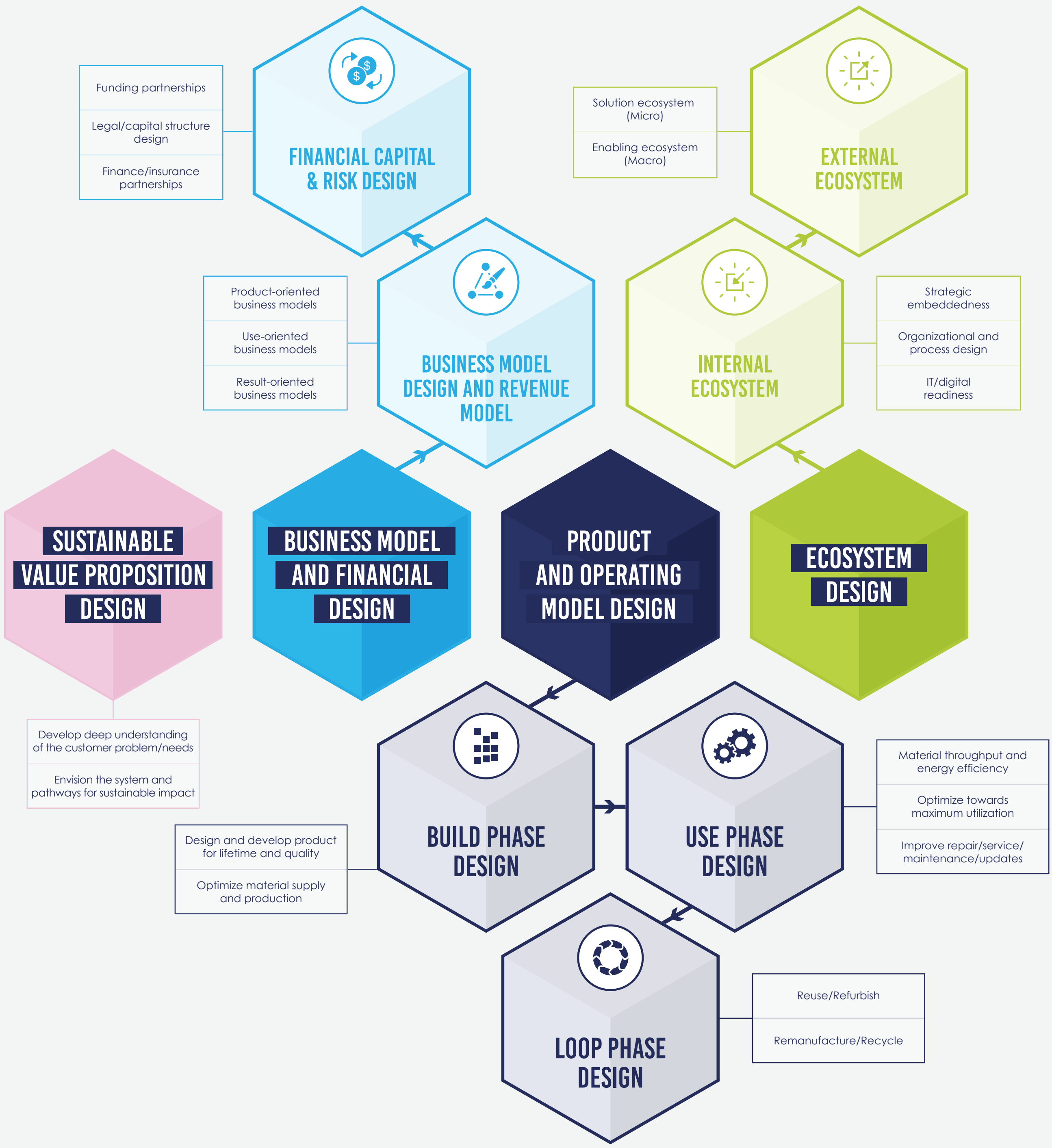
- **Sustainable value proposition design (section 3.1.)** that inherently addresses specific customer needs while integrating a sustainable impact ambition as foundation for XaaS models.
- **Business models and financial design (section 3.2.)** that allow for different ownership configurations and pricing schemes as well as financial and risk design considerations.
- **Product and operating model design (section 3.3.)** for optimizing resource productivity by building on a holistic set of circularity levers.
- **Ecosystem design (section 3.4.)** with respect to the internal organizational and business solution level, as well as an external enabling system level.

3.1 SUSTAINABLE VALUE PROPOSITION DESIGN: COMBINE CUSTOMER NEEDS AND A SYSTEM IMPACT AMBITION AS THE FOUNDATION OF A XAAS STRATEGY

A sustainable value proposition is a promise concerning the economic, environmental and social benefits that a company's offer delivers to customers, the planet and society at large, considering both short-term profits and long-term sustainability.[39] Adapting the value proposition to customer needs and sustainability is a continuous and iterative design process. Companies need to ensure that the XaaS model is designed such that it represents an ideal problem solution fit and is grounded in the sustainable value proposition. For this, it must build on a deep understanding of customer needs (section 3.1.1.) and integrate a sustainable system vision (section 3.1.2.).

EXHIBIT 9

Four building blocks to configure XaaS models.



Source: SYSTEMIQ.

3.1.1 DEVELOP A DEEP UNDERSTANDING OF THE CUSTOMER'S PROBLEM AND UNDERLYING NEEDS

Designing an XaaS model should start with profoundly understanding the respective customers, the underlying problems and user needs (see Case box 2). For developing an XaaS model, a customer-problem-first approach is favourable above a technology-first or product-driven approach, which often takes a narrow perspective. Ideally, the ambition of XaaS models must be that the underlying human or societal need (e.g. housing, mobility, nutrition) or the customer problem is better solved by shifting from selling a product to turning that product into a product-service-bundle – which is then more effective and sustainable in terms of utility provision. The utility is what the customer buys and considers as intangible value, not the physical product.[40] In the end, customer utility counts and is the ultimate measure of customer value.

Common types of customer needs include affordability, functionality, quality, reliability, low costs, transparency, accessibility, or controllability. Most of these customer needs work together to bring about a purchase decision.[42] There are various tools which can help to discover underlying needs that companies aim to address with service-oriented offerings (see Appendix B.1).

> "A user-centred value proposition is critical for XaaS models. Product-service-bundles need to be closely tailored to underlying user needs. Beyond that, oftentimes the users are needed to enable systems to work in a circular way – they may for example need to return an item post use or share usage data."

Chris Grantham
Circular economy portfolio director at IDEO

EXAMPLE 1

The basic need of a car might be mobility, getting passengers from A to B (without the need for ownership of the car that provides mobility whenever needed).[41]

EXAMPLE 2

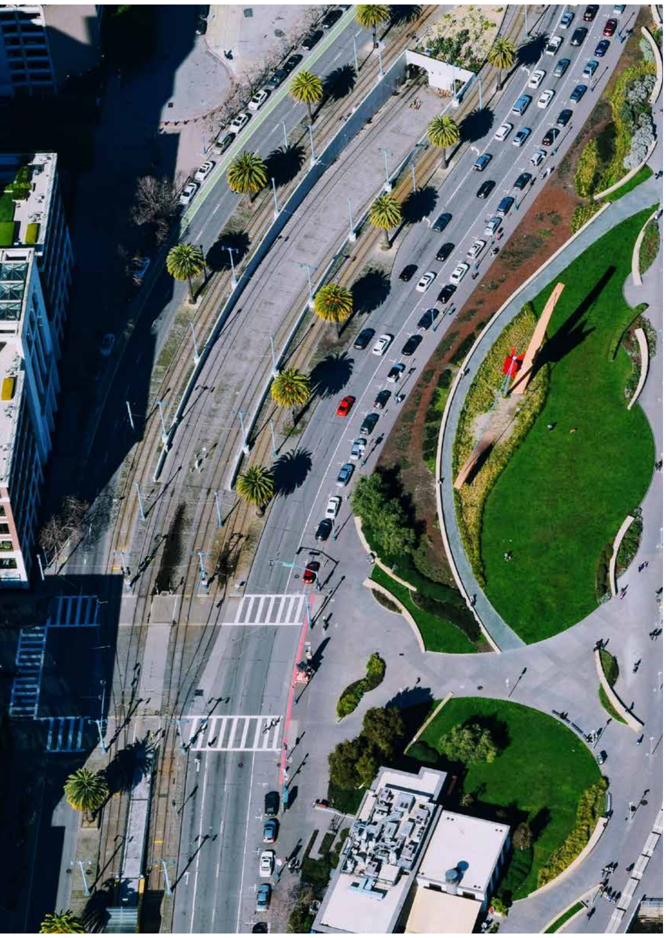
The basic need of clothes might be to express personality on different occasions without necessarily owning all the clothing items but having access to them.

EXAMPLE 3

In the case of housing and building products, the valued purpose might be protection and safety.

CASE BOX 2:
CWS – PROVIDING SYSTEMIC SOLUTIONS FOR HYGIENE AND WORKWEAR

By focusing on solving customer needs from a systemic perspective, CWS offers full-service solutions for hygiene/washroom and workwear. The Hygiene-as-a-Service model involves everything from equipment to operations and professional support services. The Workwear-as-a-Service model integrates product design strategies for durability, repair and professional washing services, as well as recycling partnerships. Products and services are part of a circular system: for example, textiles are cleaned in a resource-efficient way and can be reused extensively, thereby significantly increasing customer convenience.[43,44]



3.1.2 ENVISION PATHWAYS FOR SYSTEMIC IMPACT

Producers should assess their own environmental, social and governance (ESG)[iii] related footprint in the wider system they are active in. To discover systemic issues within a respective system, producers need to assess the sustainability impacts of their company and products throughout the value chain. This is often important to put the aspired XaaS model into perspective and create a fact base for optimizing environmental, economic, and social impacts. For example, on a product level, lifecycle assessments (LCAs) can be a way to discover the environmental impacts quantitatively and qualitatively along the product life and help to mitigate negative effects.[94,95] Next to LCAs companies can use circularity metrics on an organizational and product level to assess the extent to which circularity strategies (e.g. reduce, reuse, recycle) contribute to a decoupling from resource consumption. Material footprints, which assess the material input along a value chain, are particularly helpful.

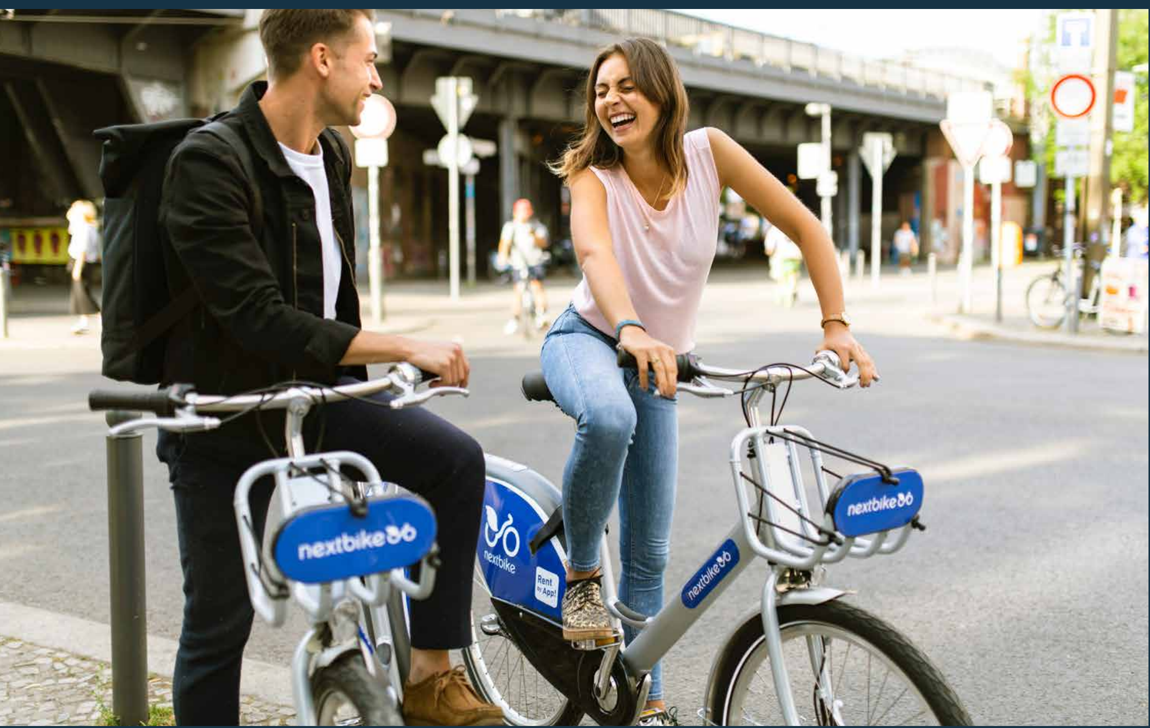
Each XaaS model operates in a specific system and producers need to understand their individual impact in the system related to ESG on a macro level. As described, besides addressing a fundamental customer problem and understanding underlying needs (in the narrow sense), it is important for producers to understand that their XaaS model is typically related to human societal needs in the wider sense. Hence, it operates in a wider system with impacts such as on CO_2 emissions, biodiversity, and other planetary boundaries, as well as social impacts such as on health or pollution. To successfully operate an XaaS model in a world where society

iii Environmental, social and (corporate) governance refers to the three pillars in measuring the sustainability impact of businesses. However, this publication focuses on the environmental and economic impacts of XaaS models.

must aim to achieve absolute resource decoupling, companies should envision how the system develops, what the critical systemic challenges are (e.g. in the mobility system, systemic issues would be low utilization, carbon emissions, or high primary resources demand) and how the XaaS offer interacts with the system (e.g. consider emerging rebound effects). When developing XaaS models, many producers purely focus on the product, which often results in models which don't work successfully in the wider system.

For producers, it is critical to explore the individual possibilities to improve the systemic impact. Based on the understanding of systemic issues, companies can decide which topics can be addressed (especially in the context of the XaaS model) and where specific activities could have the highest impact. For example, offering Batteries-as-a-Service requires IoT technology to control functionality of the batteries, hence the increased transparency in the value chain could in turn avoid environmentally harmful disposal at the end-of-life. Questions that need to be addressed are "what systemic challenges can the company influence, and where does the XaaS model with its focus on access, utility and performance really make a difference?"

Maximizing system impact also means mitigating unwanted systemic effects (e.g. rebound effects). This means evaluating consumer behaviour, especially during the use phase of XaaS models. On the one hand, this requires an integrated perspective on the product and operating model, especially regarding how different options for addressing customer needs can be compared to objectively evaluate and quantify their environmental performance. But perspective is also needed on how to comprehensively think about critical design choices to avoid direct negative effects within an XaaS model (e.g. if consumer behaviour leads to faster product attrition). In the age of digitalization, producers have opportunities to use tracking and tracing technologies to enable their consumers to use their products in a more environmentally friendly way. For example, carsharing providers can nudge more careful customer behaviour through telematics-driven incentives. On the other hand, a systemic lens is needed to circumvent undesirable rebound effects (see section 2.2.2). For example, such effects may be triggered by relative price changes and respective behavioural changes, hence producers should evaluate how pricing may induce environmental rebound effects and explore pathways to proactively mitigate these.



3.2 BUSINESS MODEL AND FINANCIAL DESIGN: EXPLORE XAAS BUSINESS MODEL ARCHETYPES AND RISK MITIGATION STRATEGIES

3.2.1 BUSINESS MODEL DESIGN: CONFIGURE A XAAS BUSINESS MODEL ORIENTATION

There are four main archetypes that guide XaaS business model design. Exhibit 10 introduces the four archetypes, which are either product-, use- or result-oriented. The fourth archetype includes sharing platforms.[iv] In practice, however, these models cannot always be clearly distinguished from each other and there are many different combinations. For example, there are product-oriented business models with linked subscription-based services. Companies may offer different business model orientations and payment schemes at the same time, depending on the market they are operating in.

A critical design choice is whether the XaaS provider still transfers product ownership or keeps the ownership (producer ownership). Transfer of ownership indicates a product-oriented XaaS model. Those XaaS models build on selling products but add extra services for substantial value creation. Some product-oriented XaaS models may even move into use-based value creation through services rather than actual product sales. Such services are part of the sales proposition and can include maintenance agreements, consumables subscriptions and take-back provisions. Service contracts are typically based on a use- or result-oriented business model. For example, maintenance agreements or delivery of consumables can be billed on a subscription basis. Take-back provisions are particularly suitable for service providers, which have a continuous demand for their own (obsolete) components (e.g. for remanufacturing new products, spare parts), want to control the secondary market, or want to secure supply of critical resources (see Case box 3).

CASE BOX 3: PHILIPS – CIRCULARITY AND TAKE-BACK SCHEMES

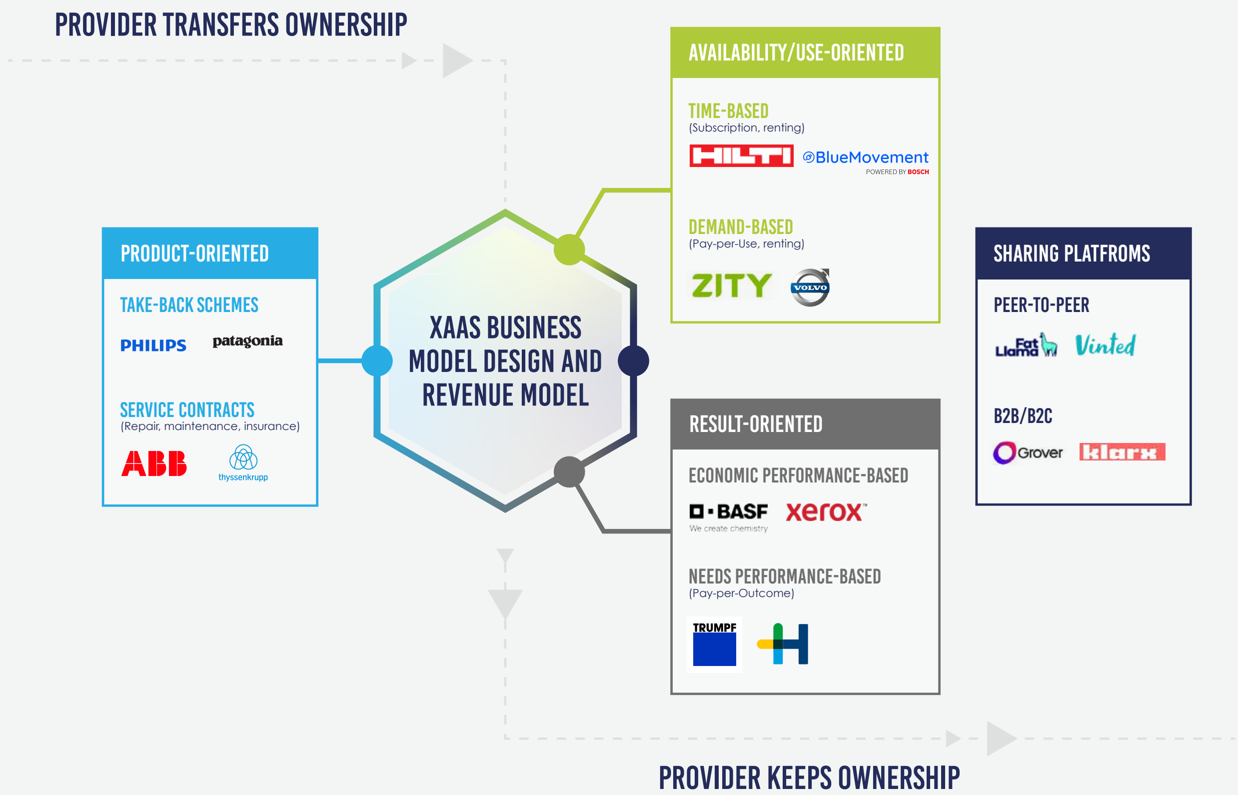
Philips is successfully applying various XaaS business models to operationalize the company's strategic objective of generating 25% of sales from circular products, services and solutions by 2025. To do so, Philips committed to take back all large medical equipment by applying product-oriented XaaS models. Typical equipment to be recycled or repurposed by Philips includes MRI and CT scanners. To execute the product-oriented business model, the company is collaborating with various partners across the globe.[45]

Keeping ownership as a XaaS provider indicates a use-oriented, result-oriented business model or an XaaS model based on sharing platforms. Assuming responsibility for the product over the use phase until the end-of-life can create an incentive to design products that are amenable to life extension and value retention processes (e.g. remanufacture, refurbishment, or repair). Producers

iv The four archetypes already served as a guiding structure for the XaaS landscape overview in Chapter 2.

EXHIBIT 10

Key business model configurations for XaaS models.



Source: SYSTEMIQ collation based on Tukker, A. (2015).

or XaaS model providers sell the access to utility, availability or function of products which may be shared with multiple users (e.g. through renting, sharing, pooling). Since recurring revenue streams replace one-time revenue recognition, financing XaaS models emerges as an important topic. In the B2C context, these models fulfil customer desires for maximum flexibility and convenience. In the B2B context, these models allow customers to focus on their core business, while the XaaS model ensures the performance of the product.

An important characteristic, from a financial perspective, is that these models enable customers to shift from capital intensive upfront investments (CapEx) to recurring operating expenses (OpEx) with a possibility for off-balance sheet accounting in a B2B context. Use-oriented and result-oriented models can reduce the overall TCO for customers. Only the access to and utility from using the product are remunerated instead of the entire product. This eliminates upfront investment costs (CapEx) and shifts these to the recurring operating expenses (OpEx). Hence, in a B2B context, capital-intensive investments and acquisition costs are shifted from the balance sheet to the P&L and reduced to the amount of access/utility provided. This provides opportunities for balance sheet improvements compared to other financing models such as leasing, since the introduction of IFRS 16 prevents leases from being accounted for off-balance sheet (see Info box 2 in Appendix B.2). At the same time, the CapEx to OpEx model increases cost transparency and planning certainty as customers shift to pay-as-you-earn models.

Companies adopting use-oriented business models typically offer a product-service-bundle (including added services) through an availability/use-based model and payment scheme. Added services often include repair, insurance (e.g. against theft), breakdown replacements, transport services or collection of products at the end-of-life. In use-oriented XaaS models, the provider can decide between either a fixed contract duration (e.g. subscription model), or usage-based pricings (e.g. Pay-per-Use). Several companies offer both models to their customers. For example, the machine tool producer Hilti offers both a fleet model for tool lease (see Case box 4) and a peak demand pool for tools based on Pay-per-Use.

CASE BOX 4:
HILTI – FLEET MANAGEMENT

Hilti has established a circular economy programme with the goal to lead the construction industry. The company provides construction tools in a service-based fleet management solution as a one-stop service to customers (time-oriented XaaS model). For a fixed monthly fee, a customized fleet of power tools can be accessed. Complementary services are provided: inventory management, repair and replacement, insurance and access to new models after the initial term has expired. The model reduces downtime and increases flexibility. Additional tools can be ordered to compensate for peak times (use-oriented XaaS model) while effectively reducing the investment risk for the customer.[46]

Companies adopting result-oriented business models offer the product-service-bundle based on results/performance or output of a product (e.g. parts produced by a machine). Offering products in result-oriented business models provides maximum flexibility for customers and fundamentally aligns incentives between XaaS providers and their customers (see Case box 5). According to Walter Stahel, the real difference is between service offerings that guarantee the performance of the service – and those that do not. Performance guarantee equals liability. Focusing on a guaranteed outcome is the most systemic solution in terms of value creation.[47] In order for this model to be successful, producers must be able to measure the performance or output that the customer receives precisely in advance. Therefore, producers should closely collaborate with their customers to assess how well the model is accepted and agree on how to determine the value and overcome emerging uncertainties (e.g. in terms of ownership costs, product utilization and contract terms). Value-calculation tools and TCO analyses with pooled data from several customers are key tools to determine the value of result-oriented business models.[48] Academics argue that result-oriented XaaS models have the greatest potential for the circular economy, but also require the most radical change of the business model. Therefore, to date, these lack widespread adoption. Compared to use-oriented XaaS models, producers have the built-in business incentive to use fewer products (dematerialize) or use refurbished/remanufactured products to keep costs low while delivering the agreed outcome.[49] In case of higher uncertainty on how to measure or determine the outcome/value, use-oriented business models based on other factors (e.g. use and time) may be more suitable. But technological innovation in terms of IoT sensors and data analytics makes result-oriented models more and more feasible and attractive.

Sharing platforms are an additional XaaS business model type, typically representing a platform-model that goes beyond the use-/result-oriented models offered by single producers/providers and typically offering multiple products (e.g. beyond single brands). The models are increasingly adopted by platform providers (often start-ups), not only by producers (see Case box 6). Sharing platforms mainly facilitate the sharing of overcapacity or underutilization; they thereby increase productivity through efficient matchmaking of supply and demand and often allow customers to choose among different brands. After models such as AirBnB in the building sector and Uber in the mobility sector have experienced a strong upswing in recent years, they are also becoming increasingly popular in the manufacturing sector (e.g. Grover, Whirli, unown). The business model appears to resonate not only with customers but also with investors: since its beginnings in 2014 the sharing economy market is expected to grow twentyfold by 2025 (335 billion USD).[51] As sharing platforms have so far often not been offered by

CASE BOX 5:
KAESER KOMPRESSOREN – COMPRESSED AIR-AS-A-SERVICE

Kaeser Kompressoren offers compressed air in a result-oriented business model. In the SIGMA AIR UTILITY model, customers only pay for the compressed air provided via the equipment that is built, installed, and operated by Kaeser (e.g. pricing per cubic metre of compressed air). A global service network and digital services ensure reliable availability of compressed air with highest possible energy efficiency and continuous optimization of the system. Kaeser not only cover operation and maintenance, but also the responsibility for safe and legally and regulatory compliant operation.[50]

CASE BOX 6:
GROVER – SHARING PLATFORM FOR COLLABORATIVE CONSUMPTION

Grover is a sharing platform for technological devices such as notebooks and TVs replacing traditional ownership models with flexible subscription services. After the subscription term, products are returned and offered again. On average, products are recirculated four to five times, thus increasing the utilization of unused devices. Reuse and repair services effectively extend the life of the equipment. Grover aims to enable large retailers and OEMs to adapt their business model by integrating consumer-electronics providers on the platform.[52,53] With plans to triple subscriptions by the end of 2021, Grover has recently closed a new funding round that will enable it to meet the growing demand for rental services.[54]

the producers themselves, the question naturally arises as to what extent platform providers can integrate sustainability aspects – beyond the higher utilization rates – into their product portfolio composition or even the product design and manufacturing processes of suppliers. However, due to their increasing market power, it is now possible for platform providers to exert greater pressure on producers in terms of sustainability. Last year, for example, Uber announced that 100% of rides will take place in electric vehicles by 2030 in the US, Canada and Europe, and by 2040 for the rest of the world. Depending on the increasing market power of Uber, these strategic goals can greatly increase the demands on producers for more sustainably designed cars, in this case battery electric vehicles (BEV). Sharing platforms which help to maximize utilization could benefit producers whose products and assets have a low utilization or ownership rate.

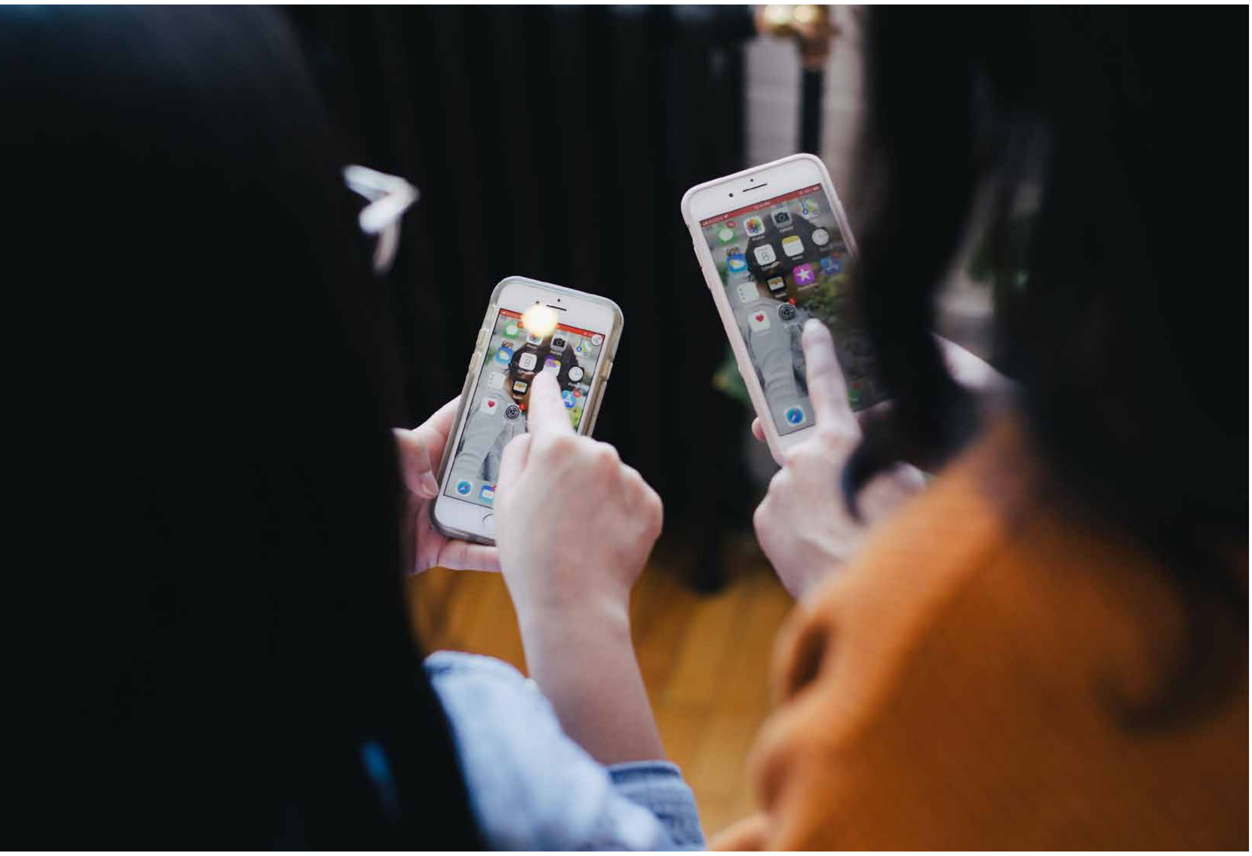
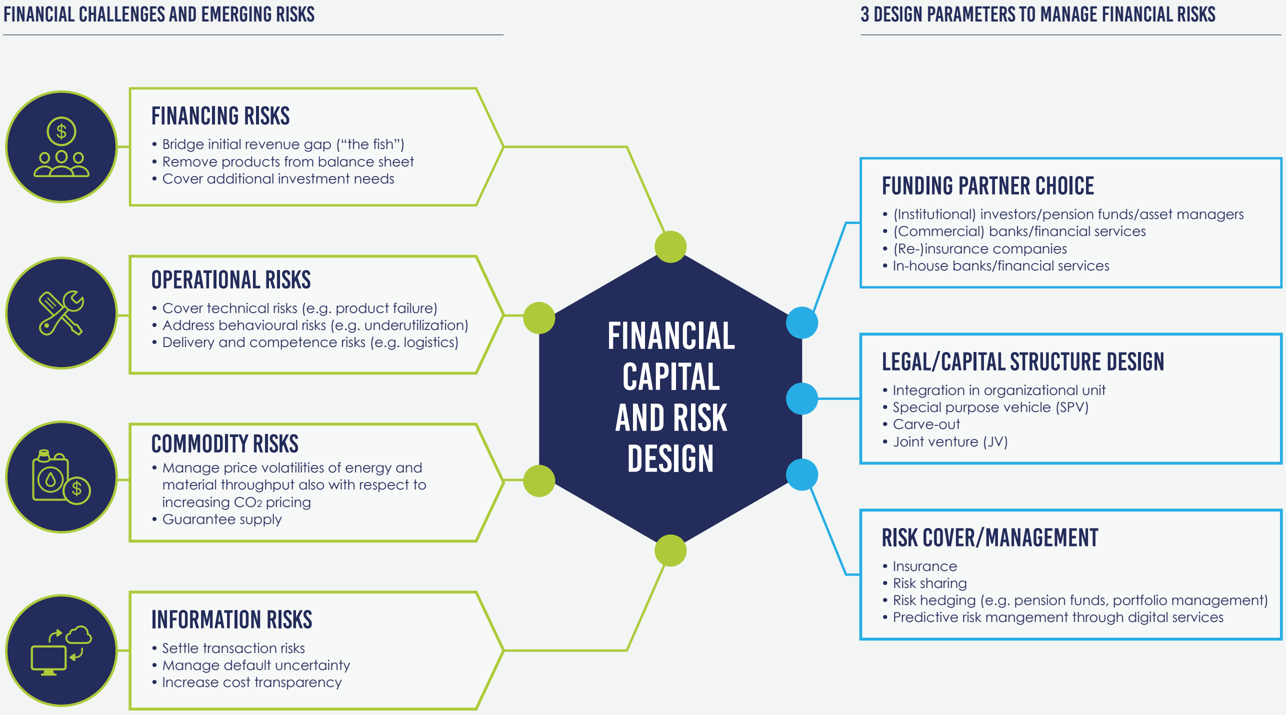


EXHIBIT 11

Managing financial challenges and risks is a critical design choice for XaaS models.



Source: SYSTEMIQ collation.

3.3.1 DESIGN THE FINANCIAL SET-UP AND MANAGE RELATED RISKS

Four types of financial challenges and risks must be considered in XaaS models and can be shared with other partners or mitigated through risk management strategies. These include financing risks, operational risks (technical, behavioural, delivery risks), commodity risks and information risks (see Exhibit 11). For example, financing risks refer to capital risks associated with funding/ investment requirements and risks related to bridging initial revenue gaps (see Info box 1). Not all business models are equally affected by these challenges and risk types to the same degree (e.g. product-oriented business models might not be affected through financing risks as products are still being sold to customers).

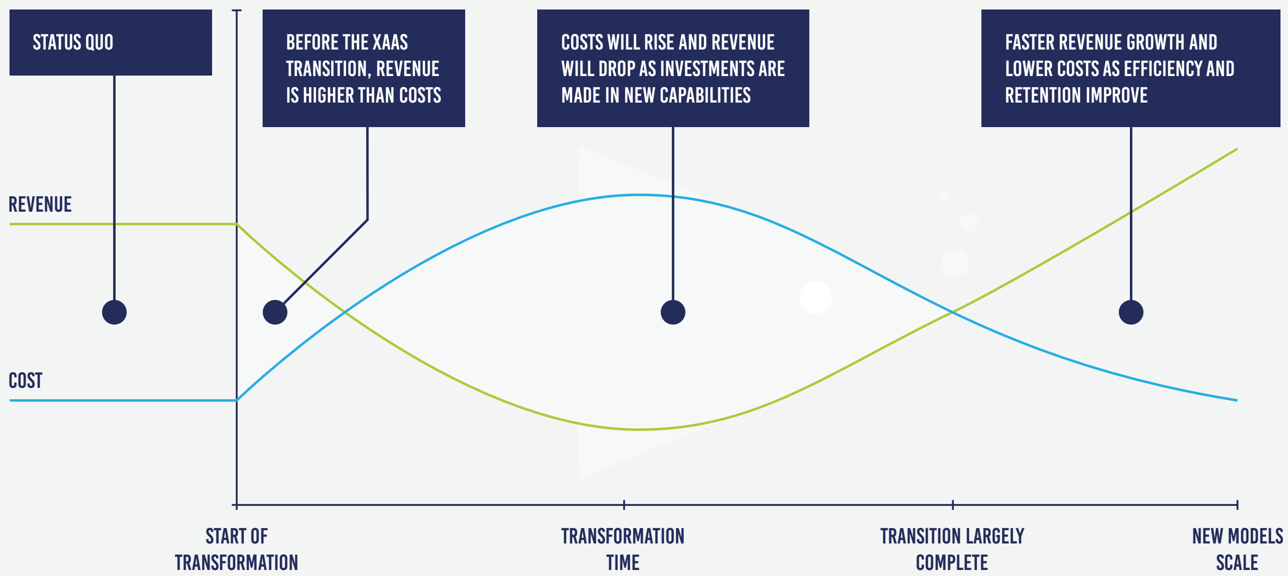
INFO BOX 1:

THE MOVE TOWARDS XAAS MODELS (E.G. USE- AND RESULT-ORIENTED MODELS) IS ECONOMICALLY CHALLENGING FOR BUSINESSES, ESPECIALLY IN THE FIRST 5-10 YEARS.

Producers or XaaS model providers need to plan for an interim period when costs will be higher and revenues lower before the financials find their new trajectory, called "swallowing the fish" (see Exhibit 12). The term refers to the shift from technology (products) as an asset to technology (products)-as-a-Service. During this time, initial revenues drop as upfront contracts are replaced by smaller but regular income streams. Simultaneously, operational costs rise (e.g. in customer services, organizational change) to establish and support the XaaS offering. When the transition gains momentum and scale, regular revenue streams overtake costs which continue to fall (as scaling effects and delivery increase).

EXHIBIT 12

XaaS transformations typically need to bridge a critical transition phase from a financial and risk perspective.



Source: Technology Services Industry Association (TSIA) (2013).

Pathways to mitigate these challenges are dependent on the respective context. For example, producers may adjust their pricing model and charge a premium, which is particularly interesting for product-bundles in use-oriented business models (e.g. tool fleets) that can significantly generate value through the added services beyond the original product. Other examples include partnerships with financial institutions (e.g. banks, insurances).

As more and more XaaS models emerge across sectors, the financial and risk management ecosystem tailors solutions as well, paving the way for the XaaS industry revolution. Related to the above-described developments, there are three design choices to manage the emerging risk profile of XaaS providers and ecosystem partners (see Exhibit 11).

(a) **Collaborating with funding partners can mitigate financing risks – a major challenge for the XaaS implementation, especially for capital-intense goods and in stock market-driven organizations**. The investment climate increasingly demands assets that enable decarbonization. Asset managers committed to sustainable finance seek new investment opportunities to diversify their portfolios and look at XaaS as a new asset class. Banks, (re-)insurance companies, institutional investors or venture capital investors have the ability to provide funding and risk coverage. In some cases, selling the assets (including risk transfer) to the financing partner secures revenue/ liquidity for the XaaS provider (Case boxes 7-8). This seems to be especially relevant for use- and result-oriented models. If the financing partner is from within the same organization (e.g. internal bank), aligned interests for use-phase optimization exist. If it is external, profit-sharing mechanisms and participatory rights enable the producer to maintain control over the use and loop phase, a crucial aspect of sustainable XaaS models.

(b) **Designing legal and capital structures to alleviate financial and operational risks can follow different routes.** One option is the set-up of an intraorganizational unit within an established organization (e.g. departmental set-up or internal business building). This can help to leverage benefits from the parent company's brand, capabilities, and financing power. Another

CASE BOX 7:
BNP PARIBAS LEASING SOLUTIONS – A FINANCIAL PARTNER TO REALIZE XAAS MODELS

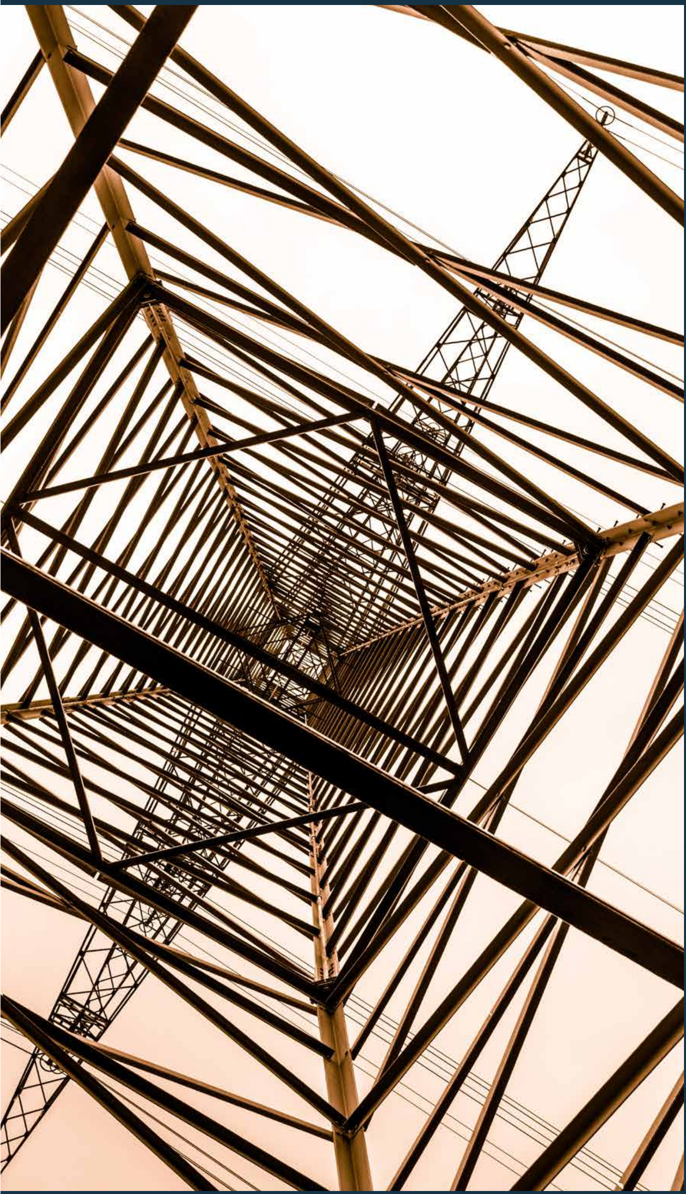
The subsidiary of BNP Paribas offers rental and financing solutions that promote a shift from an ownership to an access economy for apparatus such as medical equipment, construction equipment, utility and industrial vehicles. The company buys the equipment from the manufacturer on behalf of the customer in exchange for a monthly rent fee. Full-service leasing offers include repair, maintenance and spare parts services. At the end of a contract, the equipment is rented out again, promoting the reuse of unneeded assets.[55]

CASE BOX 8:
INTESA SANPAOLO RENT FORYOU – OFFERING OPERATIONAL RENTAL OF CAPITAL GOODS

With its services, the Intesa Sanpaolo Group promotes the transition towards a circular economy by providing financial support for investments to redesign the industrial system. Since its launch in 2018, the disbursements provided by its circular economy credit facility amounted to 2.2 billion EUR.[56] Intesa Sanpaolo Rent Foryou, a company of the Intesa Sanpaolo Group, supports the uptake of XaaS models by offering operational rental of capital goods for producers and companies that prefer access to goods instead of ownership. With its offerings, it aims to focus on the needs of producers and customers by maximizing the value of goods and rental contracts.[57]

option is to create new standalone entities (e.g. for start-ups, or carve-outs), to ensure the highest degree of flexibility. This can also take the form of special purpose vehicles (SPV), a ringfenced investment opportunity for a consortium of operating XaaS partners. Producers also have the option to form a joint venture (JV) with their customers and potentially other partners.

(c) **Beyond that, there are further approaches for managing and covering specific operational risks.** First, depending on the specific risk-types, an insurance partner can underpin the XaaS model. When printing company Xerox and the machinery and equipment company TRUMPF launched their first XaaS models, for example, they joined forces with reinsurance companies.[58] Second, the contractual design of formalized partnerships with customers and other support companies can be important to limit operational risks (e.g. extended service periods, downtime agreements). Third, contractual arrangements between producer and buyer can hedge commodity risks (e.g. price fluctuations of commodities, scenario-based limits). Fourth, digital services help XaaS model providers and partners to better predict occurring risks (e.g. performance transparency, pre-emptive maintenance).



CASE BOX 9:

SIEMENS SMART INFRASTRUCTURE – ENERGY EFFICIENCY-AS-A-SERVICE

Siemens Smart Infrastructure (SI) offers a range of result-oriented business and financial models for energy efficiency projects such as pay-as-you-save and performance guarantees to Energy efficiency-as-a-Service (EEaaS). The value propositions of such models include minimizing risks (project and execution, financing and performance), eliminating upfront capital expenditure and shifting CapEx to OpEx accordingly as a balance sheet neutral solution. However, all these models differ in risk and ownership transfer. For EEaaS models, Siemens SI assumes full producer responsibility: Siemens bears the financing and operating risk and retains ownership. In an extension of the model, namely Energy-as-a-Service contracts, the customer is compensating for the delivered energy and does not have to bear any upfront costs. Whereas Siemens SI is providing the technical expertise, Siemens Financial Services (in-house bank) is providing the necessary financing.[59]

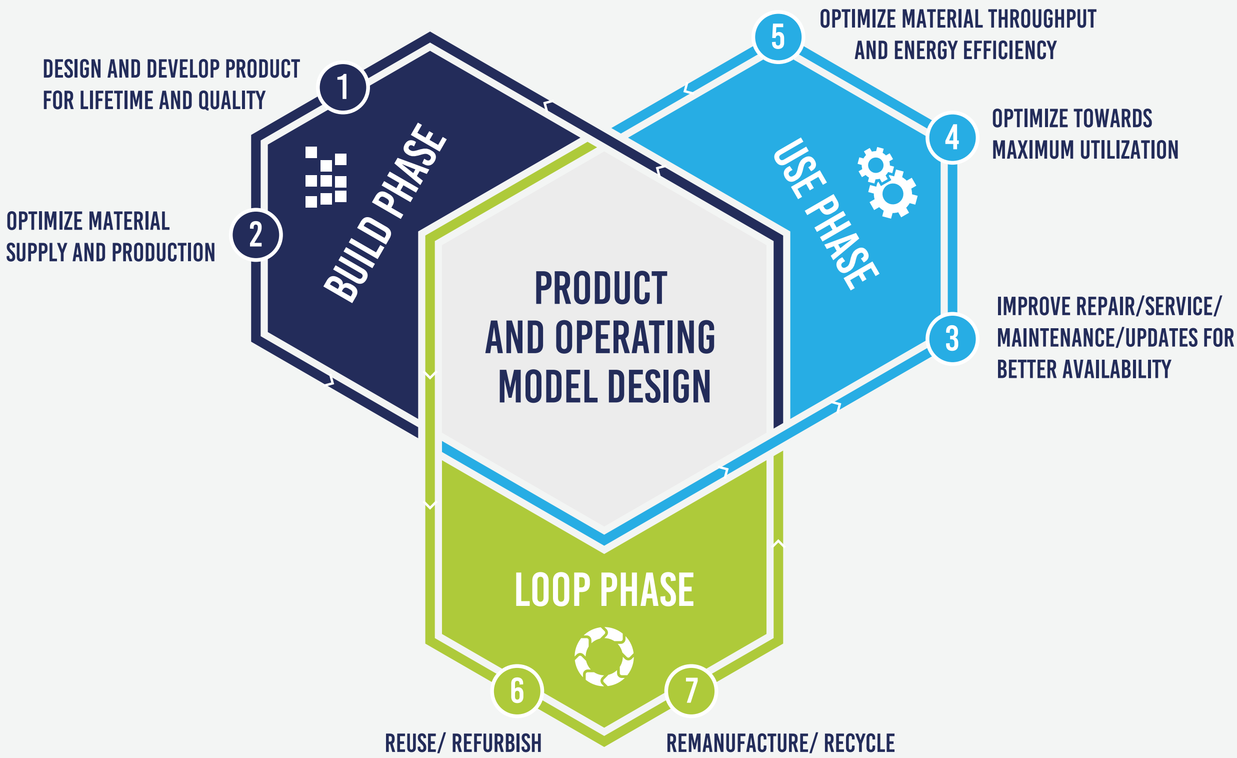
3.3 PRODUCT AND OPERATING MODEL DESIGN: OPTIMIZE FOR TCO AND ENVIRONMENTAL BENEFITS

XaaS models can be designed to achieve sustainability effects while offering benefits to customers in terms of TCO optimization – provided that the product and operating model is designed in line with circularity principles (Exhibit 13). In other words, unlocking sustainability effects and decarbonizing the product and its use means that a circular product and operating model design needs to be implemented in the XaaS model. The configuration of the business and financial model influences all lifecycle stages of a product. For example, producer ownership and the associated internalization of use and loop phase costs incentivize producers to consider these phases in the design of the product.

Academic research confirms that XaaS models can contribute to achieving dematerialization and decarbonization of industrial production systems – under the condition that circularity levers reinforce resource and energy efficiency.[49,60] The specific configuration of XaaS models along a set of key circularity levers is critical. Exhibit 13 highlights that XaaS models should optimize the entire lifecycle of a product which consists of (a) **the build phase** (encompassing the design stage and production of the product, including the materials and resources required), (b) **the use phase** (the operative stage of the product-service-bundle in its use by a customer), as well as (c) **the loop phase** (the stage of the product after its end-of-use or end-of-life, which

EXHIBIT 13

Seven circularity levers address all three lifecycle phases of the product.



Source: SYSTEMIQ.

entails that it is either reused or the materials are recovered). The three lifecycle phases embed a set of seven interdependent circularity levers that can lead to positive environmental impacts and TCO improvements at the same time.

a) **In the build phase, product lifecycle effectiveness is more strongly considered.** Retained ownership in particular, but also take-back obligations, shift the perspective towards seeing products as revenue-generating assets (for as long as possible) and internalizing end-of-life considerations. Two levers address this effect:

Lever 1: design and develop products for lifetime and quality. The design phase is critical in determining the lifecycle impact of products: over 80% of the lifecycle environmental impact is determined in the design stage.[61] Offering XaaS models increases incentives to design for lifecycle productivity. Accordingly, producers can opt to design for durability, choosing materials which are potentially more costly but last longer, reducing exchange and wear-off of parts and components – making the asset a revenue-generating entity over an extended lifetime, eventually resulting in better economic effects for both the XaaS provider and customer. For producers, the monetary boundaries of their customers may be less directly limiting of some product design choices (e.g. more durable materials, use phase improving technology). Product design in general is typically less driven by cost optimization than by quality optimization. Producers can design for modularity which facilitates the replacement of defective parts and maintenance. Since end-of-life treatments such as dismantling and recycling are the responsibility of XaaS model providers (or respective partners), they have incentives to improve design for disassembly, refurbishment or recycling. Beyond that, producers should aim to design for connectivity to increase uptime/lifetime (e.g. through predictive or preventive maintenance measures). Using sensors and data analytics, product performance can be measured, helping to create feedback loops for the product design to meet new requirements.

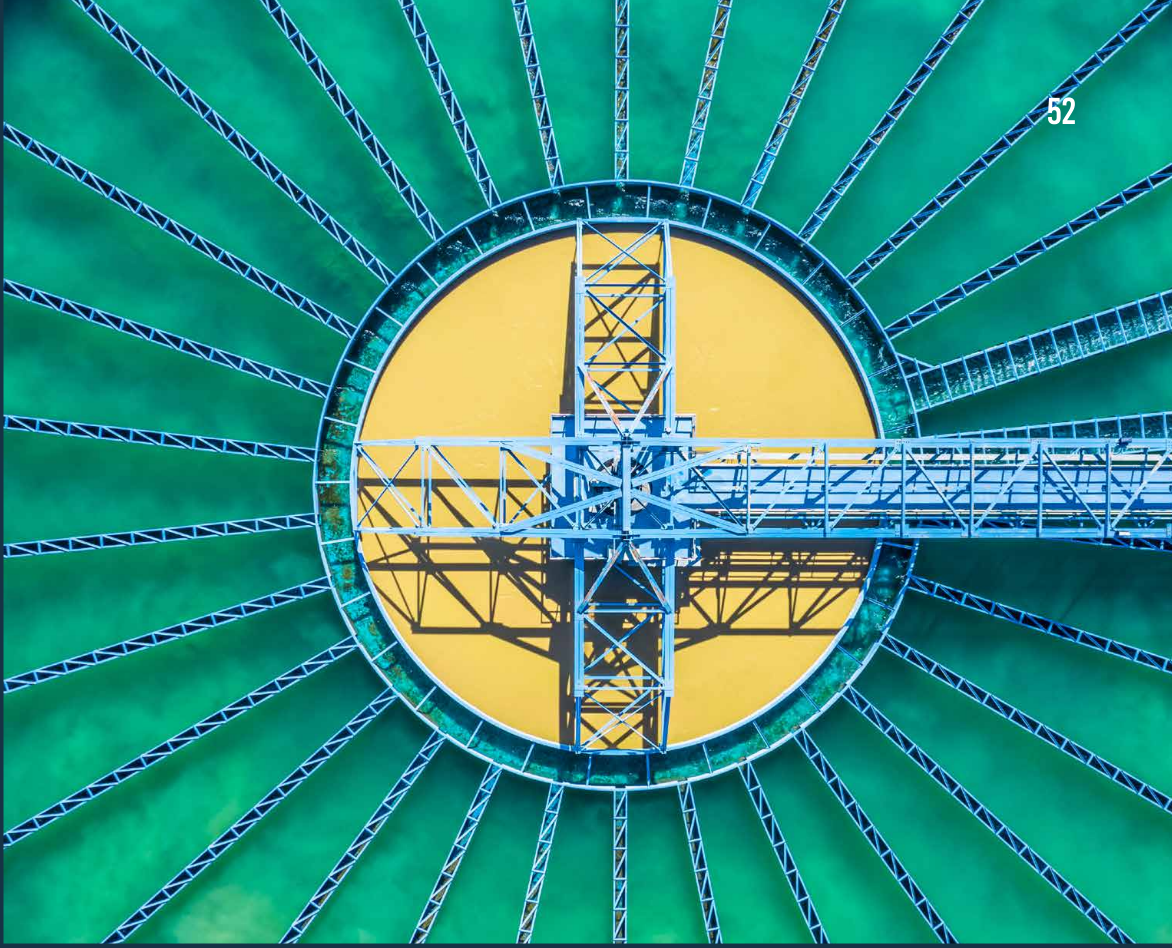
Lever 2: optimize material supply and production. Designing XaaS models towards decarbonization involves sustainable material choices and resource productivity in production. This particularly relates to the quality of the materials but also the sourcing according to sustainability standards throughout the value chain. XaaS models can strengthen integration in the value chain and often require stronger collaboration with other partners in the ecosystem, such as end-of-use/life managers and material providers, ensuring better access to recycled or other low-carbon materials (e.g. green steel). For example, frontrunners in the motor vehicle industry recognize the environmental and economic benefits and start to act: BMW recently introduced a "secondary first" policy.[62] XaaS models are particularly relevant in that context as end-of-life control over the car can accelerate reverse material flows and the creation of closed loop systems (e.g. reintroducing recycled materials as secondary inputs). This also applies to waste waste from a company's own production, which can be introduced into the emerging material recovery networks. Technology can support the purchase of low-carbon or recycled materials/ components with the help of traceability tools (e.g. blockchain-based), platforms (e.g. for recycled materials) or IoT technologies (e.g. test and assess used products with sensors and data analytics).

b) **In the use phase, XaaS providers can significantly influence resource productivity.** This builds on three levers:

Lever 3: improve repair/maintenance/servicing/ updates. Since the producer or XaaS model provider often has more and deeper knowledge about the product than the customer, this can significantly improve service and operational support solutions. Customized XaaS models (e.g. result-oriented models) aim to increase the productivity of products (i.e. reduce downtimes and associated costs), whereby improved repair-maintenance systems are important to achieve uptime improvements with corresponding positive TCO effects. Smart usage with sensors, IoT, data analytics, and integration with ERP and MES systems can enable continuous monitoring of the product status or usage. This allows predictive or preventive maintenance schemes to be implemented, technical progress to be integrated more quickly (e.g. over-the-air updates or upgrades), or trainings to be tailored (e.g. advanced machine handling).

Lever 4: optimize towards maximum utilization. XaaS models typically democratize consumption and can enable product access for more customers than traditional models (e.g. sequentially or at the same time). Thus, the utilization of products can be massively increased. Maximizing utilization spreads the build-phase emissions, material resource requirements and costs of an asset over "more utility" provided (e.g. the passenger kilometres provided by a car). Often platform-based XaaS models can increase utilization through linking with digital marketplaces, user platforms or social networks. Use-phase process optimizations through monitoring, maintenance and training can result in increased uptime and operative functionality. Digital technologies can facilitate a higher utilization (e.g. machine learning applications and data analytics can improve the product effectiveness in the use phase).

Lever 5: material throughput and energy efficiency can be improved. The internalization of use-phase costs incentivizes producers to be as resource-efficient as possible in terms of utility provision. In XaaS models, being competitive does not depend on the build cost, but on the entire lifecycle cost and service quality. If energy and resource consumption in the use phase are internalized as costs for the producers, investing in more use-phase efficiency becomes viable as it improves the profit margin in the long run. This is especially relevant for products with a high energy consumption (e.g. electricity) or material intensity in the use phase (e.g. in the case of machinery, the material flow related to production processes on the machines), which can be influenced by the XaaS provider. The strong service orientation of XaaS models improves the quality of the product's operation and strengthens the customer relationship, ensuring aligned interests between producer/ service provider and customer to optimize the use phase of a product continuously. Improving resource efficiency has a positive impact on both environmental and economic



outcomes. Again, technology can further drive material throughput and energy efficiency (e.g. digital twins can optimize product use and associated energy consumption by tracking operations and simulating outcomes).

c) **In the loop phase, XaaS models create incentives for producers to take responsibility for an asset at the end-of-a-use phase or end-of-life, enabling them to steer further use cycles of a product, reuse components or even manage closed material loops.** Two circularity levers address this:

Lever 6: reuse/refurbish. The extended responsibility for assets leads to increased reuse of products (e.g. through sequential use phases, second-life, resale) to keep and restore embedded value. In addition, especially when based on a modular design, products can be refurbished by exchanging worn-off parts or replacing more technologically advanced (and energy-efficient) core components. Hence, resource flows and cycles are slowed and narrowed. This decreases the TCO because costly virgin material and energy inputs are prevented. Since the XaaS solution ecosystem enables a closer partnership of actors along the value chain, reuse/refurbishment activities can be better coordinated.

Lever 7: remanufacture/recycle. Retaining control over the asset and embedded materials until the end-of-life increases the potential for material recovery. This entails remanufacturing practices, where components or parts are reused to produce new products. In addition, XaaS systems can play an important role to create closed loop material systems and recycling streams at high-quality (e.g. currently in the automotive sector, vehicles are mostly downcycled and value is lost). Accordingly, this can increase recycling rates and allows the capture of the actual value embedded in materials at end of use/life. This can be further reinforced through ecosystem effects from a deepened collaboration with complementors along value chains (e.g. material recovery partners) and technologies (e.g. digital product passports providing lifecycle information for appropriate end-of-life treatment).

What is the Cradle to Cradle (C2C) philosophy?

Definition: Cradle to Cradle® is a design concept which is inspired by nature. It describes the safe and potentially infinite circulation of materials and nutrients in cycles. The aim is not only to minimize negative influences but also to create a positive ecological footprint. As a result, products, processes, buildings, and cities will emerge which are safe for humans, healthy for the environment and successful for business.

Principle 1: Nutrients remain nutrients

- All constituents are chemically harmless and recyclable. Waste as we know it today and which is generated according to the pre-existing take-make-waste model will no longer exist, only useful nutrients.

Principle 2: Use of renewable energy

- The creation of products and systems is powered by renewable energy of the sun in many ways. Wind power, hydroelectric power, geothermal energy and biomass are further sources of renewable energy.

Principle 3: Support diversity

- Natural systems work and thrive through their complexity; i.e. nature promotes an almost infinite variety of designs, making systems flexible while at the same time resilient. When applying this principle to our economic and value system, biological, cultural, social and conceptual diversity is promoted, and context-specific solutions are favoured.

Which companies have adopted the C2C approach?

BRANDS
SOCIAL. GREEN. FASHION.

BRANDS FASHION: Apparel collection for the biological cycle and product-as-a-service

- 100% compatibility for humans and nature; no toxic substances leach from textile
- Produced with renewable energy
- Biodegradable fibres, sewing thread and printing paste
- Take-back and recycling possible due to already integrated service system of workwear in the B2B sector
- In the event of system leakage, no littering of environment due to biodegradability

made in Germany
megawood®

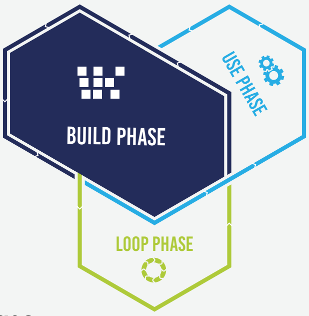
NOVO-TECH: Floorboards for the technical cycle and product-as-a-service

- Wood polymer composite boards designed for a use-time of up to 30 years
- Ingredients fully defined and positively assessed
- Take-back after use-time; fully recyclable: old boards serve to 100% as input for new boards
- Produced with renewable energy
- Transfer of usage rights possible and encouraged by Novo-Tech

EPEA
PART OF DREES & SOMMER

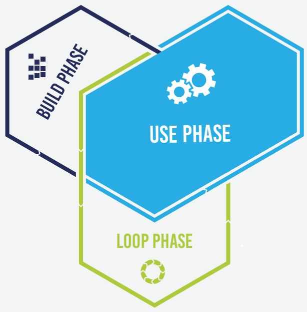
How are the C2C principles implemented along the key value levers?

From a Cradle to Cradle perspective, build phase, use phase and loop phase are interrelated and should be thoroughly considered during the design process. Loop scenarios are constructed either for the biological cycle (consumption products, e.g. cleaning products, natural fibres, degradable packaging) or the technical cycle (service products, e.g. flooring, electronics, furniture).



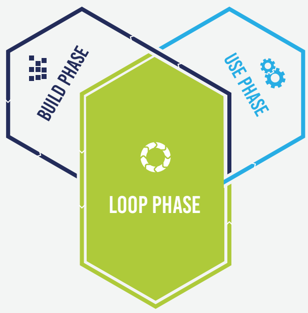
Build phase

- C2C works with a positive material definition (contrary to the common “free from” approach). Inputs for the manufacturing of a product are known down to the molecular level regarding their ingredients and evaluated for their toxicological and circularity performance. Only ingredients with good performance are chosen.
- As the manufacturer usually does not have access to the molecular material information, a material trustee steps in, receives the recipe from the supply chain, and delivers only the C2C assessment to the manufacturer. This way, both confidentiality and C2C eligibility are ensured.
- Not only should the products be designed for regeneration, the energy used during the production process should be regenerative as well. Therefore, C2C products must be produced with rapidly renewable energy.
- Designers and product developers need to ensure that products are made without problematic substances. In a C2C product, the selected materials are safe for humans (no toxicity issues) and do not impede the cyclability in the loop phase.
- Already in the build phase, material regeneration is considered and logistics for collection and recycling are set up.
- Applying the Cradle to Cradle principles in the design stage ensures safer, more sustainable products made for the circular economy.



Use phase

- In the use phase, material information and material value of C2C products is maintained owing to the positive material definition. With this, perpetual cycles of use and reuse are made possible.
- As all ingredients are known and positively evaluated, no toxicity emerges from C2C products, making it safe for humans and the environment.



Loop phase

- Since it was considered in the build phase of the C2C products, the technical systems for the collection and recycling of materials are in place.
- As envisaged and carefully incorporated in the product design, the product has 100% recyclability in the biological or technical cycle. With this, an actual regeneration of the material sources is achieved at the end of the use time.
- No degradation or pollution of biological or technical material flows occurs in the loop phase.

3.4 ESTABLISH THE INTERNAL AND EXTERNAL STRUCTURES TO MANAGE RESOURCE AND INFORMATION FLOWS

To implement XaaS models, it is important to take an ecosystem perspective both with respect to the internal organization as well as external collaboration partners. Few, if any, businesses have the financial resources and organizational capabilities to successfully design, develop and implement these service-oriented models by themselves at the necessary speed. For incumbent companies, switching to XaaS models can involve significant organizational change. For emerging companies, establishing XaaS systems from scratch involves a complexity of design choices. Seeking alliances with partners for jointly delivering the XaaS model can be critical (e.g. specialized service companies, digital/technology innovators, or suppliers). Typically, one of the actors in the partnership network is taking the role of a central orchestrator. What makes ecosystem design distinctive is that it requires a true system perspective. For instance, it is not sufficient to design the value creation and delivery model, it is also necessary to explicitly consider value distribution among ecosystem members.[63] The ecosystem perspective should differentiate between three levels (see Exhibit 14).

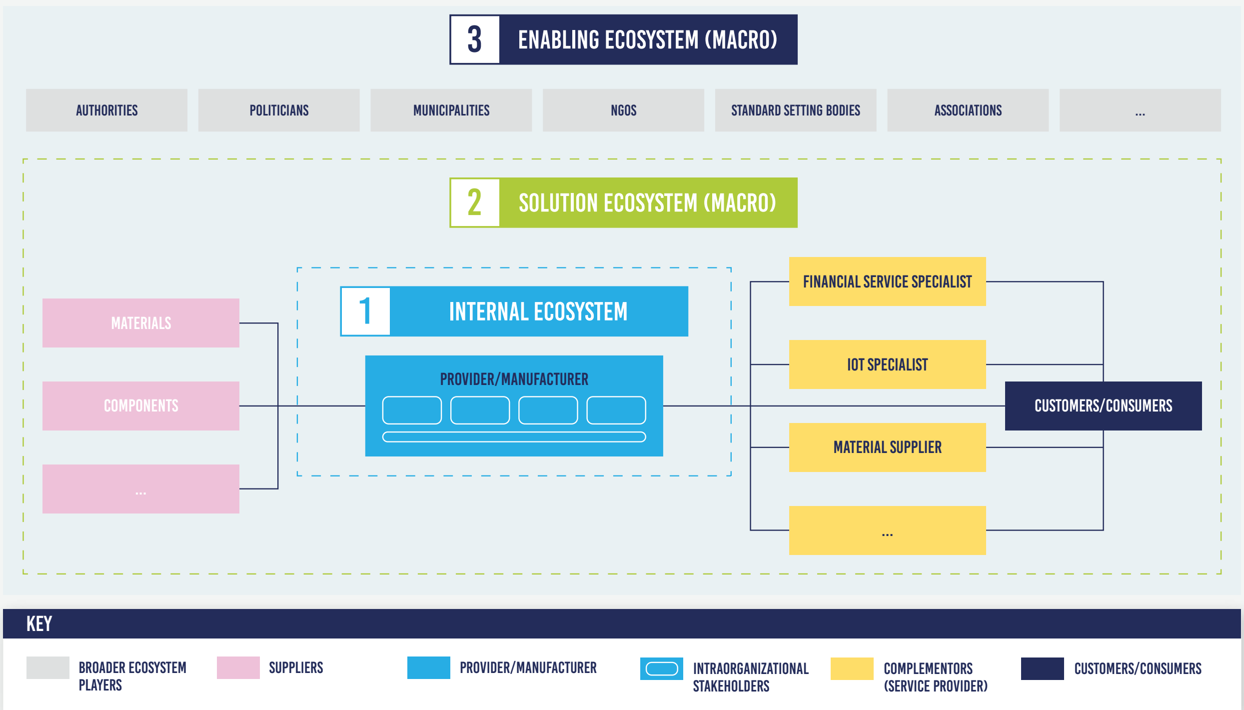
1) **Internal ecosystem**: intraorganizational activities and structures to manage the XaaS model.

2) **Solution ecosystem (micro)**: coordinating activities among partners to deliver the XaaS model.

3) **Enabling ecosystem (macro)**: collaborations and networks among partners within, across and beyond industry boundaries (e.g. to scale XaaS models).

EXHIBIT 14

The ecosystem perspective needs to differentiate between three levels.



Source: SYSTEMIQ collation based on Boston Consulting Group (2019).

3.4.1 INTERNAL ECOSYSTEM: STRENGTHEN THE ORGANIZATIONAL STRUCTURE AND PROCESSES

For many companies, establishing a consumer-centric (vs. product-centric) XaaS model requires a collective effort and changes within the internal organizational model. In particular within established incumbents, XaaS transitions have to ensure strategic embeddedness, adapt organizational structures and build new capabilities. Beyond that, it is essential to assess whether the IT/technology stack is ready to manage a circular business model and processes (e.g. ERP, predictive analytics).

3.4.1.1 STRENGTHEN STRATEGIC EMBEDDEDNESS, ORGANIZATIONAL STRUCTURES AND CAPABILITIES

The strategic embeddedness of XaaS models is of utmost importance and requires support by the senior decision-makers within the company. Putting XaaS models high on a company's strategic agenda is not only important to ensure a high ambition level that combines economic and environmental impact, it also ensures that internal XaaS initiatives receive the required buy-in and resources. Hence, there is a need for committed C-level managers (and potentially even key shareholders) to sponsor such a change.[64]

In some organizational areas, XaaS models entail a fundamental shift to key activities and processes. For example, a stronger service orientation and lifecycle product responsibility may require new structures and processes. Companies need to (a) decide on how/where to integrate XaaS models within the actual organizational structure to ensure flexibility and independence for XaaS initiatives but also to synergize with the core business and strengths. In addition, (b) controlling/KPI processes and (sales) incentive schemes may need to differ for XaaS models and adjust for the initial revenue gap and the recurring revenue logic. Moreover, traditional sales companies may need to adjust sales incentives and an accounting mindset that properly reflects the material value and is tailored to product-service-bundles that represent revenue-generating assets. Overall, (c) processes need to be streamlined towards agility to deal with more (internal and external) information and be responsive.

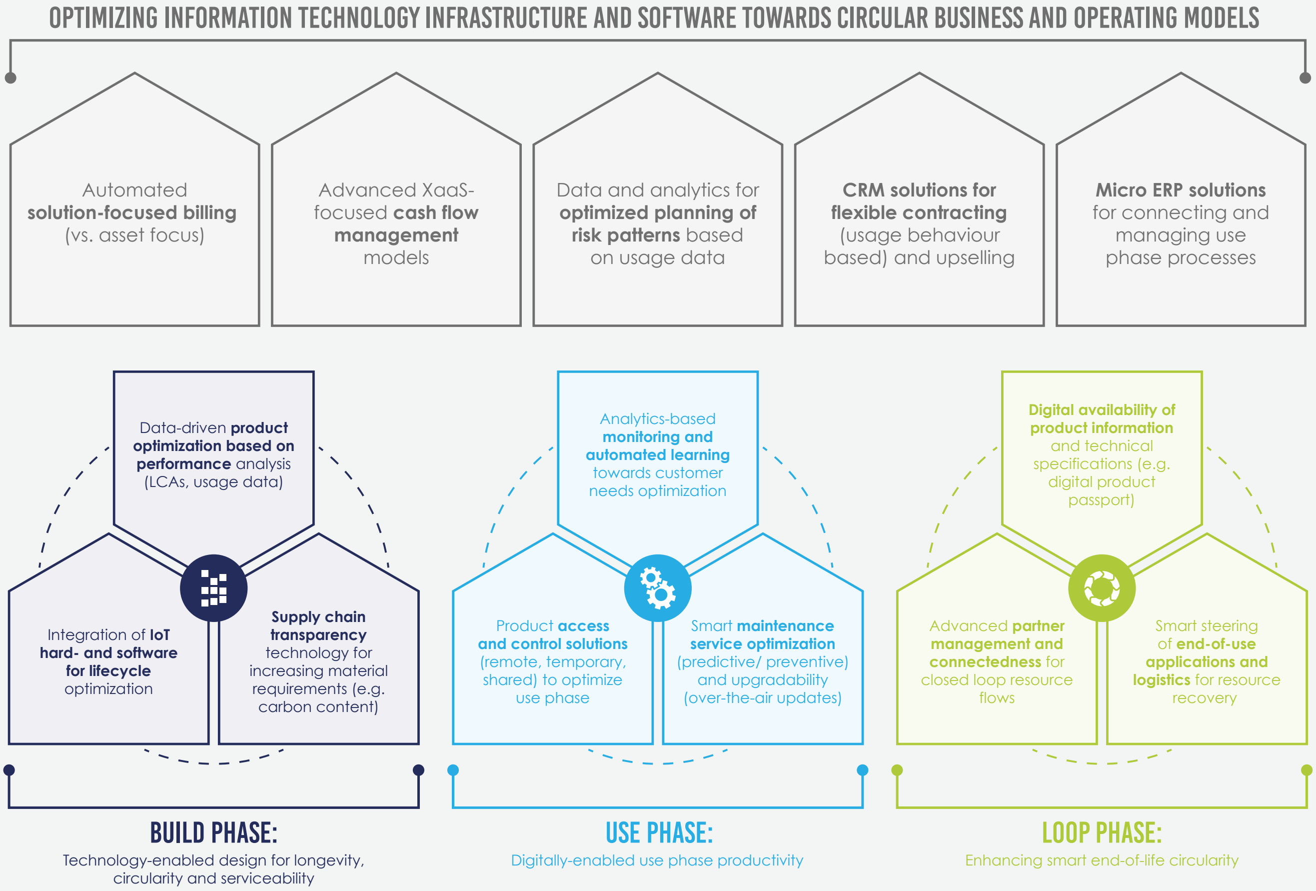
Since XaaS models typically require more interdisciplinarity among different organizational units (e.g. sales, product development, customer service, controlling, finance, treasury, and supplier management) and potentially new company activities, collaboration may require breaking organizational silos. Simple measures such as creating positions of responsibility that promote the exchange within the departmental teams are essential. This can be achieved by, for example, linking the development department, the design department and the repair/aftersales department. Optimizing the organizational structure may benefit from exploring new ways of working (e.g. agile sprints, scrum). A new set of capabilities may be required to realize XaaS offerings – including both soft skills and hard functional skills (e.g. carbon footprint/LCA expertise). Please refer to Appendix B.3 for further details on strategic embeddedness and organizational change.

3.4.1.2 ADDRESS IT/DIGITAL REQUIREMENTS FOR XAAS READINESS

Leveraging IT and analytics capabilities is important to achieve XaaS readiness. With value creation increasingly relying on IT/digital capabilities and ecological regulation raising data requirements, investments in digitalization and associated capacities are rising steadily.[11,65] The IT/digital infrastructure and application landscape of an

EXHIBIT 15

IT/digital capabilities will need to reflect change requirements of XaaS (non-exhaustive).



Source: SYSTEMIQ.

internal ecosystem has to be ready to enable XaaS models from several perspectives; in particular, by supporting involved business units to manage changed processes and data needs, by interconnecting the business functions internally, by actually offering the XaaS services along the full product lifecycle, and by ensuring necessary data flows through interoperability with the external partner ecosystems. A set of important IT/digital change requirements for key applications in the business and operating model is summarized in Exhibit 15. Appendix B.4 presents a further elaboration.

For many organizations this might require a substantial investment in their IT/digital capabilities or a more intense collaboration with (new) technology service providers. Developing IT/digital solutions that enable and accelerate corporations to shift to XaaS models represents a vital field for entrepreneurial innovation (see Case box 10).

CASE BOX 10:
NITROBOX – ENABLING BILLING AND PAYMENT FOR SERVICE-ORIENTED BUSINESS MODELS

Nitrobox is a smart software solution (SaaS) provider enabling companies to implement monetization models for complex digital business models (transaction-based, usage-based, as a subscription or hybrid models). The Nitrobox Agile Monetization Platform connects customer and order applications with existing backend systems such as SAP. It provides comprehensive order-to-cash/ partner-to-pay functions such as convergent billing and invoicing, payment automation, contract management, and revenue recognition. Hence, it allows companies to roll out their new monetization strategies within weeks without having to change legacy ERP systems and supports the transformation towards innovative business models such as multi-sided platforms and marketplaces, Equipment-as-a-Service and IoT models, on-demand and smart mobility services.[66,67]

3.4.2 SOLUTION ECOSYSTEM (MICRO): SET UP COMPLEMENTARY PARTNERSHIPS FOR XAAS DELIVERY

The micro-level solution ecosystem entails a collaboration of complementary partners that focuses on jointly delivering a XaaS model as well as possible. As indicated in Exhibit 14, the solution ecosystem typically includes suppliers and customers, but also complementary service providers or functional specialists which help to deliver the XaaS model. Beyond just defining relationships as in linear value chains, the development of XaaS models may shift the classic boundaries of the company (e.g. managing data or new service levels, or establishing material loops). In XaaS models, the success of all partners involved should be linked to the outcome/ performance of the product-service-bundle, to fully align incentives towards customer success. To meet customer needs, XaaS providers may have to go beyond existing relationships and search for partners that contribute new resources and capabilities. For example, technology platform start-ups such as Nitrobox, circuly and lizee now offer complementary digitalization capabilities to traditional companies that seek to experiment with XaaS models, e.g. support logistics, online retail and predictive maintenance.

Ecosystem partners should develop a shared vision in line with the sustainable customer value proposition. This is why ecosystem partners should be involved in the development of the XaaS model early on to co-create the vision, business case, and roadmap for the service-oriented business model.

Solution ecosystems should be very clear with respect to roles in the ecosystem. A well-designed governance structure secures ecosystem partners' mutual agreement about positions (where each partner is situated) and activity flows (what each partner is responsible for doing).[68] Importantly, partners have to clarify roles such as the **orchestrator**: a core firm (e.g. the producer or platform host) that acts as XaaS model provider who builds the platform and assembles the partners. The orchestrator plays a critical role within the ecosystem and must ensure a fair and sustainable value distribution. The role of the lead firm or orchestrator of the ecosystem (which could, in theory, be any actor in the solution ecosystem) cannot be overstated as it can provide a clear vison and narrative as well as sufficient incentives for the ecosystem to thrive.[32] The orchestrator needs to balance three competing objectives: maximizing the size of the total pie; enabling all important domains (groups of participants) of the ecosystem to earn enough profit to ensure their ongoing participation; and capturing its own fair share of the value.[69] **Suppliers and complementors** contribute a specific product or service to the XaaS model and can participate in more than one ecosystem, particularly if they provide important components that represent a bottleneck for various ecosystems (e.g. reverse logistics competencies, material recovery). Complementors may also include financial institutions to help bridge the initial revenue gap associated with these models and assume part of the transferred risk.[35]

3.4.3 ENABLING ECOSYSTEM (MACRO): DEVELOP AN EXTENDED NETWORK FOR SCALING XAAS

The enabling ecosystem focuses on creating supporting structures and networks beyond the boundaries of the solution ecosystem. The design (e.g. shared vision, roles, interaction) of the enabling ecosystem depends on the goals that the orchestrator and respective partners want to achieve with it. Several objectives can be pursued through enabling ecosystems and drive respective partner constellations:

- The orchestrator (e.g. producer or platform host) wants to **scale the XaaS model** and is looking for cooperation with politics or industrial unions.
- The orchestrator wants to go beyond existing relationships to **strengthen value creation in a specific region** and is looking for cooperation with regional partners.
- Companies (within an industry or specific XaaS model archetypes) may set up alliances to **further develop specific innovations of common interest** that support everybody's circular business models.
- Companies want to use enabling ecosystem partnerships to **accelerate decarbonization** across a sector.
- Companies aim to **partner towards shaping a new industrial vision** (e.g. Industry 5.0 transition to a sustainable, people-centred and resilient European industry).

The macro-level enabling ecosystem may include a diversity of relevant stakeholders from politics (e.g. relevant communities, municipalities, nations), society (consumer associations and NGOs), business/industry (e.g. associations, standard-setting bodies) and research (e.g. universities, research institutions, innovation hubs). Exhibit 26 in Appendix B.5 summarizes a set of potential activities that enabling ecosystem players can contribute to foster the economic and environmental value creation potential of XaaS models. To design the respective ecosystem activities, initiating XaaS orchestrators may be guided by questions like: Which topics related to building and scaling XaaS impact require support from outside of the solution ecosystem? What should be the key objective of the enabling ecosystem? Who can help to scale environmental impact at the necessary speed? Who are the right parties to collaborate/join forces with?

Ecosystem design is a deeply strategic design pursuit

IDEO

ECOSYSTEM DESIGN NEEDS A MINDSET SHIFT

- XaaS model development at scale and the wider shift towards a circular economy requires thinking about system fitness – versus the linear economy mindset that is typically focused on having more slices than growing the value pie.
- Mindsets are needed that do not focus only on narrow proprietary services platforms, but drive an industry-wide shift to a new digital playing field that offers a more attractively convenient and diverse experience to users.
- XaaS ecosystems describe an upstream opportunity for developing a new business system, including new partnerships and infrastructure, rather than a downstream opportunity to improve efficiency within the current system.

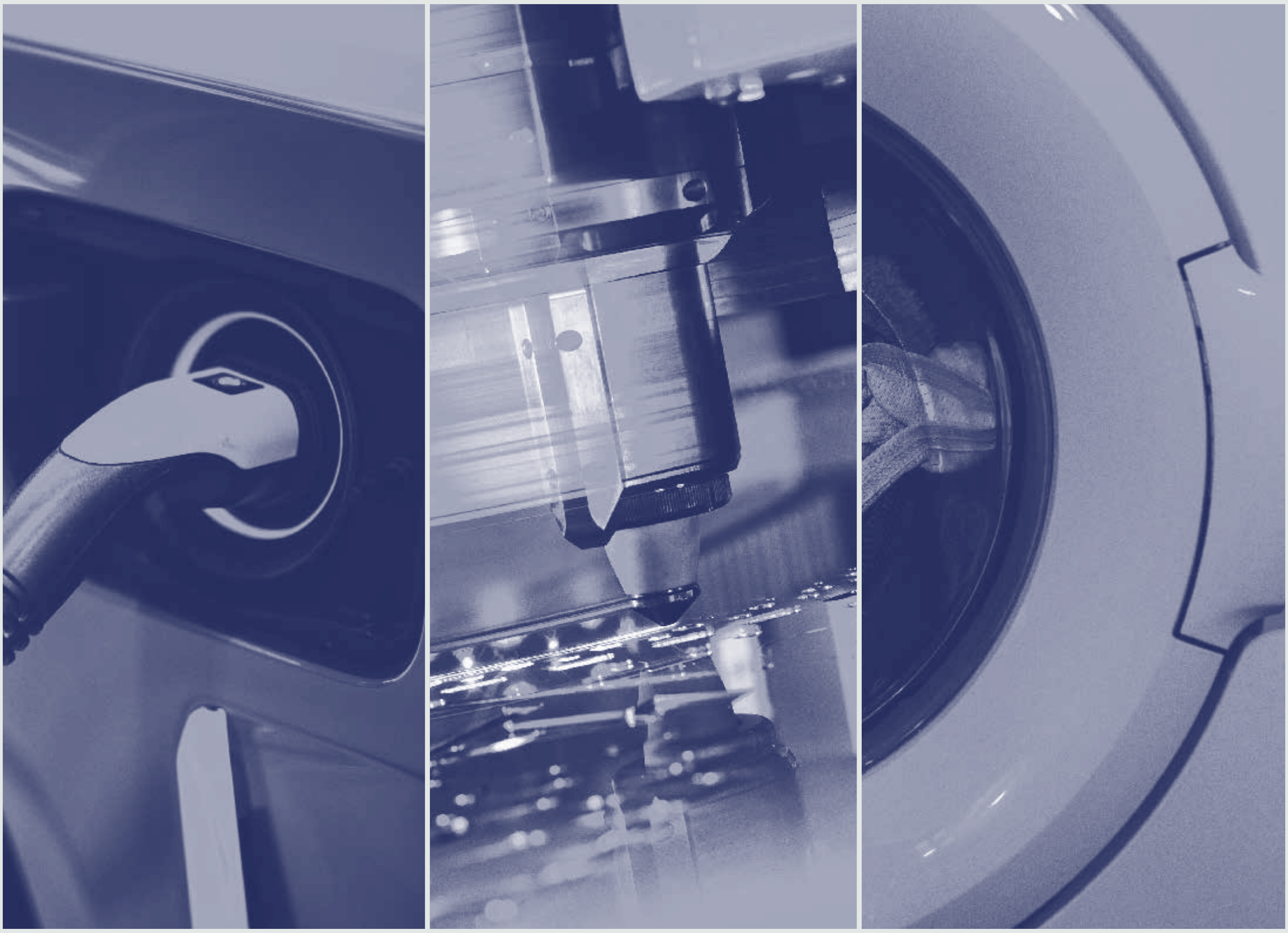
ECOSYSTEM DESIGN REQUIRES COLLABORATIVE SCALING

- Achieving far higher levels of circulation challenges current system boundaries – a single organization may not be able to deliver the kind of interoperable platform that will make this scalable from a user perspective, resulting in fragmentation of user experience.
- Most organizations will not have a core business that offers the full range of circular services from swapping, repair, resale, rental to recycling or the data infrastructure capabilities across data production, access and analytics that fuel them.
- In order to scale, XaaS ecosystem design can learn from digital ecosystem platforms, where companies change their operations from linear supply chains to value networks as part of a wider tech ecosystem.

ECOSYSTEM DESIGN HAS TO BUILD ON A DATA/TECH BACKBONE

- Designing and scaling up data production, access and analytics requires a high degree of interoperability and shared ownership within the data ecosystem in order to lower barriers for the development of new data infrastructure.
- Industry needs to uncover the drivers that will enable common data standards, interoperability and data exchange (e.g. between different platforms, apps and 'retailers/brands' systems) and avoid the proliferation of various competing identification and meta-data standards, e.g. for product, inventory and usage data.
- A strong data backbone is key to facilitating information flows and improving economic value creation potential for all actors in circular XaaS models (e.g. customer apps, recyclers, brands).

Illustration by Khyati Trehan



DEEP DIVE CASES:

THREE EXAMPLES OF CIRCULAR XAAS MODELS SIMULTANEOUSLY ENABLING ENVIRONMENTAL BENEFITS AND ECONOMIC VALUE

4

Configuring XaaS models to unleash their full potential requires the embrace of circular economy design principles and depends on the respective product and context. On average, only 1/4 of a product's lifecycle footprint arises from a company's direct operations; for some product categories, use-phase emissions (Scope 3 downstream) are the biggest source of emissions (e.g. ~50% for computer equipment, ~60% for capital goods, ~80% for automobiles (internal combustion engines)).[22] This chapter investigates three exemplary product-service-systems and quantifies the environmental and economic effects of a product and operating model designed for circularity. The modelling illustrates feasible combinations of circularity levers that can be reinforced by XaaS models. The analysis explores the impact potential, especially with respect to decarbonization and TCO dynamics. The approach compares traditional product-sales-based models to selected XaaS scenarios for different use cases. For this, first, each deep dive builds a Business-as-Usual scenario (BAU) that captures the CO_2 emissions and TCO. Second, the circularity levers to optimize product and operating models (see Exhibit 13 in Section 3.3) are specified and clustered. Third, scenarios are defined and quantified, representing different realizations of XaaS models and respective lever combinations or assumptions.

The models show that designing the XaaS model for circularity can reach CO_2 emission reductions of up to 44% (Car-as-a-Service), 65% (Equipment-as-a-Service), and 35% (White Goods-as-a-Service) (Exhibit 16).

The **Car-as-a-Service (CaaS) example** highlights that retaining ownership and related material efficiency strategies as well as a more intensive use of vehicles can drive improvements of the CO_2 footprint. For instance, increasing utilization in a free float carsharing model decreases CO_2 emissions by 25% – but if coupled with lifetime extension and material recovery this impact can grow up to 44% compared to a traditional sales model. Thus, critical considerations are the full integration of the model levers: maximize utilization, lifetime extension, and material recovery. To illustrate, assuming that the mobility demand of the European BEV fleet in 2030[70] would be met by 20% circular subscription models and 20% carsharing, the BEV stock could be reduced by 5.8 million (17%) vehicles equalling ~70.9 Mt CO_2 avoided. Further annual BEV-related emissions can be decreased by 8.3 Mt CO_2.

The Equipment-as-a-Service (EaaS) use case shows that the digitally enabled model can improve the equipment's lifetime capacity and resource efficiency, facilitated by smart services and access to the equipment throughout the lifecycle. Optimizing the material throughput and material recovery are key to decarbonizing the use-phase emissions. The example of a sheet metal laser cutting machine shows that a large share of emissions lies in the use-phase material flows and, for instance, decreasing scrap through improved processes can reduce CO_2 emissions by 19%. Increasing the share of secondary materials in both build- and use-phase saves an additional 22%. Aggregating the results illustrates that 6.3 Mt CO_2 emissions could be avoided by 2030, if 30% of newly installed reference machines are offered in comparable EaaS models until then. Fabrication yield improvements and reduced scrap are key for decarbonization: with the energy required to produce 1kg of metal raw material, an average metal processing machine can be operated for over one hour.

The White Goods-as-a-Service (WGaaS) example showcases that washing machine subscriptions can lead to increased lifetime utilization and use-phase resource efficiency. Combining both, lifecycle CO_2

iv Not included in the overview, but in the detailed use case descriptions.

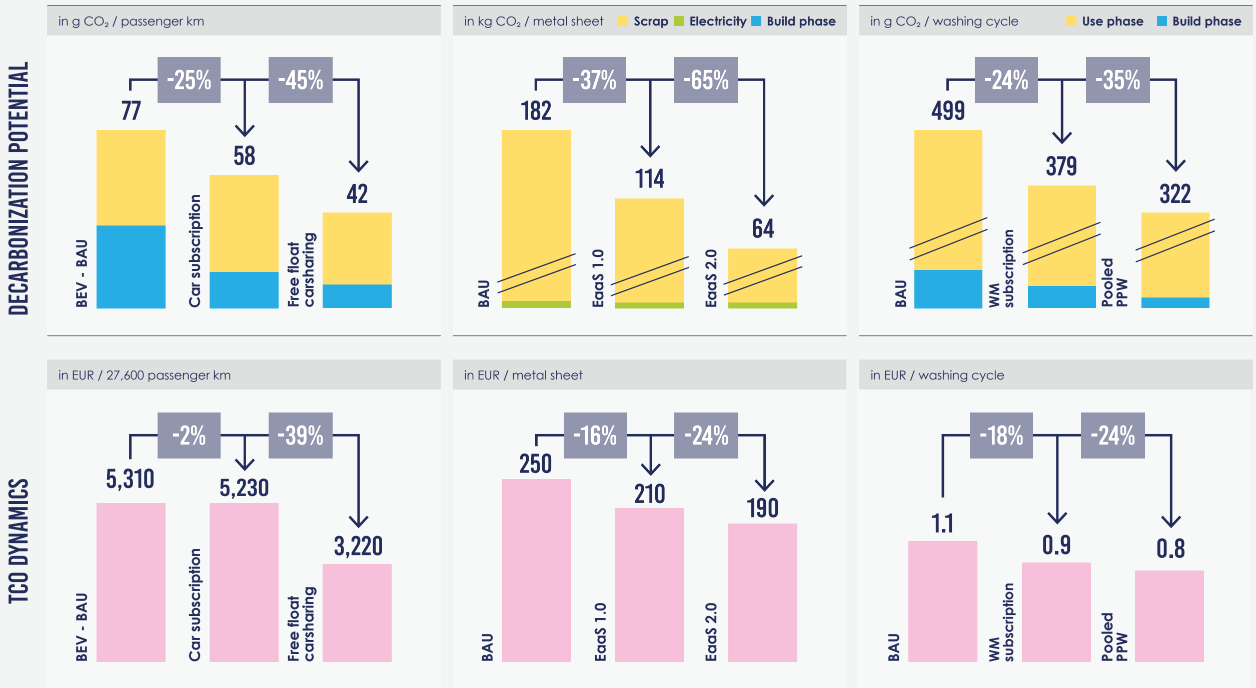
emissions of washing machines can be reduced by 22%. With electricity being the largest share of use-phase emissions, bundling renewable energy contracts by a service partner in an integrated service offer could additionally reduce the lifecycle emissions by 51%[iv].

If 20% of washing machines sold in the EU until 2030 were provided by circular subscription models and 10% by pooled Pay-per-Wash solutions, the consumption of 49 million m³ water and 1.2 TWh electricity and – coupled with material efficiency in the build phase – 1.3 Mt CO_2 could be avoided. From a TCO perspective, households could save between 43-76 EUR per year (in total ~2.2 billion EUR until 2030).

EXHIBIT 16

Transitioning to XaaS: Measuring the ecological and economic effects of three use cases optimized for circularity.

THE POWER OF XAAS	CAR-AS-A-SERVICE (CAAS)[1]	EQUIPMENT-AS-A-SERVICE (EAAS)[2]	WHITE GOODS-AS-A-SERVICE (WGAAS)[3]
	CaaS can maximize utilization and vehicle lifetime and enhance the productivity of resources in use.	**EaaS can optimize lifetime capacity and material throughput**, addressing structural inefficiencies.	**WGaaS can enhance resource efficiency** in the build and use phase and lifetime functionality.
	Decarbonization is driven by a higher utilization, smart servicing and design for extended lifetime.	**Decarbonization is driven** by optimizing the cutting process and lifecycle smart support services.	**Decarbonization is driven** via longer lasting, more efficient appliances and optimized user behaviour.
	TCO improvement as customers only pay for utility, but depends on the pricing strategy of producers.	**TCO improvement** due to increased capacity and decreased waste, shifting CapEx to OpEx.	**TCO can be decreased** through higher utilization, but depend on the pricing strategy of the producer.
	Seamless integration of CaaS into intermodal transport towards future of sustainable mobility.	**Optimizing material flows and utilization in closed value networks** for a sustainable manufacturing.	**Leveraging efficient domestic appliances** to reduce residential resource consumption.
	Battery electric vehicle as case example.	**Metal laser cutting machine** as case example.	**Washing machine (WM)** as case example.



Source: SYSTEMIQ analysis based on multiple sources.
[1] SYSTEMIQ analysis based on OECD and ITF (2020), IRP (2020), Ecoinvent (2020), Volkswagen AG (2021a, 2021b, 2021c), Schwacke (2020), expert interviews.
[2] SYSTEMIQ analysis based on data provided by TRUMPF Group (2021).
[3] SYSTEMIQ analysis based on Sigüenza et al. (2021), Bocken et al. (2018), Homie (2021), BlueMovement (2021), EcoTopTen (2021), expert interviews.

4.1 SHIFTING TO CAR-AS-A-SERVICE (CAAS)

Offering circular Cars-as-a-Service (CaaS) can be an important element to shape the future of sustainable mobility and address current structural challenges associated with passenger car transport. Road transport is a major driver of carbon emissions accounting for 20%[v] of Europe's total emissions.[71] It is the only sector without significant reductions in recent years, increasing emissions by 33% since 1990.[71] Including lifecycle CO_2 emissions embedded in materials and production, it is estimated that the automotive industry alone emits 4.8 Gt of CO_2e globally (9% of global emissions).[72] The mobility system centred around individual car ownership inherits significant structural inefficiencies: the car is only used 5% of the time for driving, occupancy rates are on average 1.5 persons, 50% of city land is dedicated to parking spaces and roads. Besides, road transport can cause negative social consequences such as local air pollution, accidents, or stress.[73]

Without circularity and resource efficiency strategies, the transition of the transport sector towards sustainable mobility is incomplete. CaaS can facilitate moving from traditional ownership towards an intermodal mobility system that decouples environmental impacts from mobility provision. The uptake in electrification of road transport powered by more and more renewable energy will eliminate tailpipe emissions in the long run. As this transition takes shape, emissions embedded in the build phase[vi] become increasingly dominant (up to 60%).[74] Decarbonizing the build phase through material efficiency strategies will become crucial to reach climate neutrality for the automotive value chain.

CaaS begins to shape the wider mobility market and is a first step to changed use patterns decoupled from ownership (i.e. providing access to mobility when needed). From a systems perspective, the integration of cars with more sustainable modes of transport is crucial to decarbonize the transport sector: for example, integrating carsharing into existing public transport systems through digital booking and routing systems can lower the threshold for users to switch to those more sustainable modes seamlessly.

The automotive industry increasingly offers cars in the form of subscriptions, carsharing or other forms of mobility service solutions[vii] – but sustainability often seems not to be a strong focus yet.[75,76] The market for alternative vehicle ownership models for smart and flexible mobility is expected to increase by a factor of 4 to 463 billion EUR until 2035.[77] To unleash the full environmental benefits, current CaaS models need to adhere to circular strategies enabled by producer ownership, such as increased utilization, remanufacturing and reuse, product life extension, and enhanced end-of-life recovery.[78] Two CaaS models are the subject of further investigation in the following: car subscriptions and free floating carsharing.

v Passenger cars and vans are responsible for 15% of carbon emissions within the EU.

vi Materials such as steel, aluminium, and plastics contribute ~55% to the vehicle's cradle-to-gate emissions.[180]

vii A variety of on-demand shared mobility services have emerged: carsharing, on which the focus of this report will be, means the provision of a vehicle for individual users as needed (e.g. car rental (station-based) or free float carsharing operations). Ridesharing is the shared use of vehicles from private ownership (peer-to-peer). Ride-pooling is the shared use of commercially operated fleets (bundling of trips in minivans through applications). Other on-demand mobility services include ride-hailing, which connects passengers with local drivers via digital platforms.

Car subscription models are currently a wider industry trend targeting customers that no longer want to own a car. A wide variety of subscription models are brought to market, directly by car manufacturers such as Volkswagen or Volvo or via service providers such as finn.auto or Cluno. However, if cars are only offered as a subscription to increase sales without adjusting the product and operating model, the sustainability impacts will be limited. CaaS has the potential to leverage systemic effects, if producer interests are aligned with those of the customers in terms of mobility provision over a maximized useful period, including design adjustments to optimize for longevity, for example. At the same time, retained ownership streamlines reverse material flows and facilitates value retention strategies such as refurbishment at scale. This is especially relevant for traction batteries, as recovery of used battery materials will be crucial to meet the demand of the battery electric vehicle (BEV) uptake.

Carsharing solutions gain popularity but face substantial limitations in creating sustainability impacts: often product and operating models are not adjusted and rebound effects occur. Carsharing solutions are more and more available in urban areas: in Germany alone, 2.29 million customers are registered across the country with 226 providers (station-based and free floating).[79] According to the International Resource Panel (IRP), besides downsizing of vehicles, a more intensive use of cars through car- and ridesharing is the most important strategy to reduce lifecycle CO_2 emissions: shared mobility makes up ~70% of the estimated decarbonization potential.[78] But current modes are typically not optimized for sustainability: vehicles are not designed for the purpose of carsharing. Users are not incentivized to drive considerately and fuel-efficiently. Both limit the vehicle's useful life to short periods. After this, minor reconditioning works are performed, and cars are sold to the secondary markets shortly after. Lastly, carsharing is currently rather a substitution for public transport, but nevertheless has the potential to significantly reduce car ownership.[80,81]

New mobility services should be socially inclusive – otherwise much of the sustainability potential can be lost. Shared mobility must be available in regions where public transport is not well developed to provide a real alternative for car ownership. Various forms of sharing are conceivable: peer-to-peer, station-based, and free floating. Low income areas should not be left out from offers. Policy steering and regulation is required to provide an effective framework in which carsharing can contribute to reducing vehicle-related emissions and making mobility more accessible.[78]

4.1.1 CIRCULAR CAAS MODELS CAN DECARBONIZE THE BATTERY ELECTRIC VEHICLE FOOTPRINT BY 25-45%

To measure the decarbonization effects of a circular CaaS product and operating model, the analysis takes the lifecycle emissions of a standard BEV[viii] sold to customers as the BAU reference scenario. Based on this, circularity levers are applied in clusters, quantifying the direct and indirect effects for two CaaS scenarios optimized for circularity.

Car subscription model: vehicles are provided via flexible time-based subscriptions, where access to the car can be purchased on a monthly basis, while the provider retains ownership. The service offer includes everything except fuel, i.e. servicing, maintenance, insurance. Once returned, the car is retrofitted and

viii The baseline scenario models the VW ID.3 – a standard C-segment BEV with the latest technological features (especially battery technology). Since road transport will be electric and with renewable energy shares in the electricity provision growing, the decarbonization focus will shift to build-phase emissions. Therefore, BEVs are used as the reference case.

provided to other customers. Comparable models can be observed with Riversimple, a pioneer of circular car subscription (see Case box 11), and based on a wider industry trend without specific circularity focus, e.g. Volvo CARE, VW Auto Abo, and finn.auto.

Free floating carsharing model: electric vehicles are offered in a free floating, data-driven (urban) carsharing system where access to the car can be purchased flexibly on a trip-by-trip basis. A platform – in our scenario provided by the car producer – connects customers to the available vehicle fleet. This results in more trips per car per day, at best with a higher occupancy rate (persons per vehicle). Comparable models are offered by ShareNow, ZITY, and WeShare (see Case box 12).

Exhibit 17 highlights the overall effects of shifting from a traditional sales model for BEVs to a car subscription and carsharing model designed for circularity. The inherent logic of XaaS models (i.e. producer ownership and (partial) use-phase cost internalization) enable the design of the respective CaaS product and operating model for circularity to maximize the lifecycle decarbonization in the build and use phase.[ix] Three clusters[x] and corresponding underlying levers drive the circularity of the respective CaaS scenario. A detailed analysis of both scenarios and the cumulative application of the circularity levers are presented in Appendix C.1: Deep dive Car-as-a-Service.

CASE BOX 11:
RIVERSIMPLE – PIONEERING A CIRCULAR CAAS SUBSCRIPTION MODEL

Riversimple operates hydrogen-powered fuel cell electric vehicles in a full-service subscription model. From the business model to the design of the car, circularity principles are applied. The model internalizes all use-phase costs (e.g. hydrogen for the fuel cells), which generates incentives to produce/procure for maximum efficiency. Furthermore, it optimizes the design for longevity (i.e. maximized quality), treating the vehicle and its materials as a lifetime revenue-generating asset. The company aims to implement XaaS models along the supply chain, from the materials to the fuel cell.[96]

CASE BOX 12:
WESHARE – PROMOTING FLEXIBLE E-CARSHARING SOLUTIONS

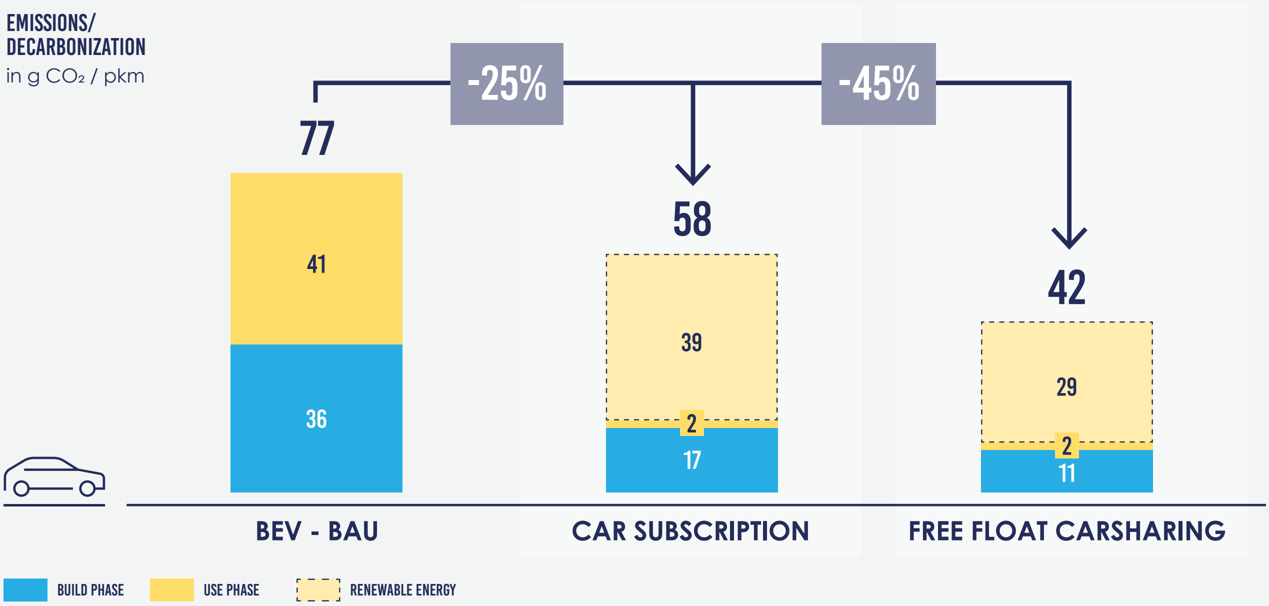
WeShare, a subsidiary of Volkswagen, is an e-carsharing provider currently operating in Berlin and Hamburg. The vehicles are charged with 100% renewable energy from the public charging network and from charging stations of cooperation partners. Customers can access the vehicles flexibly via apps and can choose between a minute model or a fixed rental period. A reduced standby price is also introduced. Frequent users can opt for an additional subscription to decrease the minute-based use rates. WeShare also provides carsharing services for businesses as a substitution option for company cars.[97]

ix The build phase encompasses all emissions embedded in the vehicle: from materials and components – esp. battery – (Scope 3 upstream) to the energy used in the respective manufacturing and assembly process (Scope 1 and 2). Use-phase emissions consist of the emissions required to run the car – electricity in the BEV case (Scope 3 downstream).

x Maximize utilization, lifetime extension, and material recovery.

EXHIBIT 17

A circular Car-as-a-Service product and operating model can decarbonize the CO_2 emissions caused by b e v by 25%-45%.



Source: SYSTEMIQ analysis based on OECD & ITF (2020), IRP (2020), Ecoinvent (2020), Volkswagen AG (2021a), Volkswagen AG (2021b) and expert interviews

A CaaS product and operating model optimized for circularity can decarbonize the CO_2 emissions caused by BEVs by 25% (car subscription) to 45% (carsharing).

The circular car subscription model can decrease CO_2 emissions embedded in the vehicle by 19 g CO_2/ pkm compared to the BAU scenario mainly through life-extending measures and material recovery strategies. Car subscriptions only slightly increase **vehicle utilization** compared to a traditional car sales scenario. The highest decarbonization potential in the car subscription scenario lies in **extending the useful life** of a vehicle: a lifetime extension by 50% leads to a decarbonization effect of 13% per passenger kilometre. Retaining ownership of the vehicle incentivizes the producer to increase lifetime per design as the vehicle generates revenue over the associated extended useful life. Vehicles that become a revenue-generating asset over a longer period can offset increased costs resulting from design for lifetime efforts. From a sustainability perspective, the design for lifetime lever is crucial: the design of the car determines its lifecycle environmental performance. With producer ownership, extended refurbishment strategies become viable: reconditioning the car throughout its lifecycle and exchanging outdated technical components can further increase the lifetime and corresponding lifecycle efficiency. **End-of-life value retention and material recovery** decrease the carbon footprint by 11%, facilitated in a circular scenario by stable reverse material flows and a closer cooperation with ecosystem partners. Moving towards closed-loop recycling and correspondingly increasing the share of secondary materials alongside remanufacturing, reuse and refurbishment of used cars reduces virgin material and energy consumption. Bundling **renewable energy** contracts and smart home charging stations in an integrated offer – as done by Octopus Electric Vehicles – can reduce use-phase emissions substantially.[84]

A free float carsharing model optimized for circularity could decrease CO_2 emissions by 35 g CO_2/pkm, which is driven by a higher overall utilization of the vehicle, coupled with lifetime extending measures. Carsharing can increase the initially low **utilization** of vehicles by a factor of 4 to 5 (in pkm provided), from 5% in the BAU scenario to 23%. Providing access for multiple customers to one car is the biggest lever to maximize utilization and reduces the vehicle's CO_2 footprint by 25%. This could lead to 54% fewer BEVs being required to meet the overall mobility demand compared to BAU.[xi] Increasing the km provision (as more persons can access the car on a daily basis) and the occupancy rate (assuming two persons per vehicle due to cost sharing) per vehicle lead to the build- and use-phase emissions of the car being distributed over more mobility (pkm) provided, thus decreasing the footprint per pkm. The effect of a higher occupancy rate through pooling and sharing rides is the main driver of the CO_2 reductions. Hence, strategies to increase the occupancy per ride should be considered. Potentially, incentivizing higher occupancy rates through discounts for ride-splitting or exploring dynamic pick-up options could lead to an increase. Coupled with a **lifetime extension** per car the overall vehicle stock in circulation can be significantly reduced and consequently decarbonized. While the higher utilization can lead to vehicles reaching their end-of-life within a shorter period,[xii] extending the lifetime mileage of the vehicle (per design, purpose-built vehicles, maintenance, reconditioning) can enable the full decarbonization benefits. A suitable example for a vehicle design to optimize lifetime productivity is the Mobilize by Renault EZ-1 prototype (see Case box 13). Optimizing the vehicle design for lifetime can lead to producers generating revenue over this increased period: retained ownership creates incentives to maximize profit over the longest product period possible. **End-of-life value retention and recovery** (loop-phase material recovery, remanufacturing, and improved production input materials) can save up to 14% of the CO_2 footprint, provided materials are kept in closed loops and secondary material is prioritized as input. If the car producer operates the sharing platform and retains ownership of the vehicles, enhanced end-of-life value retention and material recovery strategies can be applied. Full-scale refurbishment of used vehicles can lead to their lifetime extension and related material savings. Partnering with **renewable energy** charging station providers to power the shared vehicles can contribute to a decarbonization of the use phase.

xi Only accounting for maximizing the utilization would lead to a vehicle stock reduction of 31%. This is in line with the IRP Shared Socioeconomic Pathway 2 (SSP2) scenario which shows a decrease of the vehicle stock by 33%.[78]

xii Carsharing can be a viable strategy to address accelerating technological cycles (especially battery technology and digital equipment of the car) as a more intensive use reduces the lifetime in years.

CASE BOX 15:
MOBILIZE EZ-1 – A CITY VEHICLE DESIGNED FOR SHARED MOBILITY

The Mobilize EZ-1 prototype by Renault is conceptualized for urban, electric carsharing models. Digital solutions (digital key access, interaction via smartphone, payment per drive-time or kilometres), the future energy ecosystem (battery exchange system, smart charging) and resource-saving mobility provision (small vehicle size) are bundled in this concept: thereby it addresses the shift of customer needs from owning to using in an affordable and sustainable way. The EZ-1 is built according to several principles of the circular economy. For example, the vehicle is purpose-built and downsized, reducing material inputs. Service-life is extended through the battery exchange system. If the batteries of the electric vehicles are no longer suitable for use in the vehicle, they are given a second life as a stationary energy source or recycled. Beyond that, the EZ-1 consists of 50% recycled materials and is 95% recyclable. At the end-of-use, maintenance and recycling services are performed at the Renault Re-Factory.[99]

Renault Group © Greg JONGERLYNCK/DPPI

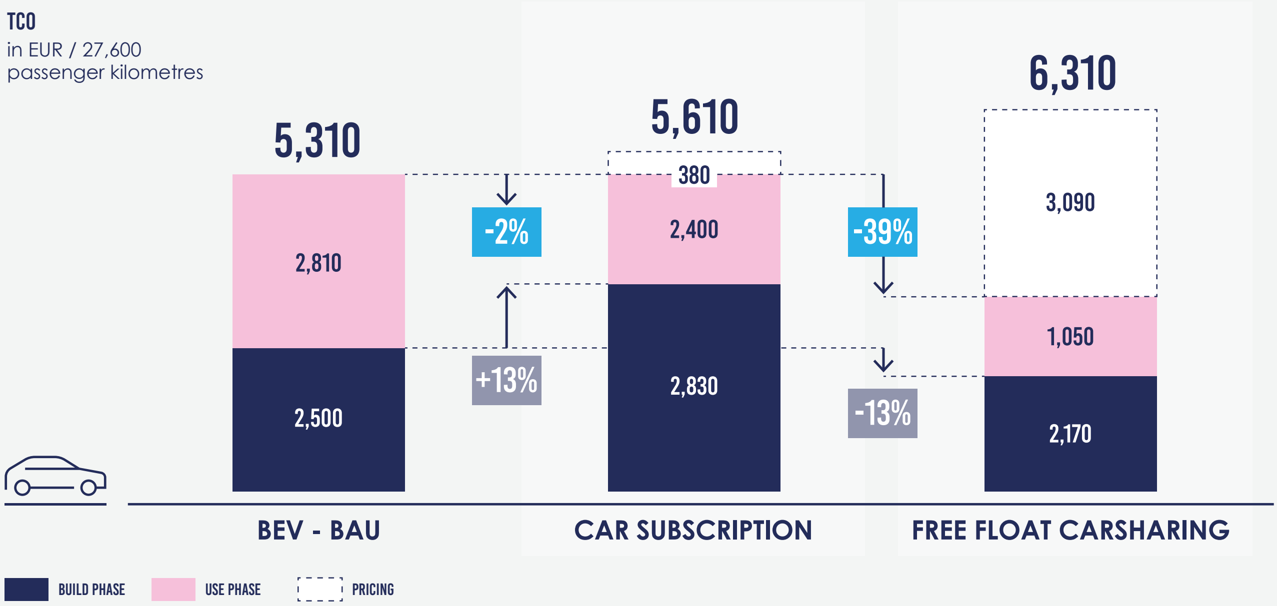
4.1.2 CIRCULAR CAAS MODELS CAN REDUCE MOBILITY COSTS BY 2-39%

CaaS can decrease TCO by 2% (car subscription) to 39% (carsharing), but the overall customer cash-out costs[Xiii] depend on the price assumptions for the respective CaaS offerings – opening possibilities for value pricing strategies for producers (Exhibit 18)[xiv].

Opting for a car subscription eliminates upfront investment costs for the customer and shifts the payments over the time of usage with a potential effect on BEV uptake. BEVs on average have higher upfront prices compared to ICEs due to associated battery costs. BEVs are projected to reach upfront price parity with ICEs by the mid-2020s.[86] Lower upfront investments can thus incentivize customers to opt for BEVs, accelerating the uptake of electrified passenger transport. Build-phase costs in the modelled scenario increase, as the lifetime extension per design is driving costs. These are partly offset by improving the use-phase cost base. In car subscription models, costs occurring in the use phase (insurance, maintenance, tyres) are all included in the subscription offer; typically electricity and parking are the only additional use-phase costs. The provision of additional services increases the share of producer costs – but in sum decreases these costs as CaaS providers should have better financing and procurement conditions than private customers. End-of-life material value

EXHIBIT 18

A circular CaaS model can decrease TCO by 2%-39%, but will depend on the pricing strategy of the provider.



Source: SYSTEMIQ analysis, Schwacke (2020), and Volkswagen (2021c).

retention and recovery (reuse, refurbish, recycle) can decrease TCO, as fewer primary resources are required as input factors. These effects can decrease TCO by 2% in the circular car subscription case, assuming that profits stay constant for the OEM. However, depending on the pricing of the provider, TCO could even increase for the consumer compared to buying a car. This indicates that the potential profit pool for the producer increases. The customer pays for the value offer that consists of higher flexibility (in terms of contract duration) and more services included. Yet, mobility pricing of alternative car ownership models continues to converge with traditional ownership models.[77]

Carsharing can reduce TCO by up to 39%, as fewer cars are required to meet mobility demand while users only pay for the usage of the car per trip, eliminating upfront and associated costs occurring in the use phase. All use-phase costs (also electricity) are bundled in carsharing offers. As a result of the higher utilization, producers would have to produce fewer cars to provide the same mobility demand, which reduces the manufacturing costs. Hence, if a customer were to travel only by carsharing, the user would only pay for the respective mobility in terms of (passenger) kilometres travelled and not for the ownership and corresponding unused capacities. End-of-life material value retention and recovery can further decrease TCO as reusing the resources employed results in cost reductions. While costs to

xiii Total customer cash-out cost is the sum of the build phase/use phase/pricing differential split. The split indicates who bears the costs initially.

xiv The build phase/use phase split indicates in which lifecycle stage the costs occur. The consumer pays the total costs (= consumer cash-out costs) as indicated for one year of mobility in terms of passenger kilometres travelled (27,600 pkm).

produce vehicles decrease, the specific pricing per drive-time or kilometre determines what the user pays. This currently entails a price differential, depending on the pricing strategy of the provider. This indicates that the profit pool increases with the customer paying for the increased value offer (e.g. higher provider risk or customer flexibility as the car can be accessed only when needed).

4.1.3 FROM CAAS TO MOBILITY-AS-A-SERVICE: A SYSTEMS PERSPECTIVE

CaaS can radically shift consumption patterns – owning is no longer required to meet the mobility demand. Sharing of unused capacities can significantly reduce the number of cars needed to meet mobility demands. Where utilization is maximized, the asset productivity in terms of utility delivery per employed resources is optimized. As a result of the free float carsharing model, ~54% fewer cars are used to provide the same utility. This has a wide range of systemic effects: less city space needed for parking (unproductive) cars (95% of parking space could be reallocated for public uses),[87] reduced externalities such as stress, congestion, noise, etc. Car manufacturers can include sharing solutions and systemic productivity levers per design. For example, Sono Motors implements digital solutions that integrate peer-to-peer carsharing, ride-pooling, and power-sharing based on solar charging. The provider's application

serves as digital key, sharing platform, and generator of real-time usage data.[88] Furthermore, company fleet management solutions could become more cost-effective and flexible through shared mobility services. For example, Greenmove provides station-based B2B e-carsharing services.[89]

From a systems perspective, a free float carsharing system must be seamlessly integrated into other even more sustainable modes of transportation (e.g. walking and bike riding for short distances; public transportation and railways) to maximize the overall environmental benefits – or else carsharing would substitute more sustainable modes of transport due to comfort instead of car ownership. Switching to an integrated, multi-modal, on-demand mobility system can reduce CO_2 emissions by 70% until 2050.[90] Public and private networks must be integrated and conveniently connected. This can be facilitated by full-scope Mobility-as-a-Service (MaaS) platform providers such as Whim (see Case box 14).

For the above advantages to materialize and to complete the sustainable transport transition, some critical conditions need to be put into place – either through design of the CaaS models or policy facilitating integrated, intermodal transportation systems. The integration of cars and MaaS services with public transit offers should not lead to an increase in total car mileage by substituting public transit. Therefore, sustainable public mobility offers need to be expanded alongside the spread of MaaS, including the development of an active urban mobility infrastructure.[90] MaaS should ideally be combined with policy tools like dynamic road pricing, preferential high occupancy vehicle lanes, or parking spaces for shared vehicles close to public transport.[93] The way city governments plan and design cities influences the way people move. Smart urban planning is critical for a sustainable mobility system.[87] Making public transport systems seamlessly connected to carsharing solutions (also in less accessible areas) can support the desired shift to fewer cars being on the road. This accessibility must be accompanied by affordability: policy changes in combination with digital innovations can facilitate this shift.[94] Furthermore, shared mobility services should also be available in low-income areas as mobility is crucial from a socioeconomic perspective (especially access to jobs).[87] Lastly, per the offer, carsharing providers could incentivize customers to drive more carefully and increase occupancy rates through ridesharing. Existing CaaS models need to be extended to cover the entire vehicle lifecycle, such that life extension measures (including the design of the vehicle) become more relevant for vehicle manufacturers. This could take place either through dedicated business model design or policy (e.g. producer ownership schemes).[95]

CASE BOX 14:
WHIM – A PLATFORM SOLUTION CONNECTING INTERMODAL TRANSPORTATION MODES

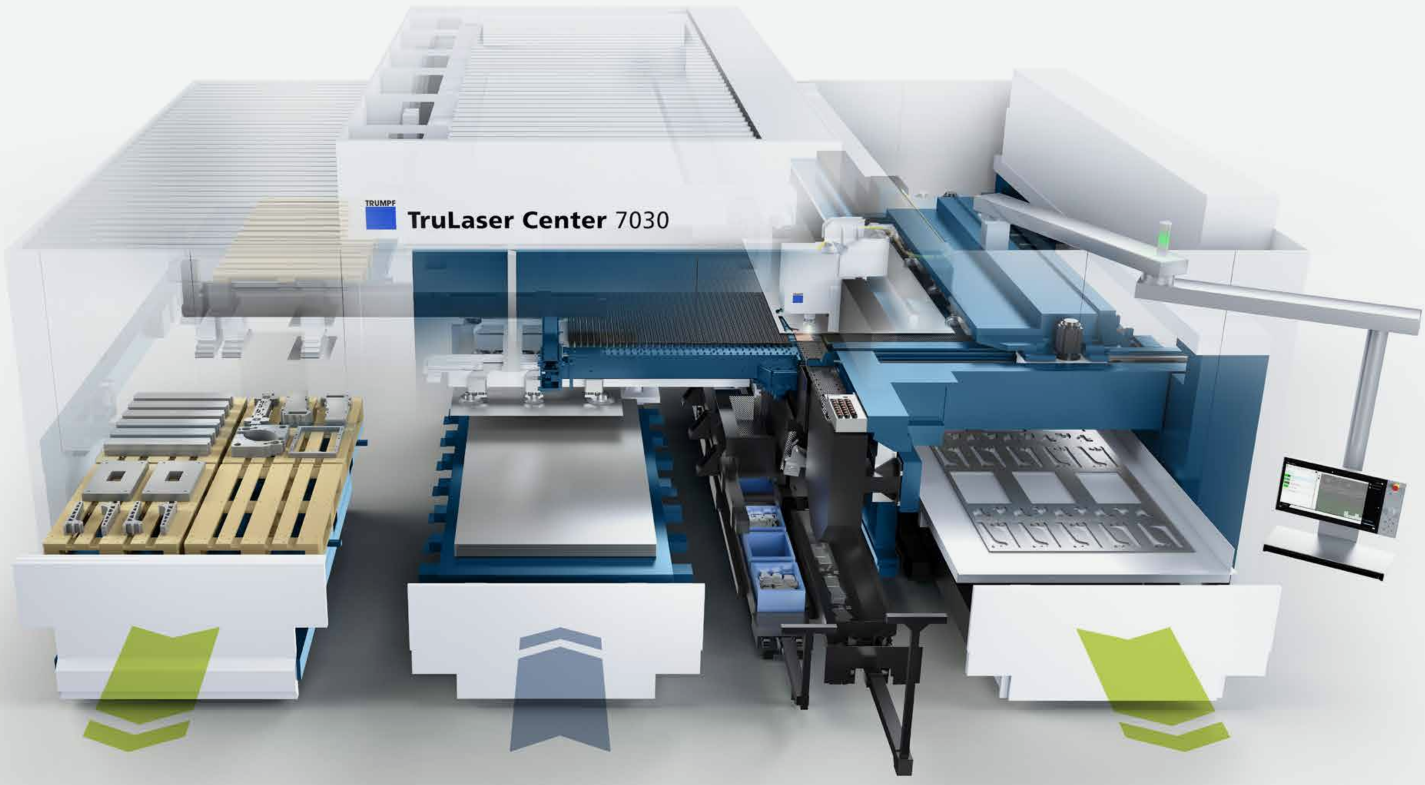
Funded by the Finnish government, Whim is a full-scope Mobility-as-a-Service platform: it connects public transport, e-scooters and city bikes, as well as rental and shared car services, in one as well as rental and shared car services in one integrated mobility app. Trips are optimized via an integrated journey planner and connected to ticketing services. Customers can pay on a pay-as-you-go or all-inclusive subscription basis to obtain seamless access to different modes of urban mobility. Thus, Whim aims to increase convenience for customers and to reduce overall demand for individual road transport with a stated goal of 1 million private cars replaced with Whim subscriptions by 2030.[91,92]

EQUIPMENT-AS-A-SERVICE

Result-oriented: Pay-per-Part

Highly automated production cell

Increased operating effectiveness



Digitalized from drawing to sorted part

All-inclusive carefree package

Financial flexibility and cost transparency

WHAT IS THE VALUE PROPOSITION AND VISION BEHIND YOUR EQUIPMENT-AS-A-SERVICE (EAAS) MODEL?

The Pay-per-Part model directly addresses customer challenges. The model allows us to unleash technology and innovation potential by focusing on the process and the efficiency in the production phase. It fully aligns incentives with customers for improving their performance, transparency and flexibility. TRUMPF and Munich Re take over operational risk and upfront investment. Customers pay only for what they need – the cut sheet metal part – and can focus more on their core business, sales and own customers. Operating effectiveness is increased and inefficiencies are resolved through learning algorithms and advanced services. EaaS can shape a new era of manufacturing, fully leveraging and advancing digital readiness and automation – eventually allowing every partner to contribute their key strengths for improving customer benefits.

HOW DID YOU EXPLORE AND DECIDE ON THE EAAS BUSINESS MODEL DESIGN?

Customer centricity is key in developing the EaaS model. We focused on understanding current inefficiencies but also future challenges, anticipating the continuous changes through digitalization and automation, and how system boundaries shift. TRUMPF's most automated full-service laser machine – the TruLaser Center 7030 – was chosen as the EaaS pilot. From the customer perspective, we developed the most ambitious performance-oriented EaaS vision as a starting point. This requires that the business model is designed for a reliable and flexible process chain – taking over operational and financial risks of the production process. With Munich Re, we set up a strong solution ecosystem that bundles these competencies in an integrated service offer. Developing a comprehensive EaaS model is complex and requires substantial efforts. Focusing on customers and collaborations with the right partners is critical to unleash the full potential of this new form of value.

HOW CAN YOUR EAAS MODEL CONTRIBUTE TO THE DECARBONIZATION OF SHEET METAL PROCESSING?

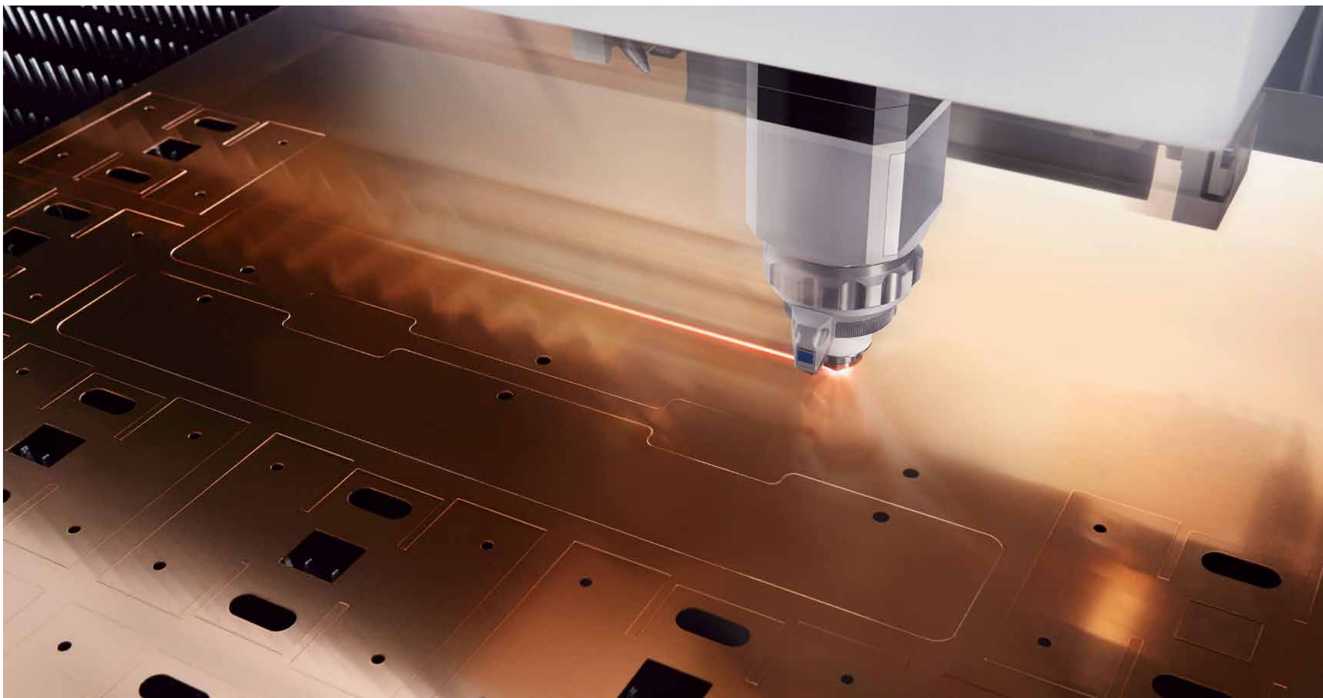
Economical and ecological considerations go hand in hand in the EaaS business model. Our model builds on several principles of the circular economy such as increasing lifetime capacity while improving resource efficiency. The Pay-per-Part model moves the productivity in the use phase of the equipment to the centre: enhancing utilization, reducing scrap, or improving material flows become relevant influencing factors to optimize. Access to the machine throughout the lifecycle combined with smart services can enable further decarbonization of operations. From an industry and value chain perspective, EaaS can be an important puzzle piece to create more sustainable material flows. Scaling EaaS models and leveraging its systemic potential may require support from regulations that reflect shifting system boundaries, consider future environmental requirements, and support creating the required data/information infrastructure.

4.2 PIONEERING EQUIPMENT-AS-A-SERVICE (EAAS)

Machinery and Equipment-as-a-Service (EaaS) models can contribute to sector-specific decarbonization as well as resource-efficient and competitive production processes in general. On the one hand, the machinery and equipment sector is a cornerstone for economic value creation in Europe contributing 17% of European value add.[96] Exploring EaaS-based value propositions can be an important driver for competitive differentiation with digitalization and service orientation moving centre stage. On the other hand, the machinery and equipment sector accounts for 18% of extracted resources, mostly CO_2 intensive metals such as steel (with a CO_2 footprint of ~2.3 kg CO_2 per kg).[97] Machines are a critical element of most industrial production processes: they produce parts, components and products across sectors. 70% of global emissions can be influenced through machinery in some way (e.g. by considering a machine's use-phase impact on manufacturing processes).[98]

Result-oriented business models, i.e. paying only for good outcomes of the machine (e.g. Pay-per-Part), mean that both manufacturer and customers benefit from any efficiency improvements occurring during the use phase of the machine. This can unleash both economic and environmental benefits for manufacturers and their customers. For example, AI-optimization of production processes yields less production waste and better outcomes. Advancing digital capabilities can improve the lifetime operating effectiveness of the equipment for both parties.

The following sections develop a quantitative perspective on one use case of EaaS, building on the reference example of a state-of-the-art sheet metal laser cutting machine. The analysis has been conducted in close cooperation with TRUMPF. Together with Munich Re, TRUMPF is pioneering a result-oriented EaaS business model for the manufacturing industry.[99] As a material-intense machine with high electricity consumption and significant material flows (including metal scrap generation), it represents a comprehensive ground for analysing environmental and economic effects across build, use and loop phase. Of course, it has to be emphasized that the results cannot be generalized for the entire machinery and equipment sector as it is marked by a diversity of types of machines and respective material flows. However, underlying optimization logics are relevant across sectors and highlight the potentials of service-oriented business models based on Industry 4.0 applications for the machinery and equipment sector.



4.2.1 EAAS CAN CONTRIBUTE TO DECARBONIZING METAL SHEET PROCESSING BY 37-65%

Alongside a BAU reference scenario[xv], two EaaS scenarios are modelled using three lever clusters[xvi].

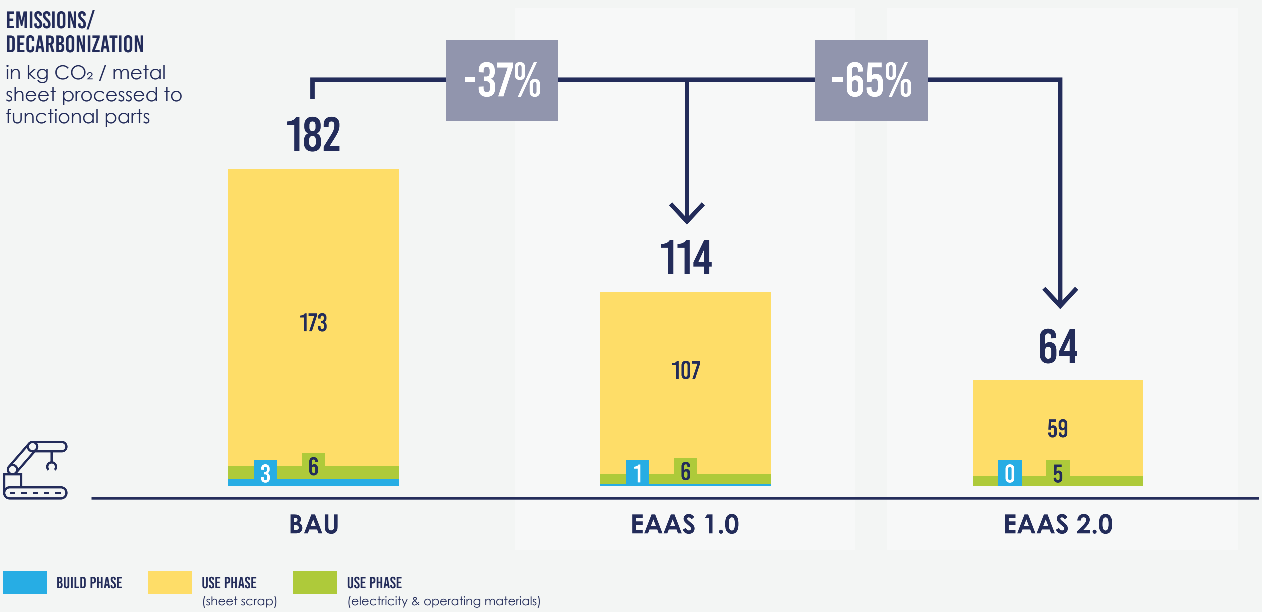
EaaS 1.0: the sheet metal laser cutting machine is offered in a Pay-per-Part business model. The EaaS provider retains lifecycle access to the machine. Performance-enhancing support services and maintenance are included in the EaaS offer. The customer only pays for the functional part produced from the cutting and sorting process.

EaaS 2.0: this scenario and the underlying levers build on more progressive assumptions compared to the EaaS 1.0 scenario – and an operating model that builds in patterns of a marketplace solution for pooling customer demand. Through demand pooling and smart nesting, the machine's capacity and material throughput can be even further optimized.

Exhibit 19 highlights the overall effects of shifting to EaaS. In both scenarios, more efficiency with respect to material use is the lever with the highest impact on lifecycle emissions (i.e. optimized material throughput plus loop-phase improvements in terms of increased secondary materials ratios). A detailed analysis of both scenarios and the cumulative application of the circularity levers are presented in Appendix C.2: Deep dive Equipment-as-a-Service.

EXHIBIT 19

Equipment-as-a-Service can help to decarbonize the sheet metal processing by 37%-65%, depending on the lever application and the respective scenario.



Source: SYSTEMIQ & TRUMPF analysis.

xv The baseline reference equipment has the same technical features but is sold in a traditional (linear) business model in the BAU scenario. Ten machines are assumed as the baseline machine stock.

xvi Maximize utilization (lifetime production capacity), optimize material throughput, and material recovery.

Baseline effects of the case analysis show that the highest lifecycle environmental impact for machinery lies in resource efficiency in the use phase – which is key for decarbonization ambitions. For metal processing equipment, build-phase emissions are mainly driven by production-related materials (especially steel) and energy. Use-phase emissions result from electricity consumption to power the equipment alongside operating materials (such as nitrogen and compressed air), material throughput and corresponding waste in production in terms of scrap from metal sheets. The latter makes up for the highest share of emissions as emissions embedded in sheet metal scrap are included for the footprint estimation. Thus, the biggest lever for decarbonization is to improve resource efficiency in the use phase.

EaaS can decarbonize the lifecycle CO_2 footprint caused by a laser cutting machine by 37% (EaaS 1.0) to 65% (EaaS 2.0).

Switching from BAU to EaaS 1.0 enables saving 37% of the machine's CO_2 footprint which corresponds to 68 kg CO_2 per metal sheet[xvii] processed to functional parts. As a result of improved equipment design, smart use services and maintenance, and reconditioning, EaaS can **maximize the utilization** and its corresponding lifetime capacity by a factor of two. Hence, twice as many metal sheets can be processed in the digitally supported EaaS production. Through this, fewer machines are required to meet the same demand as in the BAU scenario. Combining the higher utilization with an improved cutting and nesting process can lead to an **optimized material throughput** and a 20% decrease in CO_2 emissions per metal sheet. Technical features implemented in the design phase (e.g. AI optimization, over-the-air updates) lead to this optimization: digitally enabled cutting and nesting process optimization reduces the amount of scrap being produced per sheet by 5%, i.e. more functional parts are produced from one input metal sheet. Continuous access to the machine enables enables core technology to be replaced replaced once more efficient technology is available. This means that over the lifetime, the capacity and energy efficiency of the machine improves compared to the BAU scenario where the machine's capacity and energy consumption remains constant. Replacing primary metal materials by secondary materials in the build phase and in the metal sheets processed in the use phase (i.e. **increasing the share of secondary materials**) can reduce the overall footprint by an additional 22%. EaaS facilitates the control of material flows, not only in the use but also in the loop phase (e.g. end-of-life recovery, scrap recycling). Metals are particularly suited: e.g. the CO_2 intensity of secondary steel is ~1/6 compared to primary steel.[100,101]

The EaaS 2.0 scenario assumes an effective link to a marketplace production platform to achieve an even higher utilization, optimization of material throughput and improved material efficiency. In total, this scenario avoids 65% of CO_2 emissions, which corresponds to 118 kg CO_2 per metal sheet processed to functional parts. Offering EaaS models linked to a marketplace can **maximize the utilization** by a factor of three compared to the BAU scenario. Bundling EaaS models with demand from a marketplace platform can further improve the cutting process, thus **optimizing the material throughput** and decreasing the CO_2 footprint by 37%. Using smart applications to increase nesting efficiency can reduce scrap by an additional 5%, optimally using the metal sheet without tilting. Improving the (primary) material footprint by **increasing the secondary materials ratio** decreases the CO_2 footprint by an additional 45% per metal sheet processed to parts.

xvii A sample metal sheet equals ~100 kg and is mainly composed of steel in two different grades and alloys.

4.2.2 EAAS CAN REDUCE TOTAL COST OF OWNERSHIP BY BETWEEN 16-24%

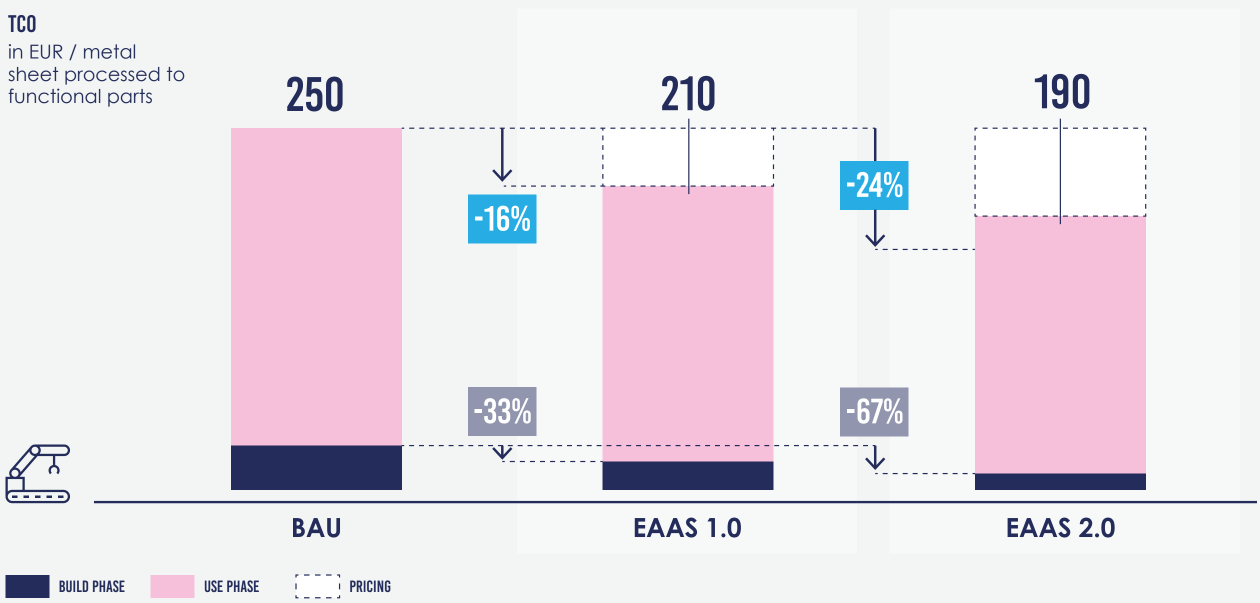
EaaS can decrease TCO by 16% (EaaS 1.0) to 24% (EaaS 2.0) through more efficient and productive metal sheet processing (Exhibit 20).

In EaaS, capital-intensive upfront investments can be shifted to operational expenses over the use phase of the equipment: the CapEx to OpEx shift can improve cost of capital and makes the equipment affordable to more customers without high upfront investments. This also means that advanced technology features can be built in. The parallel economic use of the outcome of the process and payment of the costs enable the customer to generate revenue at the same time as expenses are incurred. This advantage is often referred to as the pay-as-you-earn effect.

Besides eliminating high upfront investments, opting for an EaaS offer can yield cost reductions through the more efficient cutting and sorting process. Production process improvements result in less scrap and increased overall capacity due to increased process security, servicing, and overall effectiveness of the equipment. As the manufacturer participates in the use phase, both customer and manufacturer benefit from the efficiency gains. The EaaS performance commitment to only charge for "good", functional parts without the scrap produced affects the cost base for customers. Improving the overall effectiveness of the equipment thus yields positive TCO impacts.

EXHIBIT 20

Offering the laser cutting machine in EaaS models can reduce the TCO by 16%-24%.



Source: SYSTEMIQ & TRUMPF analysis.

The main TCO effects result from the improved cutting processes and higher lifetime capacity. The costs of the machine are distributed over more functional parts produced. This can decrease the build-phase phase share in TCO by 33% in the EaaS 1.0 scenario and 67% in the EaaS 2.0 scenario (as capacity and operating effectiveness is further increased through bundling demand). Furthermore, material costs in the use phase are reduced as more parts are processed from the same input of metal sheets. The closer connection between the EaaS solution ecosystem (equipment provider and partners) and the customer can also potentially open the possibility to further improve use-phase costs: bundling purchase power capacities can save material costs as 80% of these are due to use-phase materials. Optimizing material purchasing and flow is a major lever for TCO reduction. Furthermore, sorting and shredding the rest grid/ scrap on the customer premises by means of additional machine functionalities can yield higher returns as high-quality scrap is more valuable. Servicing, maintenance, and over-the-air updates ensure that the latest technology is available. Improving energy efficiency over lifetime by employing up-to-date soft- and hardware, reducing downtime through predictive maintenance diagnostics and bundling of maintenance interventions can decrease machine operating costs.

4.2.3 SYSTEMS PERSPECTIVE: STRENGTHENING VALUECHAIN PARTNERSHIPS AND SHIFTING SYSTEM BOUNDARIES

EaaS models can be the starting point for further systemic optimization pathways. First, new system boundaries can be leveraged to optimize resource flows. Second, new ecosystem cooperation can foster a deeper value chain integration for systemic change. Third, EaaS along the value chain can bring collaborative value creation to the next level.

With EaaS, system boundaries shift. The producer has access to the equipment throughout its lifetime, bringing use-phase optimization to the centre of attention. If system boundaries are aligned correctly, resource flows can be optimized. This decreases environmental pressure points while creating value, both for the manufacturer and the partner ecosystem as well as the customer.

EaaS can be the starting point of deeper value chain integration requiring new forms of cooperation. Traditional transactional mindsets reach limits when it comes to decarbonizing and sustainably reconfiguring current systems. For example, resolving the way data is shared along the value chain is important to make optimization potentials transparent (see the EU's digital product passport or the Gaia-X initiative). EaaS can form new value creation networks. In partnering with financial services providers, risk managers, material providers, the customer, logistics providers, and end-of-life organizations, the respective business competencies are bundled in one integrated service offer. Thus, closer forms of cooperation while focusing on an optimization of the equipment's use phase (i.e. customer success) within the EaaS ecosystem can have systemic effects such that efficiency is maximized and value creation is shared.

The consequential next step could be to establish (and link) XaaS systems along a value chain – the bundling of competencies in integrated value propositions maximizes the utility provision of each step in the value chain. A metal material provider offers Metals-as-a-Service and will be remunerated for optimal material efficiency and durability while high-quality scrap is returned to produce scrap-based secondary materials. Operating materials and relevant supporting equipment are offered as-a-service, for example Compressed air-as-a-Service. Key components of the laser cutting machine are returned and reconditioned through take-back schemes. All players along the value chain provide services instead of products, focusing on an optimal use phase and value recovery.

4.3 LEVERAGING WHITE GOODS-AS-A-SERVICE (WGAAS)

White goods/household appliances are an important component of the residential footprint, with washing machines, dryers, fridges, ovens, and dishwashers being the critical drivers in terms of domestic resource and electricity use as well as resulting carbon footprint and cost.

Washing machines (WMs) are the most resource-intensive domestic appliance: WMs make up 22% (1.4 Mt) of the materials (by weight) from new domestic appliances sold in the EU. An overall WM stock of 191.9 million is estimated.[102] The resource intensity embedded in the build phase is accompanied by a high resource consumption in the use phase: energy consumption is estimated at 24.2 TWh per year (3.8% of household electricity consumption) in Western Europe and water consumption at 1.5 billion litres per year (7.8% of household water consumption).[103]

The example of WMs shows how XaaS models can contribute to decrease housing footprint (e.g. laundry washing emissions) by enabling resource efficiency in the build and use phase of the respective household appliance. WGaaS can be strategy to mitigate environmental impact through resource efficiency, optimized customer usage patterns and smart appliances (e.g. temperature and programmes, weight load, volume of detergents used). WGaaS models can increase utilization from an initial low ~2.5% of theoretical laundry output and shift the focus on high-quality WMs being more affordable and resource-efficient throughout their lifetime.[104] At the same time, life-extending measures such as repair, reuse and refurbishment with corresponding upgrades of washing programmes and core components can impact the lifecycle environmental performance.

4.3.1 WGAAS CAN ENABLE A REDUCTION OF THE RESIDENTIAL LAUNDRY FOOTPRINT BY 24-35%

The BAU scenario describes an average WM sold in a traditional business model and reflects the current market situation in terms of resource efficiency and lifetime. Based on this, the decarbonization effects (measured in g CO_2 per washing cycle) of two scenarios are modelled applying circularity levers.

Washing machine subscription (WM subscription) – a high-quality WM is provided on a subscription-basis. The customer pays a monthly fee in exchange for the unrestricted right of use. Generally, in such business models, more efficient and long-lasting WMs are provided with integrated technological features (such as auto-dosing systems). Furthermore, WMs are subject to life-extending measures such as reconditioning and refurbishment. Services bundled in the WM subscription scenario include transport (including moving service), instalment, repair and maintenance. Comparable offers in operation are BlueMovement by Bosch (see Case box 15) and Bundles.

Pooled Pay-per-Wash (Pooled PPW) – a high-quality WM is provided to several households of a residential unit in a shared common washing area. The users are charged for each wash thus them to improve the capacity load of each cycle, and in sum wash less.[106] WMs in this model are resource-efficient. The WM is connected to a measuring/smart meter device at the outlet and to a smart application. Sensors can detect the content of the washing machine and set the washing programme accordingly. Based on this, washing cycles, energy and water consumption can be tracked and, through analytics and feedback mechanisms to consumers, provide advice on optimal behaviour via real-time insights into usage patterns. Pay-per-Wash models are offered by providers such as Homie (see Case box 16).

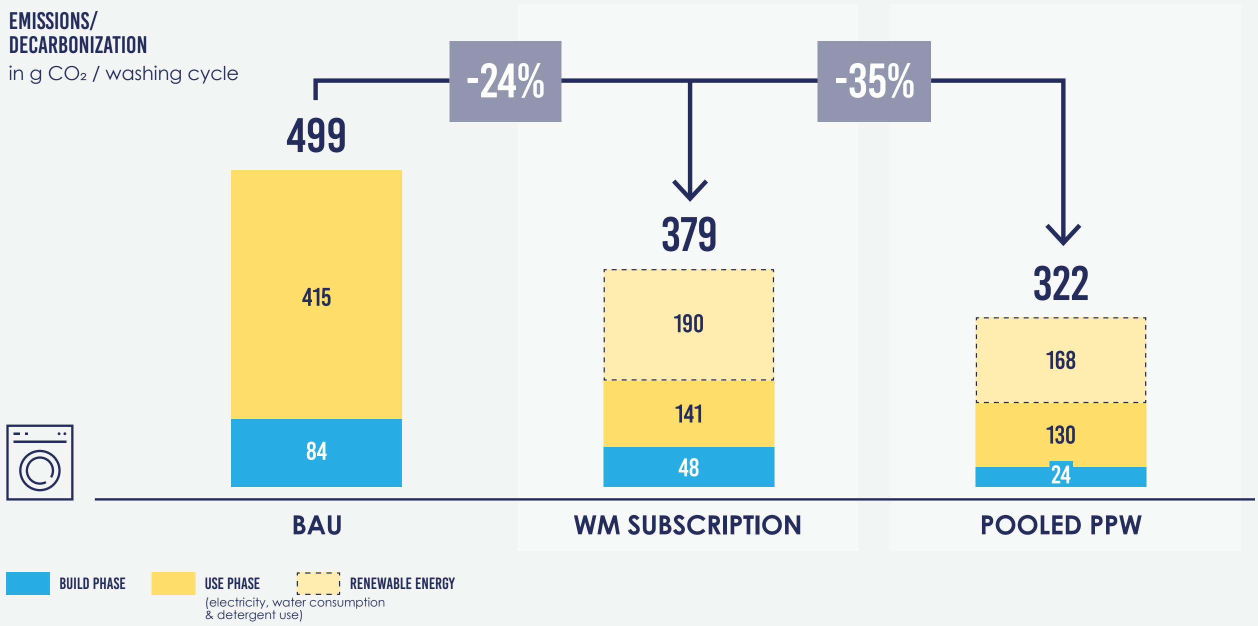
Exhibit 21 highlights the potential effects of shifting to WGaaS in the two scenarios. Resource efficiency is crucial to decarbonize the residential laundry footprint. A detailed analysis of both scenarios and the cumulative application of the circularity levers are presented in Appendix C.3: Deep dive White Goods-as-a-Service.

CASE BOX 15:
BLUEMOVEMENT POWERED BY BOSCH – THE INTEGRATED WHITE GOODS SUBSCRIPTION TO A SUSTAINABLE HOUSEHOLD

BlueMovement, a subsidiary of BSH Hausgeräte, offers high-quality and energy-efficient Bosch household appliances, such as washing machines, dryers, refrigerators and dishwashers, in flexible subscription offers. Customers can choose between different contract periods and between new versus refurbished appliances. Additional services include professional installation repair or replacement services. Upon contract termination, the appliances are collected and refurbished/reconditioned. BlueMovement has been introduced in the Netherlands and is scaling in other European countries.[105]

EXHIBIT 21

Washing Machine-as-a-Service can help to decarbonize the washing process by 24%-35%, depending on the business model.



Source: SYSTEMIQ analysis based on Sigüenza et al. (2021), Bocken et al. (2018), Homie (2021), BlueMovement (2021).

CASE BOX 16:

HOMIE – PAY-PER-WASH SOLUTION FOR STIMULATING ENERGY-EFFICIENT LAUNDRY

Homie is a Dutch start-up offering washing machines and dryers on a Pay-per-Use basis. The service includes delivery, installation with connection to the WiFi network, repair and replacement, as well as an account to monitor usage history in real time. Apart from a monthly minimum usage fee, the customer pays per washing cycle. Sustainable washing modes are provided at a discount, thus incentivizing resource-efficient washing in the eco-function.[107,108]

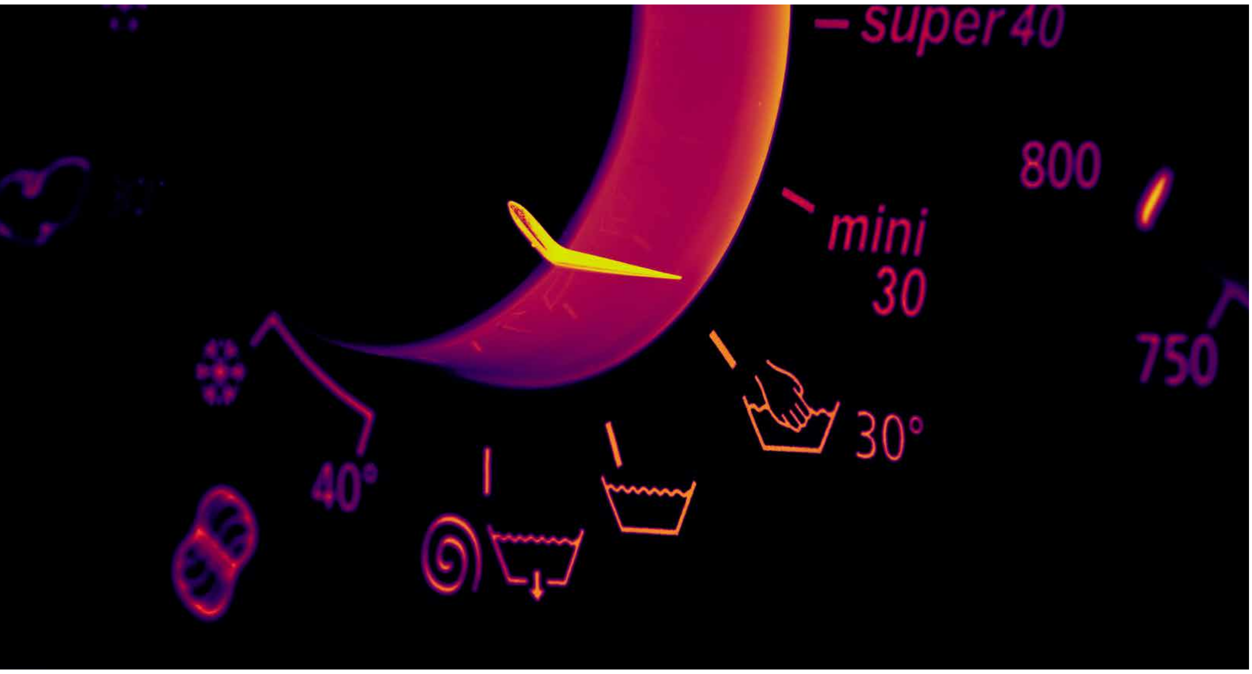
A circular WGaaS product and operating model can decarbonize the CO_2 footprint of WMs by 24% (WM subscription) to 35% (pooled Pay-per-Wash). Three clusters[xviii] and associated levers increase the circularity of the respective scenario.

Switching from BAU to a circular subscription model saves 24% of the average WM's CO_2 footprint which corresponds to 120 g CO_2 per washing cycle. Firstly, **maximizing the utilization** in terms of lifetime capacity results from higher quality WMs being offered compared to market average, improved repair-maintenance systems, and value retention strategies (refurbishment). This can reduce the lifecycle CO_2 footprint by 5%. Secondly, **optimizing the material throughput** in terms of resource efficiency is the most impactful lever. The effect – additional 18% use-phase CO_2 improvements – stems from resource-efficient, high-quality quality WMs made affordable per XaaS and further use-phase optimization through smart appliances (e.g. connectivity for optimal usage, detergent auto-dosing). Thirdly, due to stable reverse material and product flows, **material recovery** can be enhanced. Prioritizing secondary

xviii Maximize utilization (in terms of lifetime functionality), optimize material throughput, and material recovery.

materials as inputs from closed loop recycling (metals by 30%, plastics by 10%) reduces the build-phase emissions by 13%. Together with increasing the secondary materials ratio, remanufacturing strategies (20% of components) lead to CO_2 savings of 9 g per washing cycle embedded in materials (2% of total footprint). Lastly, **bundling renewable energy** in the service offer through cooperation with a green electricity provider could further reduce use-phase emissions (additional 51% of overall CO_2 emissions). This integration could contribute to a widespread adoption of renewable energy in households and an associated decrease in residential footprints.

A circular pooled PPW scenario can decrease emissions per washing cycle by 177 g CO_2 (35%). Firstly, providing access to high-quality WMs in a common washing area of a residential unit while customers are incentivized by the pricing per cycle to wash more efficiently **maximizes the utilization.** Together with lifetime extension strategies (refurbishment, lifecycle repair-servicing systems) the lifetime functionality is enhanced, which reduces the laundry footprint by 11%. Maximizing the utilization in terms of lifetime washing cycles per WM decreases the amount of WMs used to provide the same washing demand as in the BAU scenario by 66%. Combining PPW schemes with shared laundromats to leverage unused capacities can be facilitated by applications that connect WMs with users – as offered by WeWash, a spin-off by BSH Hausgeräte.[109] Secondly, **optimizing material throughput** is achieved through use-phase resource-efficiency driven by high-quality WMs connected to smart appliances that support consumers towards a more efficient usage. This optimizes the customer's resource consumption and can provide insights on the functionality of the WM. It is estimated that PPW models can nudge customers with pricing incentives to wash more efficiently and decrease washing cycles by up to 20%[ixx].[106] In sum, optimizing material throughput reduces CO_2 emissions per cycle by an additional 26%. Increasing the **material recovery** and value retention in the loop phase through remanufacturing and closed loop recycling decreases the CO_2 footprint in the build phase by 17% (1% of overall footprint). Again, offering **renewable energy** as part of the service offer could further reduce use-phase emissions by 56% (and the overall footprint by 52%).



ixx In this modelling scenario, the lower bound of the reduction (10%) is assumed.

4.3.2 WGAAS CAN DECREASE HOUSEHOLD EXPENDITURES FOR LAUNDRY BY 18-24% PER WASHING CYCLE

Offering Washing Machines-as-a-Service eliminates upfront investments for customers, shifting the cost over the lifetime of the machine. As described above, this can facilitate making energy-efficient, top-of-the-line WMs accessible to a wide customer base.

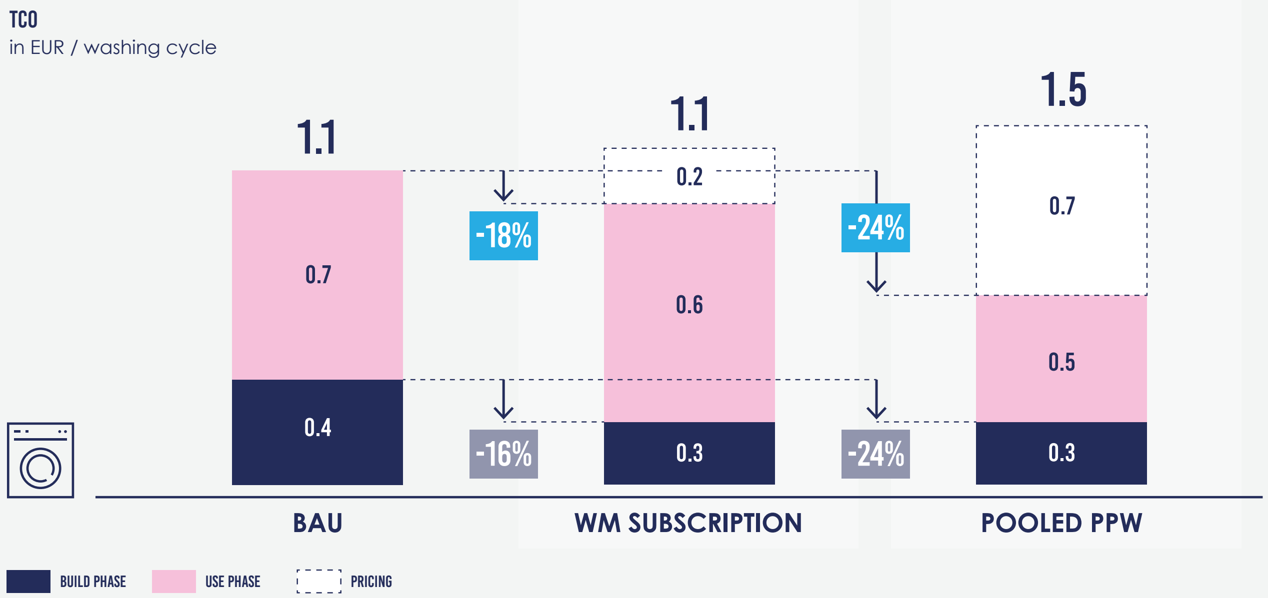
At the same time, the total consumer cash-out depends on the pricing strategy of the provider. Including observable prices for a standard offer in the modelling yields that the providers price in the value added through such offers: increased servicing (instalment, moving services) and more flexibility (e.g. with contract periods of up to three months the subscription model, and reduced overall washing in the PPW).

The extended lifetime decreases build-phase (producer) TCO per washing cycle by 18% in the WM subscription scenario, and by 24% in the PPW scenario; more washing cycles can be performed per invested EUR while lifecycle maintenance is covered by the producer (Exhibit 22).

Higher energy and resource efficiency in the use phase can decrease TCO by 0.13 EUR per washing cycle in the WM subscription scenario and by 0.17 EUR in the PPW scenario. This effect results from the resource efficiency of high-quality WMs reducing energy, water and detergent costs. In the PPW scenario, the reduced amount of washing cycles further decreases the use phase TCO. PPW providers can effectively nudge customer behaviour through offering reduced prices for more sustainable eco washing modes. For example, Homie offer a 20% pricing discount, if customers choose eco modes.[108]

EXHIBIT 22

Offering Washing Machine-as-a-Service can decrease TCO by 18%-24%, but will depend on the pricing strategy.



Source: SYSTEMIQ analysis, EcoTopTen (2021), BlueMovement (2021), Homie (2021), JRC (2017).

Combining a subscription model with an extended refurbishment strategy can be rewarding from a TCO perspective: compared to producing a new WM, refurbishment can save up to 60% of material and other input costs.[110] BlueMovement and Bundles already offer refurbished WMs in subscription models at a discount ranging between 5-20%.[105,111] This can decrease TCO in the WM subscription scenario under observable price assumptions and is included in Exhibit 22.

4.3.3 SYSTEMS OUTLOOK: SERVICE OPTIMIZATION TOWARDS FULL-SCOPE UTILITY PROVISION

The washing machine White Goods-as-a-Service case example indicates that significant benefits for environmental performance can be achieved by a variety of levers, such as higher-quality WMs employed, or customers being incentivized to wash more efficiently. There are several avenues that illustrate how such XaaS models can be the starting point to unleash larger systemic impact.

First, this logic can be extended to any home appliance. Offering WGaaS can help to accelerate the use of high-quality, more resource-efficient appliances in general. Domestic appliances account for a large share of household resource use. Thus, WGaaS offers with high-quality domestic appliances can contribute to sustainable households.

Second, integrating several appliances in a bundled service offer could further contribute to reducing resource consumption and associated emissions. Connecting home appliances via smart applications can help customers to improve usage behaviour. Local service networks, refurbishment and repair centres can contribute to retain the embedded value of appliances and extend the useful life. Prospectively, including additional complementary services such as smart metering and renewable energy supplies through partnerships can significantly reduce residential CO_2 and resource footprints.

Third, a full-service solution could be the next step to leverage systemic impacts. For example, this could consist of providing the utility of clean clothes through a full service, carbon-positive laundry scheme: laundry pick-up service, transport to bundled, high-quality, industrial WMs and professional service. Such a centralized laundry service could wash clothes more efficiently than the average household. It builds on commercial WMs and other professional laundry equipment based on automation and integration of other services (e.g. automated ironing). At-scale logistics would have to be optimized to reduce transport emissions (e.g. integrating last mile logistics of different service types). Furthermore, the full-service laundry could be adapted to existing B2B laundry services, using the available infrastructure.

5

ROADMAP TO INDUSTRY TRANSFORMATION: CATALYSE XAAS ECOSYSTEMS THROUGH DIGITAL TECHNOLOGIES, POLICY SUPPORT AND COLLECTIVE INDUSTRY ACTION

5.1 TECHNOLOGY BACKBONE: ENABLE CRITICAL DATA FLOWS FOR XAAS MODELS AND CIRCULAR VALUE CHAINS

5.1.1 ADVANCING IT/DIGITAL AS ENABLER TO SATISFY FUTURE DATA NEEDS

Digitalization and Industry 4.0 continue to transform manufacturing operations substantially and are the foundations on which XaaS models grow. Investments in digital capabilities such as data analytics and intelligence, connectivity, and computational power, as well as robotics and human machine interaction, are critical strategic decisions for many companies.[11] Key areas of digital transformation include production efficiency, service effectiveness and reinventing business models. Both the competitiveness of the industry sector and the implementation of the circular economy will heavily rely on IT/digital capabilities.

At the same time, XaaS models will drive and accelerate the overall digital transformation of companies and the wider industry. More specifically, a circular XaaS model with IT/digital capabilities at its core can respond to increasing data requirements driven by competitiveness on the one hand (e.g. customer data insights to advance an offering) and regulation on the other hand (e.g. data transparency on product, supply chain and lifecycle for regulatory compliance). During recent years manufacturers have invested significantly in digitalization capabilities: for SMEs alone, European annual investments in digitalization are projected to be 65 bn EUR in 2022.[65] These capabilities will come in handy for XaaS as they provide improved opportunities to better fulfil certain economic and ecological requirements. At the same time, XaaS models allow companies to capitalize on digital investments and capabilities by leveraging use-phase and end-of-life access to generate and monetize data and associated smart services.

- **Data requirements driven by competitiveness:** value creation increasingly arises through intangible rather than physical goods. Use-phase data can increase competitive advantages when used to optimize products/services and the associated value proposition.[112] This has reached established industries: automotive manufacturers are evolving into mobility solution providers, medical technology manufacturers into smart health service providers, and companies in the mechanical engineering industry into platform and advanced service providers. Business models will have to adapt and integrate data and analytic capabilities to be able to compete.[113] From connectivity to artificial intelligence to big data analytics, product lifecycle data collected based on XaaS models become valuable intangible assets.[114]

- **Data requirements driven by regulation:** to achieve net-zero in 2050, massive reductions are needed by 2030 and have now been politically endorsed. Reductions targets will translate into increasingly stringent climate-related regulations and associated requirements (e.g. Germany's Climate Action Law).[115] More detailed ecological reporting (e.g. carbon accounting standards) and decarbonization demands can be expected which will result in additional data requirements to be fulfilled by manufacturers. One regulatory example is digital product passports, planned to be implemented under the EU Sustainable Products Initiative.[116] These will require product-related information on, for example, environmental and material footprint. While the final product categories and technical implementation (information, data spaces, data-sharing mechanisms) are still to be defined, already existing material passports can improve the reporting on origin, composition, repair and disassembly instructions, or end-of-life handling guidelines. This is done by tracking and tracing materials, components or products using unique identifiers or tracking codes like barcodes, radio-frequency identification tags, or molecular markers.[32]

5.1.2 INFORMATION FLOWS AND OPEN ARCHITECTURES FACILITATE CIRCULAR PRODUCTION SYSTEMS

For XaaS models to unfold their full systemic power as a circular business model, the entire XaaS ecosystem needs to benefit from IT/digital readiness. XaaS fosters cooperation of partners that integrate complementary capabilities into a joint service offer. Bundling these competencies in ecosystems of suppliers, strategic partners, and customers requires connected data and information flows along the (circular) value chain.

For this to happen, the solution (micro) ecosystem and enabling (macro) ecosystem require available digital capabilities and ecosystem initiatives to be harmonized and scaled. Lifecycle data availability and connectivity lies at the core of a circular economy – and XaaS can be the business model to get there, by expanding the analytic focus from production optimization to the entire product lifecycle. Building the technological backbone for XaaS models on an ecosystem level will benefit from open architectures that enable circular production systems through several elements:

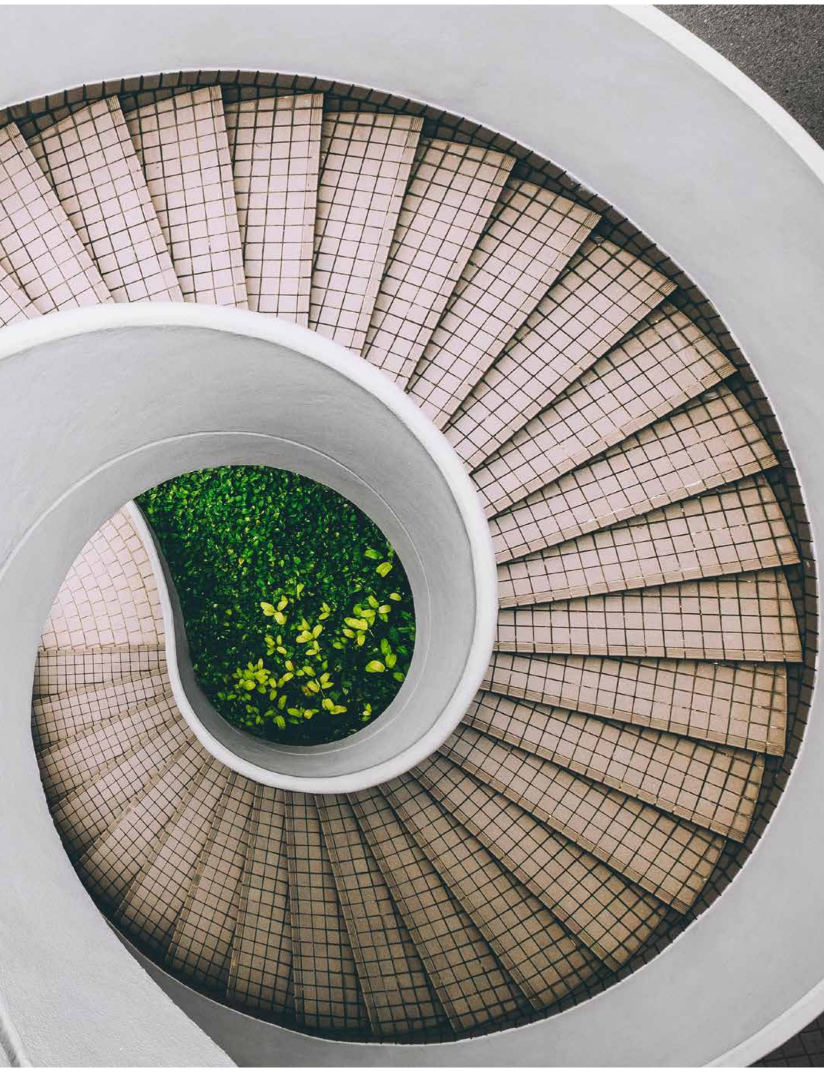
- **Support of agreed common standards and protocols (syntax and semantics)**: such standards and protocols enable a standardized and stable data exchange between operators. This requires an alignment on data syntax (data formats) as well as data semantics (e.g. the usage of carbon accounting standards)

- **Application programming interface (API) optimization and enterprise resource planning (ERP) connectivity**: common interfaces enable data flows to be shared be shared and accessed appropriately (e.g. supply chain management). The way such interfaces are implemented in products and connected to existing IT systems ensures advanced XaaS functionality.

- **Data and intellectual property (IP) protection from unauthorized access**: to secure IP and sensitive data points, access rights must be defined such that they are protected against unauthorized access beyond the respective ecosystems.

- **Digital infrastructure readiness along the value chain**: IT/digital solutions for the entire enabling ecosystem must be available such that information can be shared across the value chain. Industry initiatives can contribute to value chain participants being connected to a common digital infrastructure.

Orchestrating these elements through industry initiatives and regulatory support can facilitate solutions and enabling ecosystem integration and the uptake of XaaS models. In the machine tools sector for example, a common standard for facilitating data exchange between machines has been created (universal machine technology interface (umati)).[117] Use-phase information is thus made available via standardized interfaces for a secure and easy integration into user-specific IT ecosystems. Such initiatives provide the basis for scaling XaaS models within and across specific sectors: the availability of use-phase data and its transferability within solution ecosystems (between XaaS provider and customers, and potentially suppliers) and beyond. Another example for a cross-industry data initiative is Gaia-X, aiming at creating a common cloud-based European data infrastructure that preserves "data sovereignty" through a common digital framework ensuring interoperability, open technologies, transparency, and data security.[118] A Gaia-X-based use case is Catena-X, which is a cross-company alliance in the German automotive industry, creating uniform standards for information and data sharing throughout the entire automotive value chain. Intended goals are for example to increase transparency to leverage decarbonization potentials, and to create innovative business processes and service offerings based on the data chains.[119,120] Such an initiative could help make products, machines, software or companies connectable to cloud-enabled solutions, which will be key for integrated XaaS operating systems.



While the stakes of an ecosystem cooperation and open architectures are high, so is complexity. Besides technological and implementation questions, complexity is driven by strategic and regulatory requirements to achieve a broad and convincing agreement on data-sharing mechanisms and processes in a secure and compliant way. Ecosystem participants must find approaches and frameworks based on non-transactional mindsets to collaboratively shape the implementation. XaaS business models might help to increase the motivation to invest in ecosystem cooperation, because the upside of resource-efficient and increasingly dematerialized economic value creation advances while the downside potentially decreases as fewer participants need to align on joint standards (e.g. ownership and operations lies with the producers, not all the "actual users" anymore).

5.2 POLICY SUPPORT: BALANCE DEMAND- AND SUPPLY-SIDE INNOVATION TO ACCELERATE THE TRANSFORMATION

5.2.1 POLICY SUPPORT SHOULD STIMULATE DEMAND-SIDE INNOVATION AND CONSIDER SYSTEMIC EFFECTS

The focus on supply-side innovation (e.g. uptake of zero-carbon technologies) leads to an incomplete transition – policymakers need to further stimulate the demand side (e.g. business model innovation and sustainable consumption).[121] XaaS models are a key enabler of demand-side innovations and are critical to accelerate the circular economy transition. Bold and transformative policy support could help to:

- make producer ownership models more attractive than linear models for both companies and customers;[122]
- create conditions so that all producers design and manage their products as circular rather than disposable products;[95] and
- mitigate rebounds and negative side effects.[123]

Policy should essentially incentivize producers to retain value of products by taking responsibility over product lifetime and by keeping ownership. Producer ownership is key to achieving sustainable XaaS models with closed-loop supply chains. If not retaining ownership throughout the lifecycle, producers should at least be obliged to take ownership of their materials at the end-of-life.[124] To do so, national authorities could respond with a framework of different actions, including both encouraging measures on the one hand (e.g. lower VAT requirements for reused products and repair services) and restricting interventions on the other hand (e.g. prohibiting the destruction of returned unused products from online and offline shopping). Such a policy mix should aim to improve the business case of XaaS models for producers.[125] It is worth emphasizing that incentivizing XaaS models would not displace incumbent actors with disruptors, but would encourage existing businesses to innovate their business models.

Policy can strengthen the enabling conditions for the circular economy by supporting producers to develop and manage products in line with circularity principles. Policymakers have an important role to remove non-financial barriers for the uptake of circular XaaS models. This includes the promotion of circular strategies such as reuse, repair, refurbishment and remanufacturing across regulatory frameworks. The technical innovations needed to design and manage circular products already exist (e.g. tracking and tracing technologies) but their widespread adoption must be guided by targeted policies. These are needed throughout the entire product lifecycle starting with criteria on sustainable material sourcing and requirements on reparability and upgradability, as well as open data standards to share product information.

Policymakers should explore new measures to mitigate rebounds and other unwanted side effects with incentives and restrictive strategies. To overcome rebound effects (e.g. savings from not owning a car being used to finance short-haul jet trips), policymakers should not only think about restrictive strategies (e.g. prohibition of shared e-scooter services in some cities), but also create incentives that avoid rebounds, such as substitution effects (e.g. by reducing prices on public transport and by ensuring better connection of public and shared transport options). In addition, new policies such as regulations and standards can help to mitigate unwanted side effects of XaaS models. For example, some sharing platform operators have massively restricted the rights of employees (e.g. erosion of full-time employment, lack of healthcare and insurance benefits), which calls for legal frameworks that strengthen the employee side and improve working conditions.[123]

5.2.2 ACTIONS ALONG THREE POLICY INSTRUMENTS CAN ENCOURAGE THE UPTAKE OF XAAS MODELS AND CIRCULARITY

Overall, policymakers can address three key policy instruments to foster the shift towards sustainable XaaS models that fulfil circular economy principles and reward access over ownership (see Table 1 in Appendix D). The three policy instruments include (1) economic and market instruments, (2) regulatory instruments and standards, as well as (3) informational instruments and awareness raising (see Exhibit 23). Several policy actions could be implemented at relatively short notice. It is necessary to further evaluate which policy measures could be anchored at European, national and regional policy levels. Some of these instruments could be horizontal (e.g. fiscal incentives such as resource taxes), others could be tailored to sectors or products (e.g. EPR systems).

There are a multitude of possible policy actions that can facilitate the transition to producer ownership – a key aspect of circular XaaS models.[126] The following subchapter summarizes key actions which equally refer to the XaaS model itself (e.g. provide fiscal incentives for Pay-per-Use models) and the key value levers behind a circular XaaS model such as recycled content quotas (see Table 1 in Appendix D for further details).

EXHIBIT 23

Three main policy instruments can stimulate XaaS models until 2030.

POLICY INSTRUMENTS	SELECTED POLICY ACTIONS WITH HIGH POTENTIAL	# OF ACTIONS IDENTIFIED: SHORT TERM	MEDIUM TERM	LONG TERM
Economic and market instruments	Adapt taxation to reflect costs associated with negative externalities and review value added tax regime to increase incentives for XaaS models	15	6	1
Regulatory instruments and standards	Consider how to promote circular XaaS models within the Ecodesign Directive, either at primary level or through secondary legislation, e.g. include data access obligations Extend EPR schemes and include eco-modulation fees in EPR schemes to encourage circular design Further develop Digital Product Passports, as the ability to attach static and dynamic data to an individual product expands the possibilities for producer ownership	7	17	3
Informational instruments and awareness raising	Inform the International Accounting Standards Board (IASB) about XaaS models to remove accounting barriers (i.e. adjust current depreciation rules of valuation and depreciation of retained assets)	1	5	

Source: SYSTEMIQ collation based on Circular Economy Initiative Deutschland (2021).

1. Economic and market instruments: Improve market conditions for XaaS offerings that are both environmentally and socially more equitable

Fiscal incentives, funding support for early-stage capital expenditures, large-scale investments and public procurement are powerful market instruments to enable the uptake of XaaS business models, while phasing out environmental and socially harmful products and services. For example, in European countries, public procurement accounts for about 14% of GDP.[127] If only a small proportion is used for environmentally beneficial product-service systems, this could stimulate demand for XaaS models across sectors (e.g. intermodal mobility, office and school furniture and computer equipment).

Introduce tax incentives to encourage sustainable XaaS models.

Supply-side tax incentives

- Improve policy principles to better reflect any costs associated with environmental and health impacts (so-called "externalities"), for example through higher carbon pricing or resource taxes. Use the revenues to increase (social) spending.[33]

- Adjust waste taxes. Examples include landfill and incineration taxes, disposal bans on certain products or materials, packaging taxes and pay-as-you-throw schemes.[122] For example, France is already going one step further at the country level: it prohibits the destruction of returned products from online and offline shopping by law.[128]

- Paying VAT monthly instead of annual payments could help companies to replace traditional sales models. Companies like MUD Jeans, for example, need to pay an entire year's worth of VAT upfront when the pair of jeans is first leased to the customer. Yet they are only able to collect the VAT from the customer monthly when the lease payment is given.[129]

Demand-side tax incentives

- Review the value add tax (VAT) regime to reduce barriers for XaaS models. Existing VAT requirements add to cash flow concerns for small and new companies. Governmental bodies such as the German Environment Agency suggest linking VAT regimes to environmental characteristics of products and to reduce VAT rates for labour-intensive services (such as repair and refurbishment). Cheaper repair services contribute to TCO reductions for the user, so the use of quality appliances in XaaS models becomes more attractive than for example buying a cheap washing machine. Some countries in Europe such as France, Ireland and Spain are using tax reductions as a way to incentivize repair.[130] In Sweden, for example, 50% of the labour costs for repairs of major household appliances are tax deductible up to a maximum of EUR 5,000. This applies to repairs carried out by professionals in the home of the owner.[131]

Provide access to capital, funding grants and training especially for SMEs and start-ups.

- Ease access to capital and funding grants for XaaS models if these services have been proven to provide a positive sustainability impact. Companies implementing use- and result-oriented business models often need to make large upfront capital investment for high-quality products and materials with long product lifespans to optimize utilization. Often, they are not able to pay back in a short time perspective. Funding should also support sector-specific XaaS models such as for chemical leasing, to help companies innovate at low costs.[132] In the same vein, the Greater London Investment Fund, a GBP 100 million fund of funds, provides loan and equity finance for early-stage circular businesses, including Products-as-a-Service to support economic growth and a circular economy ecosystem.[133]

- The European Commission should consider including XaaS criteria such as retained ownership in the CE taxonomy on sustainable finance.[134]

- Provide the necessary learning environment and invest in interorganizational innovation spaces (e.g. those including incubator and accelerator programmes) for developing, experimenting with, and evaluating radical new service business models linked to circular value creation (e.g. maintenance, upgrading, repair).

Adjust public procurement rules and consider XaaS models on a governmental level to ensure green public procurement.

- One part of the challenge is that civil servants often are (understandably) rather risk-averse, and the lowest cost option is often prioritized and easiest to compare. Even if the rules accommodate the possibility of full lifecycle costing, service delivery and XaaS options, political leadership could further encourage procurement officials to choose these options. Binding criteria, targets and rules can incentivize officials on national and local levels to purchase XaaS-based offerings.

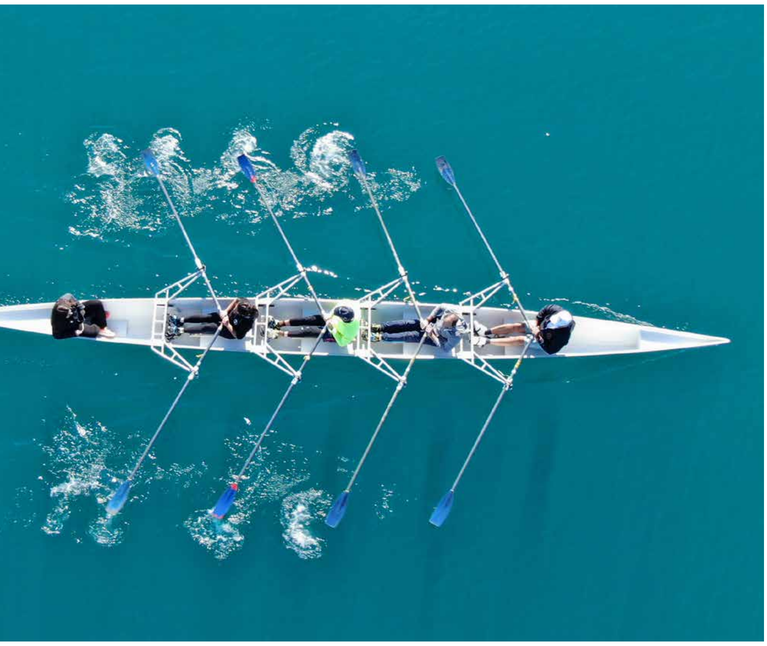
- There may be a need to agree on binding procurement criteria and to adjust current practices, for example tendering rules for governments and businesses could be adjusted to allow them to sell back equipment to privately-owned companies.

- Public authorities could create circular procurement guidelines allowing governments to prioritize and assess XaaS models.

- Lastly, governments could establish binding targets/quotas for the consumption of reused, remanufactured and recycled products.

2. Regulatory instruments and (performance-oriented) standards: reduce uncertainties and encourage businesses to innovate

In a circular economy, areas that were previously considered in isolation from each other, such as product design and product disposal (waste), are linked and benefit equally from the exchange of information and resources. This transformation requires that policymakers know how to apply circular approaches in their policymaking such that regulations are more closely interlinked. To reduce lifecycle-wide environmental impacts of products and services, legislation, e.g. Ecodesign and waste regulations, should be better connected. This includes anchoring producer ownership and circular economy principles such as "reduce" and "reuse" across legislation, for example in the Sustainable Product Initiative and EU consumer legislations. Product-group specific elements (e.g. rates of recycled content, minimum lifetime) would need to be considered in secondary legislation (implementing acts once the sustainable product policy is implemented).[135] Regulatory instruments may be co-designed by regulators from across different departments for better coordination and alignment. For politicians, it can be important to facilitate stronger exchange between line ministries, which propose or develop regulations (see Case box 17). The following adjustments to existing regulations could be implemented in the relatively short term.



CASE BOX 17:
THE EU POLICY LAB AIMS TO CO-DESIGN POLICY INNOVATIONS

The EU Policy Lab by the Joint Research Center (JRC) facilitates conversation and collaboration between policymakers and stakeholders. It aims to bring innovation to European policymaking through fostering engagement and developing interactions, processes and tools. The work is based on four complementary pillars: foresight, modelling, behavioural insights, and design for policy. Thereby, co-designing is a key element, connecting different fields of expertise. For instance, the foresight project 'A vision for the EU Sharing Economy' informed EU policy actions based on expert interviews and workshops together with then EU Commission Vice President Jyrki Katainen and the Directorate General for the Internal market, Industry, Entrepreneurship and SMEs (DG GROW).[136]

Change current waste laws from waste management approaches to systemic resource management.

- Extended producer responsibility (EPR) systems incentivize XaaS models since they involve a charging mechanism to ensure that those putting products on the market cover the end-of-life costs. Policymakers should implement existing EPRs effectively at national level for packaging and WEEE and extend their use through EU regulations to further goods categories and waste streams (e.g. textiles and construction materials).[125]

- EPRs have been criticized for providing little incentive for producers to Ecodesign. One way to improve EPRs is to include eco-modulation fees in EPR systems. Eco-modulation is a scheme proposed to reduce the fees for products designed for a circular economy. Products with circular design (e.g. a minimum percentage of recycled content, or high reparability index) could benefit from reduced fees, while those with design barriers, which are also often exported to developing countries for end-of-life treatment, could incur higher fees.[137]

- In addition, it would be useful to evaluate how eco-modulation could be used to incentivize producer ownership schemes. One of the benefits of EPR eco-modulation is the internalization of externalities, thus preventing the most difficult-to-repair/recycle designs (e.g. black and red dye in plastic packaging). Producer ownership means that these costs already remain with the company bringing the product to market, even without EPR. Consequently, in XaaS, but also in traditional distribution models, companies would be obliged to take responsibility for all lifecycle stages, from Ecodesign to recycling.[124] Overall, producer ownership leads to closed-loop options that are superior to EPR schemes.

- Include circular economy definitions in current waste regulations, specifically refine end-of-waste and “by-products”. Policymakers should integrate definitions and standards to prevent waste status of returned components/cores (i.e. returned “cores” are not waste) and distinguish product categories of remanufactured, used, and newly manufactured goods in international trade.[132] Producer ownership models can already provide a major advantage here by avoiding definition as waste. Nevertheless, end-of-waste criteria would be very useful for some materials.

- Potentially set material-specific recycled content quotas which increase confidence for investments in recycling capacity and mandates for common waste collection systems to increase the quality of recyclate streams, hence foster the development of secondary material markets.[121]

Create a level playing field for XaaS models through the Sustainable Products Initiative, including the review and widening of the EU Ecodesign Directive.[135]

- The Ecodesign Directive is supporting companies to apply circular strategies along the build phase, use phase and loop phase. However, it needs to go beyond the focus on energy efficiency to take into account product lifecycles and incentivize producer ownership to support XaaS models.[138]

- Potentially regulate the amount of recycled content in products (e.g. packaging) and increase the recyclate quality by banning substances that can harm humans or the environment.[139] This would oblige industries to use secondary materials, boosting their demand, and thereby increasing confidence for investors in recycling facilities and systems.

- Evaluate when and how to exercise the right to ban environmentally harmful practices, products, and materials as well as material mixtures, especially when alternative approaches are available. To avoid internal market issues, bans would need to be executed at EU level.

- To drive the circular transition, policymakers could consider a definition of minimum lifetime of goods and critical components which provides both clarity for the consumers and also XaaS model facilitators (e.g. independent repair services, or platform provider)[140] and assess circular criteria (e.g. on reparability and recyclability) in the European product registry for market access (i.e. Conformité Européenne/CE marking).

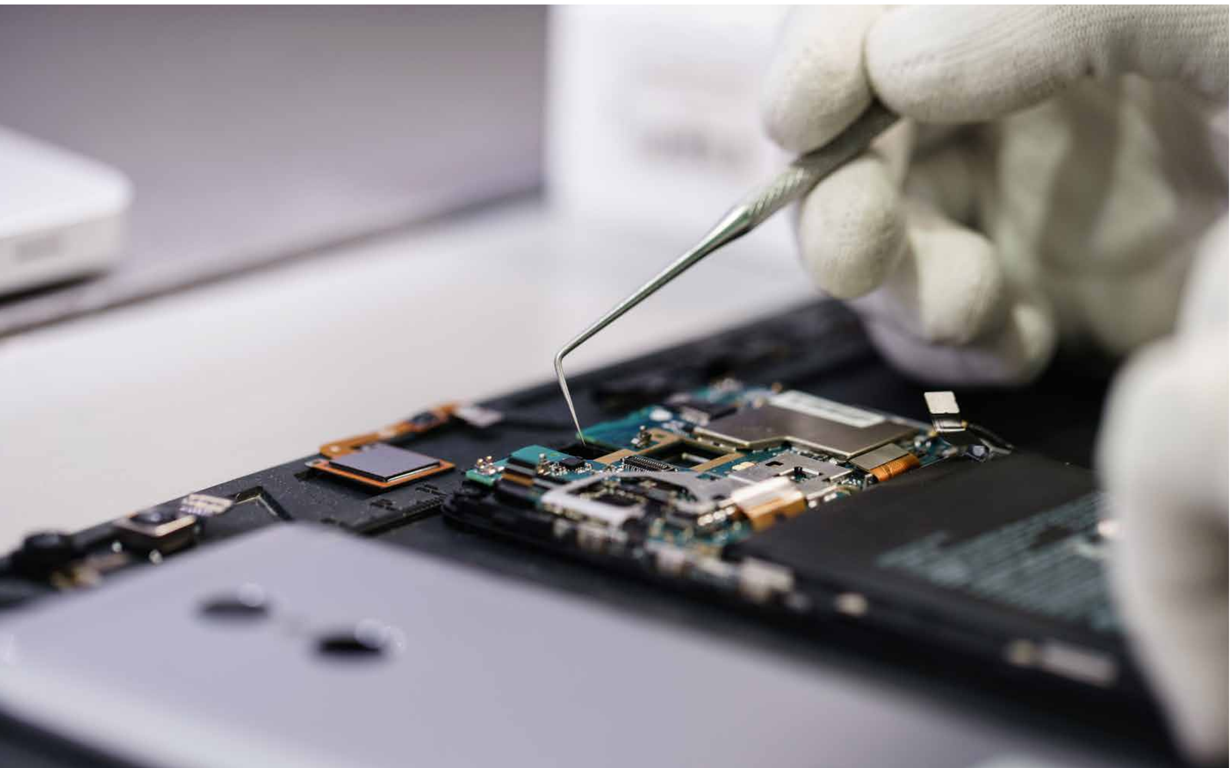
- Actors along the value chain who facilitate XaaS models should get discrimination-free access to manuals, spare parts and repair tools to ensure local repair of products.[141]

- Standards ensuring the "right to repair" for users and autonomous repair facilities could also apply to update (obsolete) software and be mandatory for more products (e.g. smartphones and computers).[142]

Prove and control sustainability impact of XaaS models through standards on environmental performance and design.

- The development of digital product passports based on standardized information is already a priority for the European Union. Digital product passports facilitate the exchange of environmental and circularity-related data among supply chain collaborators and consumers. The ability to attach static and dynamic (including product-generated) data to an individual product will enhance the possibilities for producer ownership. In turn, digital product passports can help to increase supply chain transparency, and ensure that minimum sustainability criteria (e.g. human rights due diligence) are respected.

- In addition, implementing performance-oriented standards bound by stringent environmental targets could remove barriers to XaaS models while providing an equal playing field.[125]



3. Informational instruments and awareness raising: spread information and awareness on decarbonization (i.e. environmental benefits) and TCO (i.e. economic benefits) effects of XaaS business models to empower conscious decision-making.[143]

Policymaking could include a range of education, information and awareness-raising tools aimed at public and private institutions as well as consumers.

Public and private institutions

- Educate public and private institutions working in finance, for example the International Accounting Standards Board (IASB), on XaaS models in order to remove barriers (e.g. adjust current depreciation rules of valuation and depreciation of retained assets). Digital product passports can enable appropriate residual value calculations for accounting throughout product lifecycle stages. This can help to take into account reduced sales returns, but increased asset values and future income (and hence different cash-flow).

- Foster circular knowledge development and experimentation with access- and result-oriented business models particularly targeting businesses (Case box 18).

Consumers

- Translate lifecycle footprint information of the digital product passport into labelling or scoring and make product labels and repair scores mandatory for certain products and services. Labelling should provide information on the environmental condition of products and services and specifically address resource-efficiency and obsolescence of products. These labels could declare the average product life at points of sale and should retain their validity even after the first sales cycle.

- Often customers are not sure what "sustainable" means and rely on producer information. Labels should be designed in a way to provide clearer guidance on how to compare different products and which products to choose (e.g. by implementing product circularity scores).[121]

- Provide information from product passports in a user-friendly way. By making data accessible on all products in a machine-readable and interoperable way, it should become possible for third parties to create interfaces to inform consumers about the sustainability of their choices (e.g. do the data-crunching for consumers via algorithms).

CASE BOX 18:
PLATTFORM INDUSTRIE 4.0

Initiatives such as the German Industry 4.0 Initiative ("Plattform Industrie 4.0") (supported by the Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Education and Research) drive exchange among businesses, public authorities and society and enable these market participants to discover joint opportunities and barriers related to standardization, technology, security and legal framework conditions. For example, the working group on digital business models explores which types of business models are suitable for Industry 4.0 applications (e.g. Products-as-a-Service).[144]

5.3 INDUSTRY ACTION: MOBILIZE AN EMERGING ECOSYSTEM OF XAAS PIONEERS AND INNOVATORS

5.3.1 ENTREPRENEURIAL INNOVATION CAN ADDRESS CRITICAL XAAS CHALLENGES AND FOSTER CIRCULAR INDUSTRIAL SYSTEMS

Entrepreneurial innovation will be critical for establishing circular XaaS models that leave behind incremental solutions and set the basis for the dematerialized, outcome-based, circular economy.

On the one hand, entrepreneurial innovators will be important for developing novel solutions that enable large incumbent firms to improve and scale their circular XaaS systems. Incumbents aiming to explore XaaS models require innovation on various organizational levels and a wide range of business activities in the build, use and loop phase (e.g. from the IT/digital capabilities, through organizational change management, to the entire ecosystem management). Of course, this requires strengthening internal innovation but also drawing on new forms of cooperation with external innovators when designing XaaS solution ecosystems. However, many nascent innovations have yet to be developed. Enabling innovators can contribute to solving the range of specific XaaS-related challenges described in Chapter 3. Illustrative cases show how entrepreneurial innovators have started to tap into these areas from different perspectives (see Case boxes 19-23). More broadly, enabling entrepreneurial innovations are required to shape circular economy ecosystems generally. Exemplary circularity enablers include the following:

- Controlling and optimizing material flows in the use phase
- Improving lifecycle energy efficiency
- Facilitating lifecycle producer ownership and take-back schemes
- Providing IT/digital readiness (e.g. with IoT sensors and data analytics)
- Ensuring lifetime utility maximization
- Leveraging localized repair, reuse, refurbish, and remanufacturing networks
- Enabling high-value-material recovery networks

CASE BOX 19:
RELAYR. UNLEASHING DATA FROM MACHINES TO GUARANTEE BUSINESS OUTCOMES.

Relayr provides a combination of IIoT technology and its delivery paired with financial and insurance offerings. Leveraging IIoT infrastructure and being part of the Munich Re family, the company empowers industrial companies to achieve their desired business outcomes. Relayr delivers a complete solution for risk-free digital transformations – enabling a successful transition from CapEx to OpEx.[145]

CASE BOX 20:
CIRCULY. ENABLING CIRCULAR BUSINESS MODELS.

Circuly provides subscription management software for optimizing existing or establishing new circular rental models as a white-label solution. The company facilitates the payment setup, the self-administration by the customer, and the lifecycle management of the product. It further enables the integration of third providers such as logistics companies.[146]

On the other hand, disruptive innovators and start-ups are important for developing new XaaS offerings directly. This is a vibrant field for entrepreneurs across industrial sectors, as described earlier as part of the emerging European XaaS landscape (see Chapter 2). Young companies often have advantages, especially in terms of agility and radical customer focus – which are particularly relevant elements for building circular XaaS models at the necessary speed. The European business landscape represents a fertile ground for new XaaS innovation.

CASE BOX 21:
TWIST. LETTING BRANDS SELL ACCESS TO THEIR PRODUCTS.

Twist provides an integrated platform to design, manage and deliver Hardware-as-a-Service. The platform lets producers configure circular service bundles integrating service agreements, contracts, lifecycle management and measuring, and financing. Product connectivity and the digitized lifecycle enable detailed use-phase analytics which in turn lets twist finance a more capital-efficient model.[147]

Supporting entrepreneurial innovation can follow different perspectives. One route relates to intensified collaborations between corporates and start-ups, which can create lasting mutual benefits. Incumbents may particularly benefit from catalysing entrepreneurial innovation early on (e.g. through joint build-to-order projects and improving legacy structures and routines) to acquire XaaS readiness and achieve proof-of-concepts quickly. Another avenue relates to formal support structures for entrepreneurs, which could be particularly tailored to XaaS innovation (e.g. innovation clusters, incubation programmes, university accelerators). Such programmes could be particularly effective if they address specific structural systemic deficiencies (e.g. underutilization of specific asset types) through XaaS as search frame for solutions. In a similar vein, the venture capital funding landscape should implement dedicated strategies and models for XaaS.

CASE BOX 22:
TULU. PROVIDING ON-DEMAND ACCESS TO APPLIANCES AND DEVICES.

TULU provides a smart platform and modular units equipped with a variety of appliances and devices for residential, student housing, office, and hospitality areas. Tenants can choose with which high-quality products these units are equipped. These products are connected via an app-based platform, thus providing on-demand access to appliances and devices.[148]

CASE BOX 23:
OMOCOM. INSURANCE FOR SCALING CIRCULAR BUSINESS MODELS.

Omocom provides digital insurance solutions for business models of the circular economy such as sharing, rental, leasing or resale. Through data-driven risk optimization, the company aims to improve the necessary trust base and incentives for circular business model innovation.[149]

5.3.2 COLLABORATION AND SYSTEMIC PARTNERSHIPS CAN STRENGTHEN CIRCULAR VALUE CHAINS

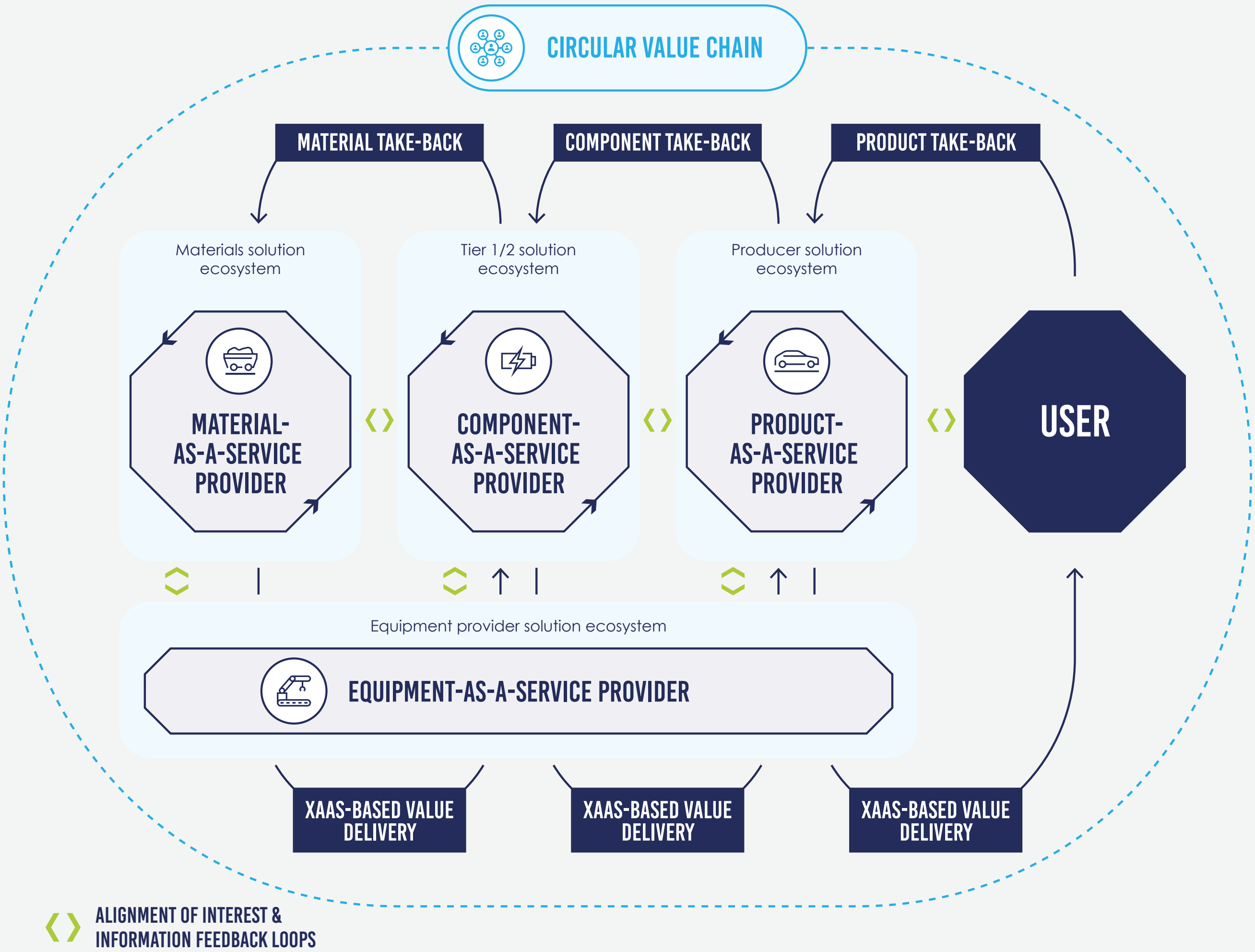
A circular industrial system requires not only individual pioneers establishing sustainable XaaS models, but especially extended partnerships that strengthen regional value creation and, eventually, wider ecosystems of complementary XaaS models that can completely reshape industries.

First, as described in Chapter 3, circular XaaS systems require many business activities and processes (e.g. reverse logistics) to work together in a solution ecosystem. Therefore, XaaS providers require partners with complementary roles. Some roles might shift; for example, customers might shift from value consumption to actively engaging in the value chain as value co-creators. Buyer-supplier relationships might change from being transactional to more integrated and relational partnerships (e.g. with suppliers also providing all the necessary information to establish a loop phase).[150] Completely new partnerships may be required to run local service operations or material recovery strategies. In sum, these developments in the solution ecosystem landscape bring partners closer together, in terms of relationships and also the regional depth of vertical integration.[47] In turn, this can strengthen regional value creation and employment, as services and circular strategies generally entail labour-intensive jobs.[151,152] Since it is often complex and time-consuming to establish such ecosystem partnership models, it will be important to find supportive ways for enabling such collaborations (e.g. through guidance on legal partnership questions such as governance and decision rights, facilitating efficient communication within solution ecosystems, or enabling partner identification through platforms). Such XaaS partnerships can build the foundation of a new European industrial value proposition: promoting high-quality and decent jobs through circular and digital business models made in Europe fostering resource-productive and technically advanced product-service-systems.[153]

Second, shaping an integrated and vertically aligned value chain can go beyond individual XaaS solution ecosystems: connecting related XaaS models can enable a fully circular value chain. The solution ecosystem represents the extended partnership model that is effectively delivering a specific XaaS model. An integrated circular value chain ecosystem goes beyond such individual models and fosters a circular value chain where XaaS models are connected and aligned. This means that starting from the final product and service provision, downstream value chain practices must be reconfigured. The implementation of circular XaaS business models along a circular value chain can provide the necessary alignment of interest for the emerging network of solution ecosystems to function together.

For example (Exhibit 24): a material provider might implement Material-as-a-Service (or Molecules-as-a-Service) and is essentially reimbursed for the utility the materials/molecules provide throughout the value chain and product lifecycles (i.e. material leasing against a use fee). The company thus is incentivized to provide long-lasting materials to component manufacturers while at the end-of-life, used/recycled materials are returned. **Component suppliers may in turn run a XaaS model for their components**, they also retain control and are reimbursed for the performance, potentially with a bonus for efficiency. **The OEM/producer offers the final Product-as-a-Service** and reimburses suppliers for the service and efficiency of their components/materials. End-of-life organizations such as recyclers are reimbursed for the service of recovering the value inherent in materials, not for the material recovered itself.

XaaS can create the necessary alignment of interest to configure circular value chains.



Source: SYSTEMIQ.

Such fully circular, service-based value chains would entail complex transactions and coordination efforts but would unleash significant benefits. The common theme of an alignment of interest could lead to the optimal use of resources and functionality of products throughout lifecycle(s). However, such extensive XaaS-based, circular value chains are complex to establish, entail many open questions (e.g. related to required material transparency on a granular level, degradation of materials, or practical handling of reverse logistics) and do not yet exist. Often such models challenge existing system boundaries and incentive structures. Further research is needed to examine the specific challenges and systemic enablers of circular value chains.

5.3.3 FACILITATING EXCHANGE AND MOBILIZING ACTORS FOR IMPLEMENTING CIRCULAR BUSINESS AND OPERATING MODELS

Mobilizing actors to facilitate the widespread adoption of XaaS models can foster the transition to a circular economy. Building integrated, closed-loop value chains requires collective action and a mutually reinforcing momentum. This means fostering active exchange and cooperation among pioneering companies as well as those who want to embark on a XaaS journey. Together, actors can experiment, learn, adapt, and scale. In the circular economy space, such initiatives already exist (Case boxes 24-26).

Cutting through the complexity of XaaS business and operating model design can be enabled by active exchange with partners and likeminded companies (in the pre-competitive space). The operational barriers to implementation in companies will depend on specific organizational and product characteristics, but there are many themes of common challenges (e.g. managing barriers, designing internal transfer pricing schemes) that benefit from sharing lessons learnt to ease the transition to XaaS. In addition, learning from best practices of pioneers can be an inspiration for other XaaS initiatives.

At the same time, common barriers on an institutional level can be jointly addressed. Joining forces to seek a level playing field in which XaaS models can thrive is more powerful when demanded together. Respective cooperations should share a systemic ambition and narrative. On this basis, specific demands for enabling conditions (e.g. policy support) can be voiced – and are anchored in a collective vision of enabling a new, green industrial growth paradigm through circular and digital business models. A circular industrial model optimized around outcomes and decoupled from primary resource use is the overlooked key to generate prosperity, to direct progress, and to renew Europe's value proposition.

CASE BOX 24:
THE CAPITAL EQUIPMENT COALITION – DRIVING SYSTEMIC CHANGE THROUGH AN INDUSTRY COALITION

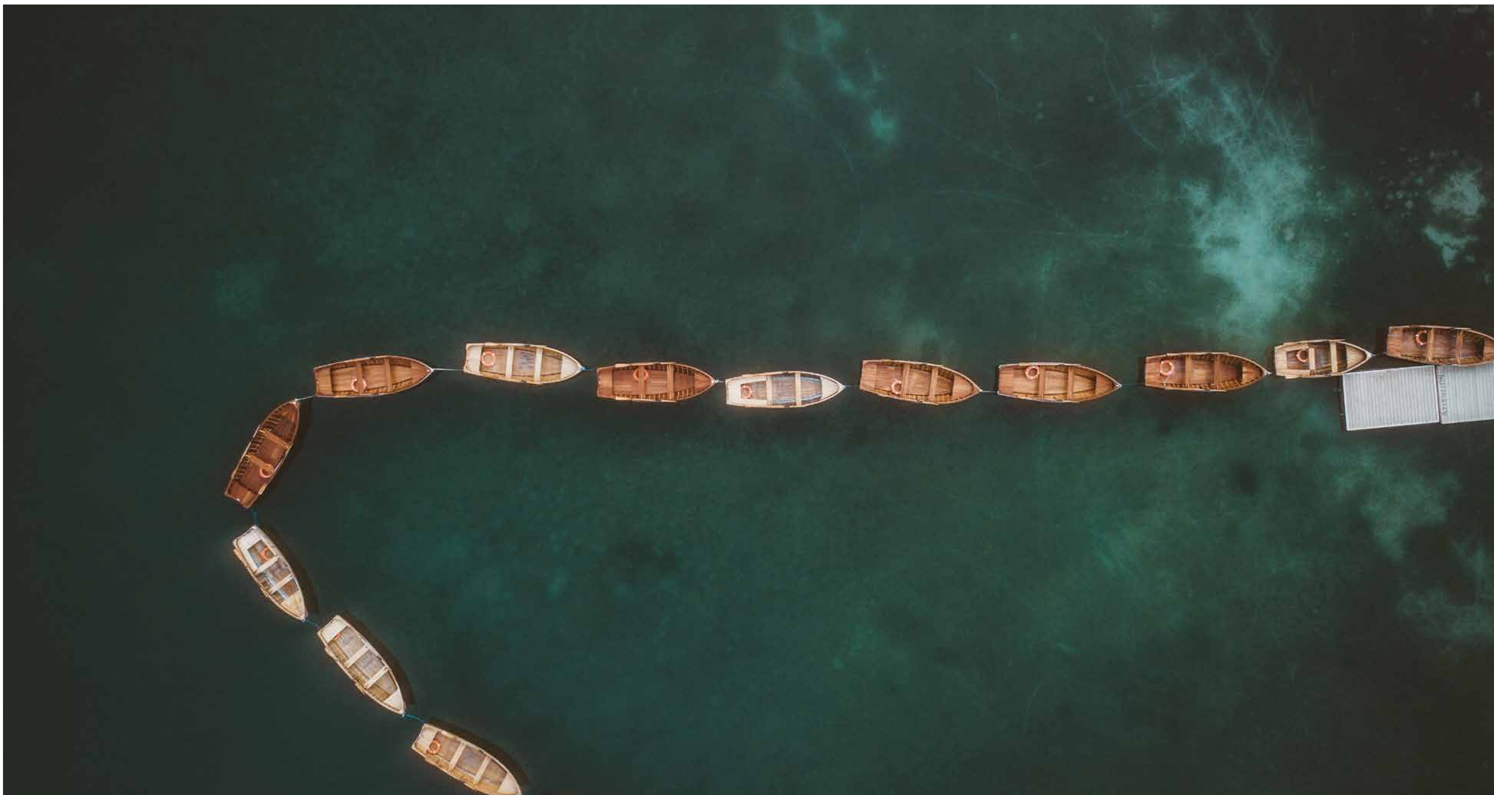
The Capital Equipment Coalition (consisting of a Europe and North America cohort) comprises forward-thinking companies working in the sector of capital equipment. The Coalition strives for a circular capital equipment industry, where material loops are closed and value is preserved to its fullest extent across product lifecycles. The Coalition collaboratively identifies challenges and opportunities, shares best practices and develops solutions to drive change towards a circular economy for capital equipment industries. It strives to engage and enable other players in the public and private sector with the knowledge to accelerate collective progress and, further, sets an example by committing through bold pledges. Through an industry approach, common challenges are better understood; shared insights trigger a rethinking attitude and can give direction to shape new ideas and ways of thinking, collaboratively influencing other systems (e.g. regulatory, broader society) and driving standardization and harmonization of a shared language (at several layers, such as technical, data, social).[154]

CASE BOX 25:
THE CIRCULAR ECONOMY INITIATIVE DEUTSCHLAND – MOBILIZING STAKEHOLDERS FOR A NATIONAL CIRCULAR ECONOMY TRANSITION

The Circular Economy Initiative Deutschland involves business, science and social actors to develop a common circular economy vision for Germany, to investigate concrete use cases and support their implementation. The working group consists of representatives of various leading companies, scientific institutions and civil society organizations. The main task of the working group is to develop a Circular Economy Roadmap, providing an overarching national strategy to achieve a resource-efficient economy. Within the working groups, exchanges take place on specific topics such as new value networks for packaging or traction batteries. In the process, opportunities and challenges regarding the implementation of the circular economy are worked out.[155]

CASE BOX 26:
SITRA – THE INNOVATION FUND FOR MAKING FINLAND A PIONEER IN SUSTAINABLE WELLBEING

Sitra is a public foundation independently funded but supervised by the Finnish Parliament. Sitra aims to create preconditions for reform and opportunities for change with respect to three themes: a carbon-neutral circular economy; capacity for renewal; and new working life and a sustainable economy. Sitra operates as a think tank and investment company and provides research, studies, training and events. For example, Sitra is the main organizer of the World Circular Economy Forum, where business leaders, policymakers, researchers, and innovators are brought together to exchange on circular economy solutions. Thus, by means of thought leadership and investments, Sitra fosters circular innovation on a systemic level.[156]



GLOSSARY

Capital expenditure (CapEx) and operating expenditure (OpEx)

Capital expenditures (CapEx) increase the capacity or productivity of a particular asset or extends its useful life. They often relate to long-term investment decisions of a company. Operating expenditures (OpEx) or operating expenses are expenses incurred when operating a business (e.g. depreciation, rent, salaries or utilities), other than the cost of goods sold.[157]

Circular economy (CE)

The Ellen MacArthur Foundation defines a circular economy as "a systemic approach to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple prosperity from the consumption of finite resources." Three principles according to which a circular economy is described in line with biological and technical cycles: (1) Design out waste and pollution; (2) Keep products and materials in use; and (3) Regenerate natural systems. The CE replaces the end-of-life concept with reducing, reusing, recycling and recovering materials in production and consumption processes.[31,158]

Decoupling (absolute and relative) and dematerialization

Decoupling refers to disconnecting the use of primary resources or the emission of greenhouse gases from economic activity. Absolute resource decoupling entails that total material consumption of a country or company decreases while economic activity (i.e. Gross Domestic Product or revenues) increases. This follows the principle of dematerialization: the reduction of resource use to achieve the same or better outcomes of economies. This requires (a) increasing the resource efficiency or resource productivity of products and services, and (b) reducing the use of primary materials (such as ores, minerals, or metals) by improving the recycling and reuse of secondary materials (i.e. moving to a circular economy).[159]

Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) is a policy principle that places substantial responsibility – financial and/or operational – on producers for the treatment or disposal of post-consumer products. It aims at internalizing environmental externalities related to the end-of-life management of products. Thus, EPR intends to foster sustainable product and waste management systems. A more stringent form of EPR includes eco-modulation fees. Eco-modulation is a scheme proposed to reduce the fees for products designed for a circular economy. Products with circular design (e.g. a minimum percentage of recycled content) could benefit from reduced fees.[160]

Lifecycle assessment (LCA)

Lifecycle assessment (LCA) is the evaluation of the impacts associated with all phases of a product or service's useful life, from cradle to grave. It focuses on individual product and service systems and is therefore often used to compare the environmental performance of goods and services. In LCA, a distinction is usually made between different activities along the value chain up to the end-of-life phase of a product.[159]

Industry 4.0

Industry 4.0 refers to the intelligent interconnection of machines and operation processes in industrial settings with the help of information and communication technology. Thereby, Industry 4.0 is characterized by four fundamental technologies that enable companies to revolutionize their value creation processes in a completely new way: connectivity (sensors, Internet of Things (IoT), cloud computing, blockchain); analytics and intelligence (advanced analytics, machine learning, artificial intelligence); human-machine-interaction (automation, virtual and augmented reality, robotics); and advanced manufacturing technologies (additive manufacturing, renewable energy, nanoparticles).[11,161]

Industry 5.0

Industry 5.0 offers a vision of industry that goes beyond efficiency and profit as sole goals and strengthens the role and contribution of industry to society and nature. It puts the wellbeing of workers at the centre and uses new technologies to create prosperity beyond jobs and growth while respecting our planet's boundaries. It expands the existing "Industry 4.0" approach, for example by specifically putting research and innovation at the service of the transition to a sustainable, people-centred and resilient European industry. This includes an economy that focuses on dematerialization, that decouples material consumption and negative environmental externalities from economic activity, growth and wellbeing. (This description builds on the definition of the European Commission DG Research & Innovation).[162]

Producer ownership

Producer ownership means that manufacturers are or fully act as owners of their materials and products. The intent of such a change would be that products are designed and managed in a circular way (e.g. avoid waste, reuse, repurposing, refurbishment, remanufacturing, closed loop recycling). From a policy perspective, producer ownership schemes go beyond EPR approaches: incentives and regulations steer producers to retain ownership and thus internalize operating and end-of-life costs by the time the product is brought to market.[95]

Rebound effect

A rebound effect occurs when a positive eco-innovation on the micro level leads to negative effects on a higher meso/macro level. This phenomenon can occur through a change in consumer behaviour, i.e. consumers use more of an efficient product, which – at least partially – offsets the efficiency improvements per unit of that product.[159] For example, cost reductions could stimulate more demand for the same product and underlying utility than before (e.g. passenger kilometres travelled by car). More comfortable and cheaper services can replace a less competitive service that has a better environmental impact (e.g. ride-hailing substituting public transport).

Secondary material

Secondary material is material that has already been used and recycled. Hence, secondary material is the recycled raw material recovered by recycling processes – in particular purified materials, base substances or metals. The goal of a circular economy is to keep the value of materials as long as possible (e.g. through reuse) and reintroduce them into production processes upon end-of-life. The inherent aim of dematerialization entails raising the quantity of secondary materials used in production and consumption.[159] Compared to newly extracted materials (i.e. primary material), secondary materials – especially metals – have a significantly lower CO_2 footprint. For example, secondary steel has 1/6 of the embedded emissions of primary steel.[101,159]

Scope 1, Scope 2, and Scope 3 emissions

The Greenhouse Gas Protocol (GHG Protocol) Corporate Standard classifies a company's greenhouse gas emissions in three scopes and requires the reporting company to account for and report all of its Scope 1 and Scope 2 emissions.
Scope 1 emissions represent direct emissions from owned or controlled sources (e.g. combustion of fuels at the company facilities or company vehicles).
Scope 2 comprises indirect emissions from the generation of purchased energy that are required for own operations (e.g. purchased electricity, steam, heating and cooling for own use).
Scope 3 emissions are all indirect emissions that occur in the reporting company's value chain (i.e. not owned), including upstream and downstream emissions. On average, Scope 3 emissions make up 3/4 of a product's lifecycle carbon footprint and outweigh Scope 1 and 2 emissions for companies by a factor of 3. So far, Scope 3 emissions reporting is voluntary but the focus of regulators increases. Examples of upstream activities comprise waste generated in operations, employee commuting and business travel, or emissions from the production of goods and services purchased by the company (e.g. materials and components). Examples of downstream activities include the processing of sold products, the use of sold products (i.e. emissions resulting from product usage), or the end-of-life treatment of sold products. The development of a complete corporate GHG emissions inventory would allow organizations to understand the impact of their operations across the value chain and focus efforts on where they can have the greatest impact.[58,163,164]

Total cost of ownership (TCO)

The total cost of ownership (TCO) is an extended cost accounting and is used to determine the total costs incurred throughout the lifecycle of an asset in order to facilitate decisions on its procurement and operation. This involves analysing all the acquisition and usage costs incurred over the lifecycle of the object.[165]

XaaS (Everything-as-a-Service or X-as-a-Service)

Everything-as-a-Service or X-as-a-Service (XaaS) is an umbrella term for all types of products (software/ hardware) offered in service-oriented business models. Everything-as-a-Service (XaaS) models combine tangible products and intangible services so that they are jointly capable of satisfying final user needs. In XaaS models, producers typically maintain product ownership and lifecycle responsibility and are consequently incentivized towards adopting circular economy strategies (long-lasting and circular design, use-phase intensification, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling). Moving to XaaS models at scale promotes the shift to a performance economy.[30,36,47,166]

TECHNICAL APPENDIX

TECHNICAL APPENDIX

APPENDIX A: SUPPORTING MATERIAL TO CHAPTER 2

Appendix A.1: Criteria for XaaS readiness (Section 2)

XaaS models have been found to work better for products that meet a combination of technical/design criteria, financial/business criteria, and market/customer criteria (see Exhibit 25). For example, products that are:

- rather investment-intensive (i.e. resulting in CapEx to OpEx shift advantages);
- technically advanced and require maintenance and repair during lifetime (i.e. allow for substantial service potential and value creation in the use phase);
- are generally mobile to transport (i.e. allow for reuse and second-life applications);
- are used infrequently by the single customer (i.e. resulting in high potential for increasing utilization);
- and/or are not heavily influenced by emotional attachment or extremely customized (i.e. can be valued similarly by different users).

EXHIBIT 25

Nine criteria help decide to what extent a product is suitable for XaaS models.

TECHNICAL/DESIGN CRITERIA

1. DURABILITY/ ABILITY TO KEEP VALUE
2. MOBILITY OF GOODS
3. COMPLEXITY OF PRODUCT REQUIRING SERVICING MAINTENANCE & REPAIR SUPPORT
4. PRODUCT AGGREGATION (MATERIALS, PARTS, PRODUCTS)

FINANCIAL/BUSINESS CRITERIA

5. UPFRONT INVESTMENT/CAPITAL INTENSITY
6. POTENTIAL FOR ADDITIONAL VALUE THROUGH ADDED SERVICES/ PLUG INTO OR CREATING AN INTEGRATED SYSTEM
7. POTENTIAL TO INCREASE UTILIZATION

MARKET/CUSTOMER CRITERIA

8. EMOTIONAL DISTANCE/RATIONALITY
9. POTENTIAL TO AVOID SIGNIFICANT VALUE LOSS AT START OF THE PRODUCT USE PHASE

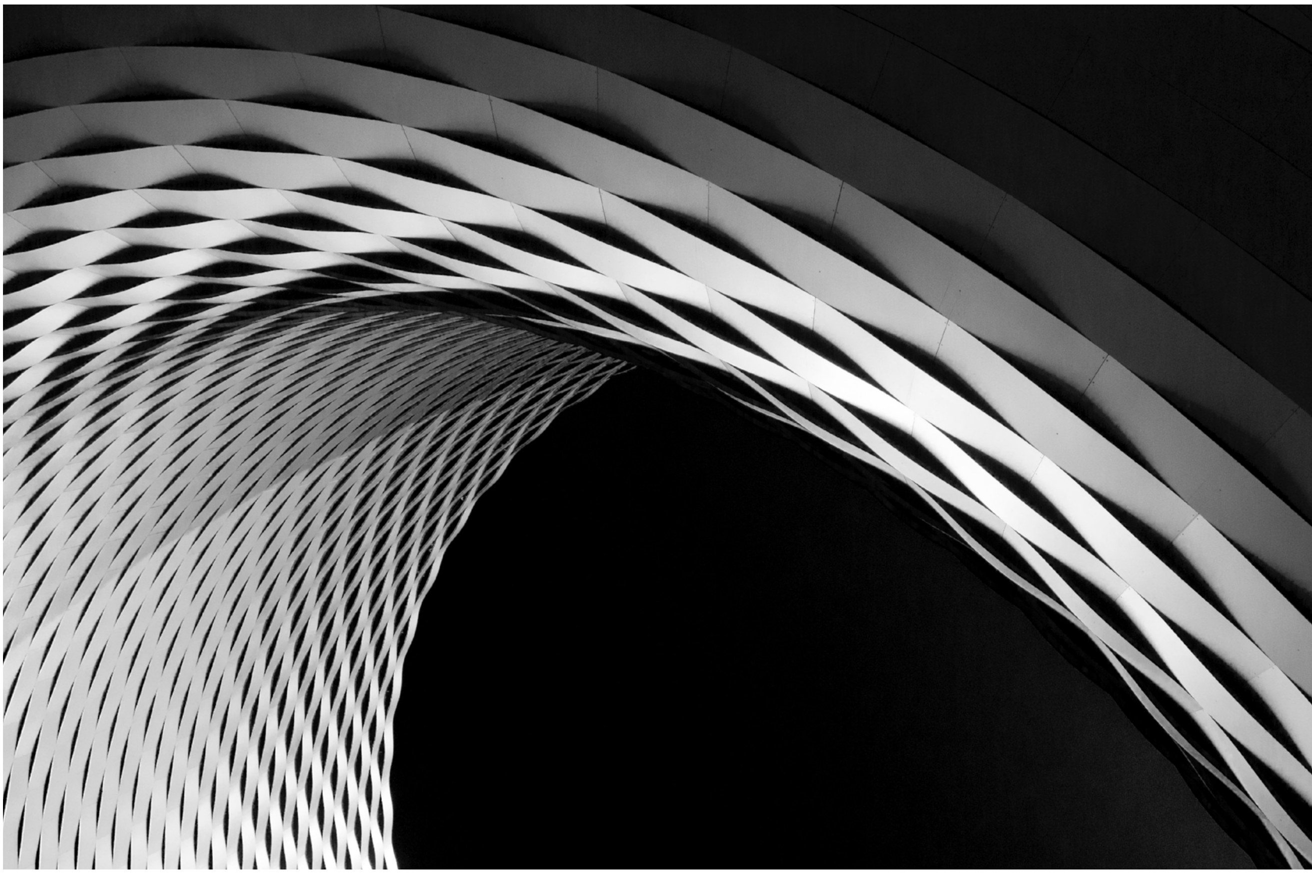
Source: SYSTEMIQ collation based on Stahel, W. (2010), Tukker et al. (2015).

APPENDIX B: SUPPORTING MATERIAL TO CHAPTER 3

Appendix B.1: Tools to discover customer needs (Section 3.1.1)

Several tools exist which can help to discover and define the underlying needs companies are trying to meet with their XaaS offerings. *Defining personas* is a qualitative approach that might help companies to understand different customer groups more deeply (based on different characteristics and needs). For example, several open-access design thinking tools and courses are provided by IDEO (see webpage).[167] *Customer decision journeys* are another tool helping companies to understand how customers make their buying decisions. For example, the Delft Design Guide presents an overview of design models, approaches and methods including customer decision journeys.[168] This tool is particularly interesting for companies which already have a product in place and want to discover how they could optimize the customer's journey with a shift away from traditional sales to an XaaS model.

Digital technologies help to discover customer needs and preferences. Today, customers are constantly connected and change consumption habits. Applying data analytics enables companies to evaluate purchase history and behaviour to discover customer needs. Digital technologies such as mobile devices and machine learning as well as racking and tracing technologies allow companies to fulfil customer needs in the moment they occur or use data for feedback loops into product/service optimization, ultimately resulting in a better customer experience.



Appendix B.2: IFRS 16 as enabler for result- and use-oriented business models (Section 3.2.1)

The international accounting standard on leasing (IFRS 16) seems to be an enabler of service-oriented business models.[169] Result- and some forms of use-oriented business models allow for off-balance sheet financing which supports a shift from CapEx to OpEx accounting and financing for companies (Info box 2).

INFO BOX 2:
IFRS 16 AS ENABLER FOR USE- AND RESULT-ORIENTED BUSINESS MODELS

Since 2019, IFRS 16 prohibits off-balance sheet accounting for operating leases. IFRS 16 is an enabler of result-oriented and some use-oriented business models depending on the contractual arrangements since it allows customers to circumvent on-balance sheet investments which results in a shift from CapEx to OpEx (especially relevant for high-value asset industries seeking to improve key KPIs such as equity ratio, EBITDA, and covenant regulations).[169,170]

In result-oriented models, the commercial customer effectively pays for the output while risks and rewards of the transaction substantially remain with the provider and the assets remain under legal control of the provider. Furthermore, some use-oriented models (e.g. Pay-per-Use) offer leeway for off-balance sheet financing.[171]

This provides opportunities for commercial customers seeking off-balance sheet solutions, as IFRS 16 holds that payments for operating leases are no longer P&L expenses to the customer. Instead, a right to use asset is capitalized (in accordance with acquisition costs) and a corresponding payment/lease liability has to be created (the discounted amount of all future lease payments is recognized as a lease liability), effectively preventing leasing as an off-balance sheet financing solution.[170,172]

As off-balance sheet financing is advantageous for some companies, result-oriented business models (only paying for the result not for access to the assets) **and some forms of use-oriented business models** (short-term access to assets; Pay-per-Use) provide an option to perform off-balance sheet investments – as long as no transfer of the right to control the use of an identified asset for an agreed period of time in return for payment occurs. This requires a case-by-case assessment of the relevant contract.

Appendix B.3: Internal ecosystem – managing intraorganizational capabilities (section 3.4.1.1)

Especially for established companies, XaaS models often challenge key activities and processes in some organizational areas: Stronger service orientation and lifecycle product responsibility require new structures and processes. Companies may need to:

- **Decide on how/where to integrate XaaS models within the actual organizational structure** (see section 3.2). Options range from full organizational integration or cross-functional set-ups to more hybrid organizations such as SPVs or spin-offs. The latter increases the independency of XaaS initiatives from the current organizational set-up (e.g. enables the implementation of new KPIs and new forms of collaboration) while the core company's processes can still be leveraged. Ensuring higher flexibility and independency for XaaS initiatives can give traditional companies an innovative boost and represent a lab for experimenting with new ways of production and consumption, that are "too sexy to kill", regardless of potentially longer returns on investment (ROI).

- **Revise controlling/KPI processes and (sales) incentives schemes that may need to differ for XaaS models.** For example, KPI-driven decision-making has to consider long-term transition horizons, bridging the initial revenue gap (see Info box 1 on "swallowing the fish" in section 3.2.2), and controlling logics based on recurring revenue streams. Moreover, traditional sales departments may need to adjust sales incentives and an accounting mindset that does properly reflect the material value and is tailored to product-service-bundles that represent revenue-generating assets.

- **Streamline processes towards agility.** Processes linked to XaaS models typically have to deal with more internal and external information (e.g. from the customer side) and have to be responsive. The challenge is typically not the theoretical availability of solutions such as data analytics, but the practical integration into the existing IT landscape and especially the interoperability with other partners (see section 3.4.1.2).

XaaS models require more interdisciplinarity between different organizational units and potentially evaluating new company activities.

- **Collaboration across functional units is essential and may require breaking organizational silos.** Different organizational units such as sales, product development, customer service, controlling, finance, treasury, and supplier management must be taken along the transformation pathway towards service-based value offerings, diverting from product sales-focused organizations. Depending on the context and potential legacy structure, XaaS models may require completely new organizational activities.

- **Some organizational units are especially affected by the implementation of XaaS models.** R&D and product design departments need to consider XaaS model requirements and circularity levers to optimize both TCO and design for sustainability. Sales organizations may need to redefine the sales narrative and shape a performance-oriented value proposition (e.g. including how to optimize flexibility while sharing risks). Customer service may need to change, from aftersales support to evolving as a relational service partner. New roles might include to maintain and optimize products or equipment as well as to perform diagnostics and data analytics, contributing to improve the equipment's and ultimately the company's performance.[48]

- **Simple measures such as creating a position of responsibility that promotes the exchange within the company department is essential for the success of the XaaS model.** This can be achieved by, for example, linking the development department, the design department and the repair/aftersales department.

A new set of capabilities may be required to realize XaaS models – including both soft skills and hard functional skills.

- **Setting up XaaS models and adjusting the described organizational structure benefits from exploring new ways of working (e.g. agile sprints, scrum).** Beyond that, change management capabilities can help to shift thinking from selling volume and quantity to delivering outputs and fulfilling needs, thereby taking all employees along on the transformation to a service-oriented organization. Departments, and in particular the sales teams, need to be trained and supported towards the service-oriented value proposition.

- **Beyond that, introducing carbon footprint/lifecycle assessment (LCA) experts can be effective to understand and optimize sustainability of XaaS models** (i.e. closed loop engineering). For example, in recent years, several companies have made the strategic decision to establish circular economy hubs within their companies to scale up such thinking within the organization. A functional circular economy responsibility can positively influence the wider organizational transition towards circularity and help define priority areas with the greatest economic and environmental impact.

Companies shifting to XaaS models need to decide on a transformation path considering three phases:

- A *pilot and design sprint phase* focusing on rapid development of use cases following a design, experiment, learn and adopt logic.

- A *test and product development phase* (e.g. investing into larger scale implementation with infrastructure build out, tests with first customers, changes of organizational structures etc.).

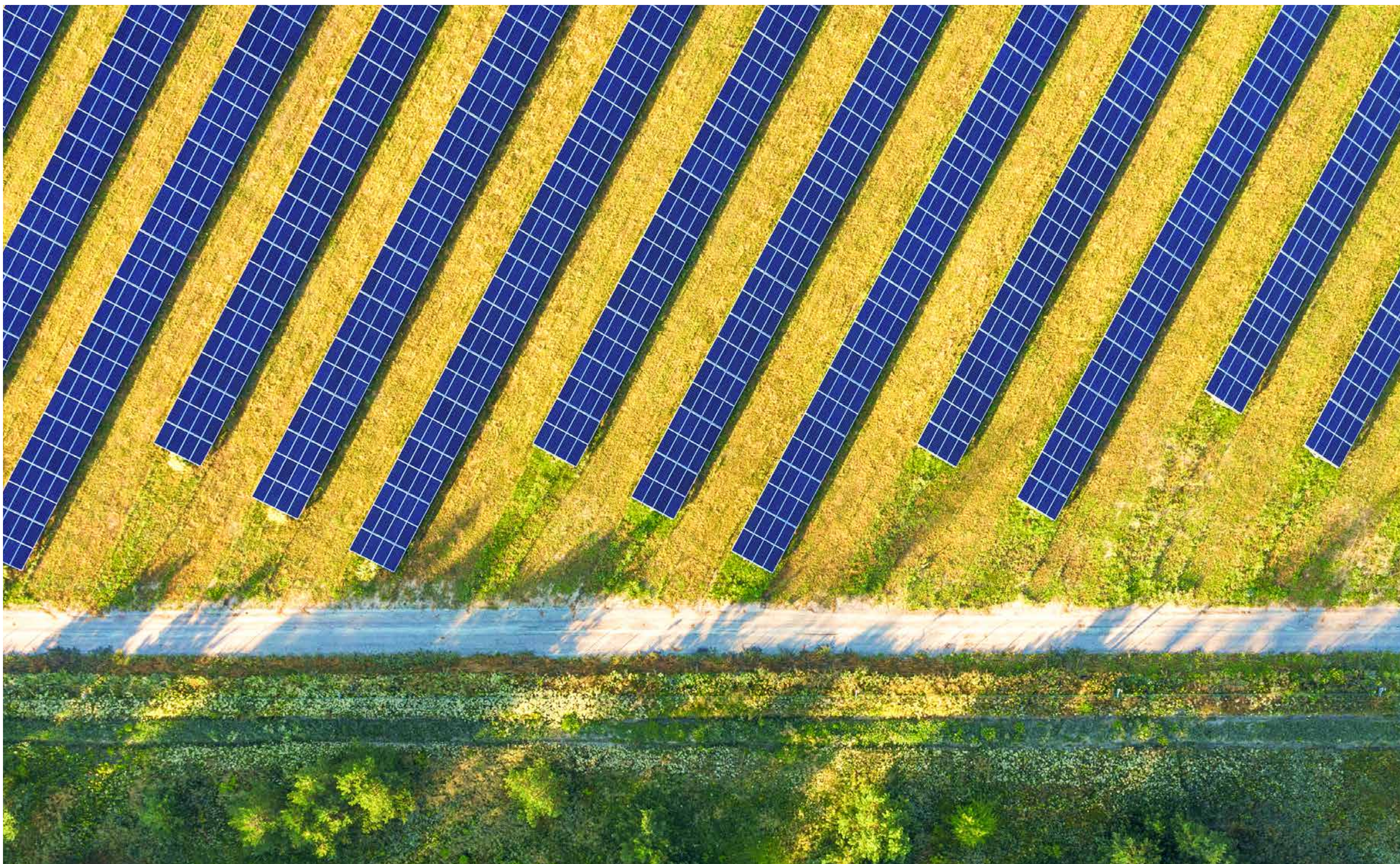
- A *scale phase* (e.g. optimize pricing, discover flexible refinancing solution to avoid inflating the balance sheet etc.).[173]

Appendix B.4: IT/digital requirements for XaaS readiness (Section 3.4.1.2)

Managing an XaaS business model and operating model requires changes in the IT tools and digital capabilities of most support business functions. Examples include billing and pricing activities, sales and aftersales activities or customer support services. For example, billing in XaaS models will become recurring and potentially more complex. Sales and aftersales may converge. Customer support services will likely move towards an even more connected experience (e.g. shared view on data from producer and client's IT infrastructure).

A strong ICT infrastructure will be vital to interconnect business functions internally. In particular, this means connecting data from operations to sales, billing, and customer service. In practice, this requires the interconnection and potentially integration of several key IT systems e.g. CRM (customer relationship management), ERP (enterprise resource planning) and MES (manufacturing execution system).

With respect to the product and operating model, digital technologies will be essential to enable the necessary operational shift. Whereas, in recent years, production processes and the product build phase have been the key focus of Industry 4.0 technologies (i.e. focusing on smart manufacturing, aiming to improve production processes in terms of efficiency), the use and loop phase is now shifting more and more into the centre of attention. Game-changing technologies already exist due to recent technological advancements; examples include digital twins, blockchain, IoT sensors, big data analytics, cloud computing, and artificial intelligence. In many companies, their application has largely focused on production efficiency and productivity, while an extension to all stages of the product lifecycle will now be needed. An efficient data flow between all lifecycle phases must be ensured. For example, by developing a material or product passport (e.g. using traceability and blockchain tools), producers can trace and assess the state of condition of most products throughout all lifecycles. A strong and robust ICT infrastructure will need to connect these stages and enable information management. This may require interoperability and standards used in alignment with other ecosystem participants.[174]



Appendix B.5: Enabling ecosystem partners and potential activities (Section 3.4.3)

The enabling ecosystem focuses on creating supporting structures and collaboration beyond the boundaries of the solution ecosystem in order to drive innovation or to represent common interests. Depending on the objective of the XaaS provider or orchestrator, the macro-level enabling ecosystem can include a variety of relevant stakeholders from politics, society, business/industry, and research. Exhibit 26 summarizes relevant stakeholders in the enabling ecosystem alongside a set of potential activities that these ecosystem partners can address to foster the value creation potential of XaaS models.

EXHIBIT 26

Potential activities which can be pursued in the enabling ecosystem by collaborating with different partners.

ENABLING ECOSYSTEM	POTENTIAL ACTIVITIES (LOCAL)		(INTERNATIONAL)
AUTHORITIES AND POLITICIANS	Support pioneers e.g. through local networks (local governmental bodies, start-ups)	Reduce barriers for local OEMs to adopt new business models	Put XaaS models on the local and international political agenda
NGOS AND THINK TANKS	Engage in knowledge sharing with pioneers and innovation leaders	Strengthen acceptance within society (e.g. NGO review boards)	Build new platforms to support XaaS models (e.g. cross-industrial coalitions)
ASSOCIATIONS	Share best practices among members	Support cooperation with political and societal players	Provide tools to assess environmental and economic impacts
STANDARD-SETTING BODIES	Drive harmonization of national regulations	Create standards (e.g. on repairability) in accordance with international commitments	Foster trade liberalization in goods such as second-hand goods
RESEARCH INSTITUTIONS	Support value creation through regional XaaS ecosystems (e.g. applied research)	Learn about latest digital technologies enabling XaaS models (e.g. pricing)	Conduct consumer research about the acceptance of XaaS models

LOCAL ↔ INTERNATIONAL

Source: SYSTEMIQ collation.

APPENDIX C: SUPPORTING MATERIAL TO CHAPTER 4

Appendix C presents a detailed description of the use case modelling as compiled in Chapter 4: (C.1) Car-as-a-Service, (C.2) Equipment-as-a-Service, and (C.3) White Goods-as-a-Service.

Appendix C.1: Deep Dive: Car-as-a-Service

To measure the decarbonization effects of a circular CaaS product and operating model, we recreate the lifecycle emissions of a BAU reference scenario in which a standard BEV[i] is sold to customers. Based on this, clusters of levers quantify the direct and indirect effects for the two CaaS scenarios presented in section 4.1 – car subscription and carsharing. The respective "lever X" indication in the following sections refers to the circularity levers as presented in Section 3.3 and Exhibit 13.

The first lever cluster: a higher utilization of the vehicle in the use phase distributes build-phase emissions more effectively in terms of CO_2 per passenger kilometre (pkm). Increased utility provision in terms of kilometres travelled and persons per vehicle spreads the embedded emissions over more lifetime pkms provided (lever 4). This is especially the case in carsharing models, where more customers can access one car in a given period. A higher utility provision per vehicle entails that fewer cars and consequently materials and energy are required to meet the mobility demand. According to the IRP, using vehicles more intensely is a crucial element to decarbonize road transport emissions and makes up ~70% of the estimated decarbonization potential. If 25% of trips were provided by ride- and carsharing in G7 countries, total fleet-wide emissions could be reduced by 17% (~8 Gt CO_2e until 2060).[78]

The second lever cluster: increasing the useful life of a car leads to the build-phase emissions being used for more mobility provision in terms of kilometres travelled. Lifetime extension can be achieved through improving the design for longevity and modularity and longer-lasting input materials (levers 1 and 2). Furthermore, improved maintenance-servicing systems supported by digital technology (e.g. digital twins providing predictive maintenance and state-of-health data) and (over-the-air) updates of critical software lead to the car having a higher useful life (lever 3). Retaining access to the vehicle during the use phase facilitates (preventive/predictive) maintenance throughout its useful life with refurbishment becoming a worthwhile option to extend the vehicle's lifetime. Refurbishment can lead to the car being in use for longer with core technology and components being replaced upon wear-off (lever 6).

The third lever cluster: material recovery and reintroduction of materials to the production process in a closed loop can improve the CO_2 footprint of materials. Retaining control over the vehicle increases the potential for value retention and recovery at the end-of-life as reverse material flows can be captured by the producer. Reuse and refurbishment reduce material and energy consumption in the production of the vehicle as the value of the vehicle is retained (lever 6). Remanufacturing of core components decreases primary material consumption. Recycling of end-of-life materials and increasing the secondary materials ratio in the production can offset half of the vehicle's carbon footprint (levers 7 and 2).[78]

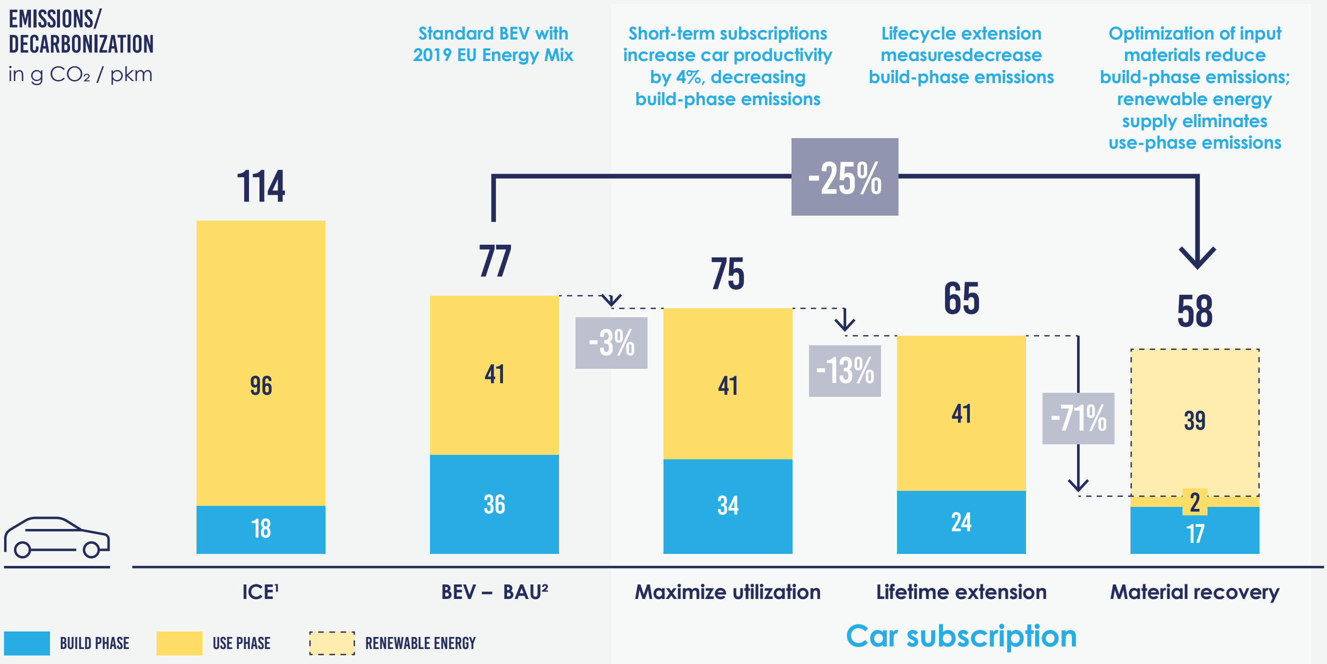
i The baseline scenario models the VW ID.3 – a standard C-segment BEV with the latest technological features (especially battery technology). Since road transport will be electric and with renewable energy shares in the electricity provision growing, the decarbonization focus will shift to build-phase emissions. Therefore, BEVs are used as the reference case.

However, secondary vehicle materials are currently mostly downcycled, losing much of their inherent economic value. For example, secondary steel is downcycled due to copper contamination.[175] CaaS can secure stable reverse material flows; through closer end-of-life collaboration, innovative sorting and scrap recovery processes could be enabled.

Car subscription: deep dive insights from optimizing the product and operating model

EXHIBIT 27

A circular car subscription model can decrease the CO_2 footprint of a Battery Electric Vehicle by 25%.



	ICE	BEV – BAU	Maximize utilization	Lifetime extension	Material recovery
LEVERS	N/A	N/A	**Increasing the annual mileage but constant occupancy per vehicle**	**Extending the lifecycle mileage via build-to-last and value retention strategies**	**Improving the material recovery and value retention in the loop phase**
LEVER ASSUMPTIONS	N/A	N/A	• 19,200 km/year (short-term subscriptions leading to more annual mileage) • 1.5 persons/vehicle constant 28,800 pkm/year	• 345,000 lifecycle kilometres	• 5% of vehicles reused/refurbished • 8% of components remanufactured • 20% of input materials as closed loop recycled content
MAIN EFFECTS	N/A	Compared to ICE, build-phase emissions increase due to emissions embedded in the battery, but use-phase emissions decrease by 57%.	Baseline annual production of 100,000 vehicles required to meet mobility demand.	The utility of a vehicle over lifetime increases, while the required annual production decreases to 67,000 vehicles.	In sum, 170 kt CO_2 are saved through materials avoided. Integrating renewable energy contracts could eliminate use-phase emissions.

[1] ICE: VW Golf 8 1.5 TSI ACT, 1.3t weight, 7.1 l petrol consumption, 230,000 lifecycle kilometres, 18,400 kilometres annual mileage, average occupancy of 1.5 persons per vehicle.
[2] BEV: VW ID.3 Pro, 1.8t weight, 62 kWh battery, 230,000 lifecycle kilometres, 18,400 kilometres annual mileage, average occupancy of 1.5 persons per vehicle, baseline assumption of 100,000 vehicles produced per annum.

Sources: SYSTEMIQ analysis, OECD & ITF (2020), IRP (2020), Ecoinvent (2020), Volkswagen AG (2021a), Volkswagen AG (2021b), and expert interviews.

Switching from internal combustion engine vehicles (ICEs)[ii] to BEVs in the car subscription scenario reduces carbon emissions by 49% (ICE to BEV car subscription) in terms of g CO_2 per passenger kilometre (g CO_2/pkm). BEVs can be decarbonized by 25% in the car subscription scenario (BEV–BAU to car subscription) and are used as the reference type in the subsequent analysis.

A car subscription model can decrease CO_2 emissions embedded in the vehicle by 19 g CO_2/pkm compared to the BAU scenario mainly through life-extending measures and material recovery strategies. Disentangling the cumulatively applied lever effects shows:

Car subscriptions only slightly increase vehicle utilization compared to a traditional car sales scenario with only minor effects on CO_2 emissions. A constant occupancy per vehicle but slightly higher amount of km travelled per vehicle in short-term subscription periods[iii] lead to a small increase in utilization. As only the short-term km provision of the vehicle increases, the reduction potential is limited to 3%.

A lifetime extension by 50% leads to a decarbonization effect of 13% per passenger kilometre. The highest decarbonization potential in the car subscription scenario lies in a lifetime extension (through designing for lifetime and quality (lever 1) and improved maintenance and servicing (lever 3)): extending the lifetime from 230,000 km to 345,000 km decreases the number of cars needed to provide the same mobility demand as in the BAU scenario and distributes build-phase emissions over more km. Retaining ownership of the vehicle incentivizes the manufacturer to increase lifetime per design as the vehicle generates revenue over the associated extended useful life. Vehicles becoming a revenue-generating asset over a longer period offset increased costs resulting from design for lifetime efforts (which is modelled such that cost of procurement and assembly increase by the same factor as the lifetime increases). From a sustainability perspective, the design for lifetime and circularity lever (lever 1) is key: the design of the car determines its lifecycle environmental performance. This can be coupled to refurbishment strategies: reconditioning the car throughout its lifecycle and exchanging outdated technical components can further increase the lifetime and corresponding lifecycle efficiency.

In the car subscription scenario, end-of-life value retention and material recovery decrease the carbon footprint by 11%, facilitated in a circular scenario by stable reverse material flows and a closer cooperation with ecosystem partners. Moving towards closed-loop recycling and correspondingly increasing the share of secondary materials (lever 2) alongside remanufacturing, reuse and refurbishment (lever 6) of used cars reduces primary material and energy consumption. The material recovery levers in the loop phase (reuse (lever 6) and remanufacture/recycle (lever 7)) have relatively small effects due to conservative assumptions (increasing secondary materials share by 20%, refurbishing 5% of cars). However, these can be potentially increased as producer ownership improves end-of-life recovery in the form of reuse, refurbishment, remanufacturing and recycling. This is important as car manufacturers move towards strategies to increase the share of secondary materials in vehicles.[62] Also, with respect to valuable end-of-life batteries, retaining ownership and appropriate material recovery can increase return or collection rates to meet future material demand.[153] Repurposing of batteries to second-life applications such as stationary storages additionally becomes a viable option for batteries that reach ~70% of capacity.

Bundling renewable energy contracts in the subscription offer can largely eliminate use-phase emissions. This can be already observed in the market: Octopus Electric Vehicles for instance offer renewable contracts

ii The ICE reference car is a VW Golf VIII 1.5 TSI ACT.

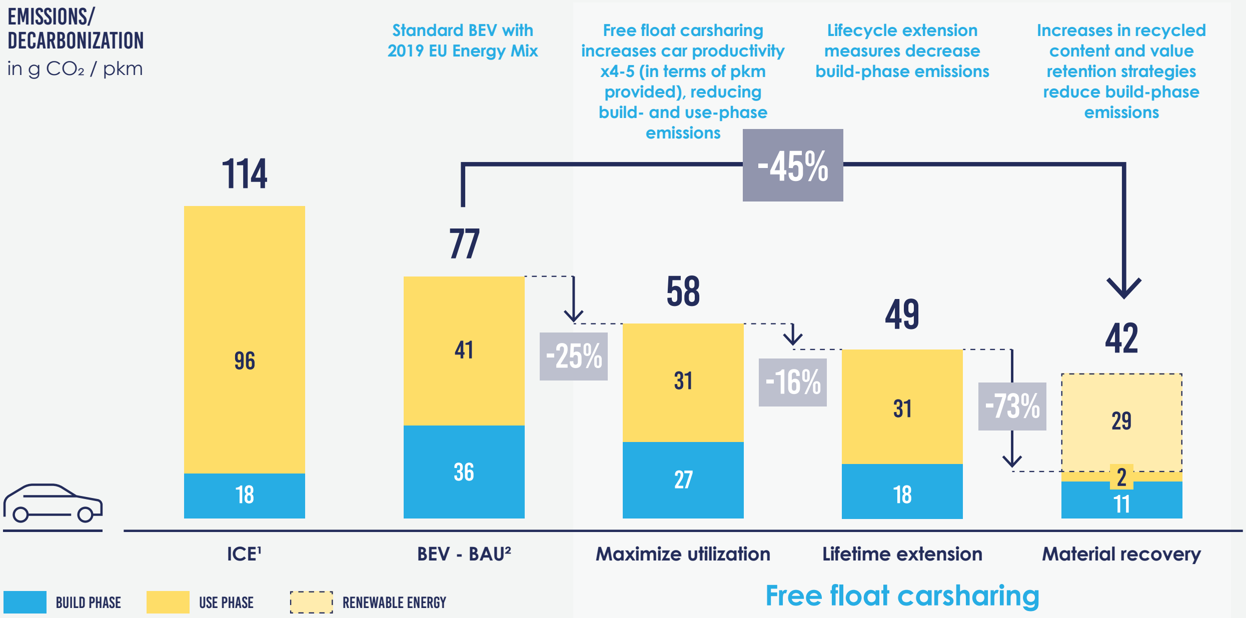
iii The slight increase in utilization results from a more intensive use in short-term subscription periods as vehicles are assumed to be subscribed to only when really needed: 4.4% is assumed as customers opting for short-term rentals drive more than the average.

to customers in their subscription models.[84] Additionally, (smart) charging appliances are provided to leverage optimal BEV charging at home. Hence, bundling functionally connected services to optimize the overall service offering improves the customer utility and environmental performance. Increasing the km provision (as more persons can access the car on a daily basis) and the occupancy rate (assuming two persons per vehicle due to cost sharing) per vehicle lead to the build- and use-phase emissions of the car being distributed over more mobility (pkm) provided, thus decreasing the footprint per pkm. The effect of a higher occupancy rate through pooling and sharing rides is the main driver of CO_2 reductions. Hence, strategies to increase the occupancy per ride should be considered.

Free float carsharing: deep dive insights from optimizing the product and operating model

EXHIBIT 28

Intensifying the use of the vehicle, a circular free float carsharing model can decrease the CO_2 footprint of a battery electric vehicle by 45%.



	ICE	BEV - BAU	Maximize utilization	Lifetime extension	Material recovery
LEVERS	N/A	N/A	**Increasing the annual mileage but constant occupancy per vehicle**	**Extending the lifecycle mileage via build-to-last and value retention strategies**	**Improving the material recovery and value retention in the loop phase**
LEVER ASSUMPTIONS	N/A	N/A	• 63,600 km/year • 2 persons/vehicle • 127,200 pkm/year	• 345,000 lifecycle kilometres	• 5% of vehicles reused/refurbished • 8% of components remanufactured • 20% of input materials as closed loop recycled content
MAIN EFFECTS	N/A	Compared to ICE, build-phase emissions increase due to emissions embedded in the battery, but use-phase emissions decrease by 57%.	Baseline annual production of 69,000 vehicles required to meet mobility demand.	The utility of a vehicle over lifetime increases, while the required annual production decreases to 46,000 vehicles.	In sum, 194 kt CO_2 are saved through materials avoided. Integrating renewable energy contracts could eliminate use-phase emissions.

[1] ICE: VW Golf 8 1.5 TSI ACT, 1.3t weight, 7.1 l petrol consumption, 230,000 lifecycle km, 18,400 km annual mileage, average occupancy of 1.5 persons per vehicle.
[2] BEV: VW ID.3 Pro, 1.8t weight, 62 kWh battery, 230,000 lifecycle km, 18,400 km annual mileage, average occupancy of 1.5 persons per vehicle, baseline assumption of 100,000 vehicles produced per annum.

Sources: SYSTEMIQ analysis, OECD & ITF (2020), IRP (2020), Ecoinvent (2020), Volkswagen AG (2021a), Volkswagen AG (2021b), and expert interviews.

Providing access to cars in the form of carsharing reduces the carbon footprint by 63% from ICE to free float carsharing and 45% from BEV–BAU to free float carsharing (Exhibit 28). A free float carsharing model increases the vehicle's productivity by a factor of 4-5, making maximization of utilization a key strategy to decarbonize the footprint of BEV.

A free float carsharing model optimized for circularity could decrease BEV-related CO_2 emissions by 35 g CO_2/pkm. This potential is driven by a higher overall utilization of the vehicle, coupled with lifetime extending measures. In total, 54,000 fewer cars are required to meet the overall demand compared to BAU.[iv] Disentangling the effects shows the following:

Carsharing can increase the initially low utilization of vehicles by a factor of 4-5 (in pkm provided), from 5% in the BAU scenario to 23%. Providing access for multiple customers to one car is the biggest lever to maximize utilization: a free float carsharing model entails on-demand access for customers in the nearby area. This means that cars need to be locally available to become a hassle-free alternative, requiring a certain stock of vehicles in circulation. Increasing the km provision (as more persons can access the car on a daily basis) and the occupancy rate (assuming two persons per vehicle due to cost sharing) per vehicle lead to the build- and use-phase emissions of the car being distributed over more mobility (pkm) provided, thus decreasing the footprint per pkm. The effect of a higher occupancy rate through pooling and sharing rides is crucial for CO_2 reductions. Hence, strategies to increase the occupancy per ride should be considered. Potentially, incentivizing higher occupancy rates through discounts for ride-splitting or exploring dynamic pick-up options could lead to an increase.

Coupled with a lifetime extension per car, the overall vehicle stock in circulation can be significantly reduced and consequently decarbonized. While the higher utilization leads to vehicles reaching their end-of-life within a shorter period,[v] extending the lifetime mileage of the vehicle (per design, purpose-built vehicles, maintenance, reconditioning) can reap the full decarbonization benefits. Optimizing the vehicle for lifetime can lead to producers generating revenue over this increased period. This is an effect of retained ownership and incentives to maximize profit over the longest period possible (the same rationale as in the car subscription scenario applies). Design is a critical lever: cars that are designed for urban spaces and carsharing can significantly contribute to their optimal lifetime productivity.

End-of-life value retention and recovery (loop-phase material recovery, remanufacturing, and improved production input materials) can save up to 194 kt CO_2 (based on the assumed vehicle stock) or 14% of the CO_2 footprint, provided materials are kept in closed loops and secondary material is prioritized as input. If the car producer operates the sharing platform and thus retains ownership of the vehicle, enhanced end-of-life value retention and material recovery strategies can be applied. Full-scale refurbishment of used vehicles can lead to their lifetime extension and thus material savings. Due to secured reverse material flows, moving towards closed loop cycles and increasing the secondary materials ratio in vehicles becomes viable. Repurposing of used batteries to second-life applications can entail additional economic benefits and extend the negative environmental impacts of battery production to a longer lifetime. As in the subscription scenario, powering the shared cars by renewable energy would largely eliminate use-phase emissions. This depends on the widespread availability of renewable energy charging stations or partnerships with such providers (as done by WeShare).

iv Only accounting for maximizing the utilization would lead to a vehicle stock reduction of 31%. This is in line with the IRP Shared Socioeconomic Pathway 2 (SSP2) scenario which shows a decrease of the vehicle stock by 33%.[78]

v Carsharing can be a viable strategy to address accelerating technological cycles (especially battery technology and digital equipment of the car); a more intensive use reduces the lifetime in years.

Appendix C.2: Deep Dive: Equipment-as-a-Service

The BAU scenario models a baseline reference machine/equipment (state-of-the-art metal laser cutting machine). Based on the BAU reference scenario (machines sold in a traditional (linear) business model), two EaaS scenarios are modelled using three lever clusters. The respective "lever X" indication in the following sections refers to the circularity levers as presented in Section 3.3 and Exhibit 13. Ten machines are assumed as a hypothetical portfolio baseline machine stock.

The first lever cluster: maximizing the utilization and enhancing processing capacities (i.e. metal sheets processed per machine) decreases build-phase emissions. Built-in technical and digital features (e.g. IT sensors and connectivity) and process improvements per design (lever 1) enable smart use services such as remote operations and predictive maintenance (lever 3). Additionally, retained access to the machine permits refurbishing and reusing the machine and related core parts and technology (lever 6). Combined, these lead to increases in the production capacity of the machine (lever 4). Hence, more output can be generated with similar material input embedded in the machine. Eventually, fewer machines are required to meet the same demand as in the BAU scenario.

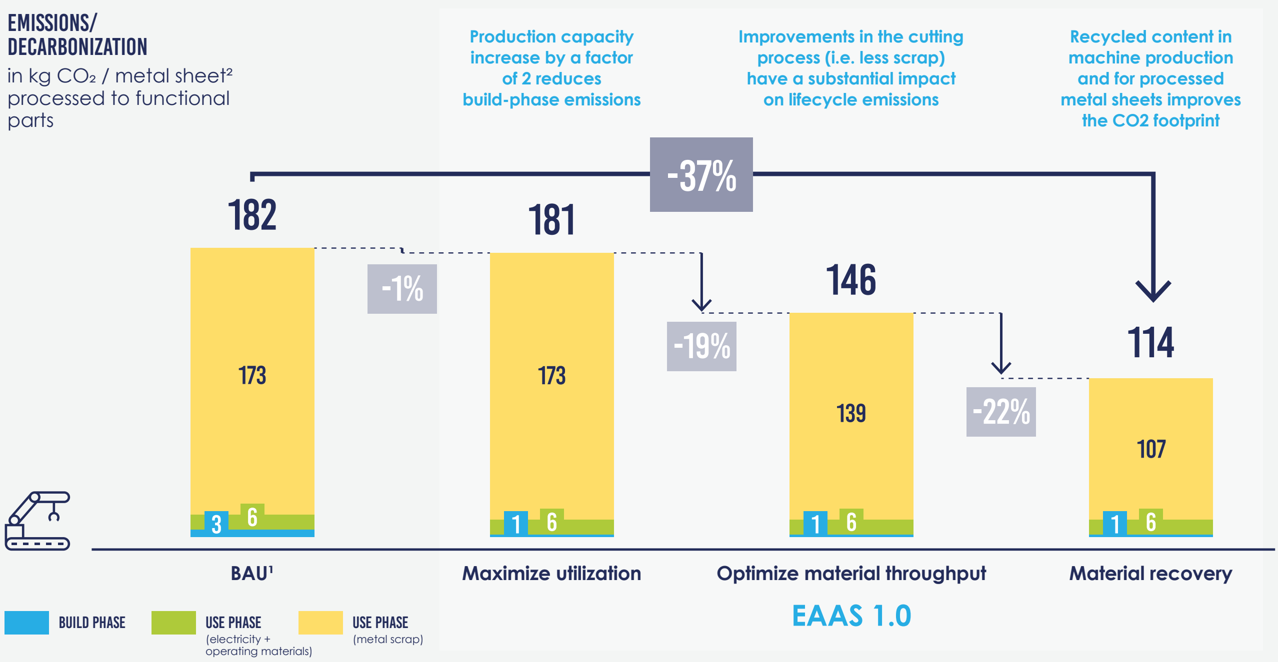
The second lever cluster: optimizing material throughput reduces use-phase emissions as production scrap is reduced and energy efficiency increases over the useful life of the machine. Digital product optimization (i.e. AI-optimized cutting and sorting process) leads to less scrap being produced per processed metal sheet. This optimizes the material throughput, so that more functional parts can be obtained from the introduced metal sheets. Thus, EaaS fabrication yield improvements can significantly reduce the emissions embedded in the waste from sheet metal processing. Furthermore, access to the machine enables enables core technology to be replaced replaced once more efficient technology is available. This optimizes the machine's lifecycle energy efficiency.

The third lever cluster: material recovery (lever 7) and increasing the share of secondary materials (lever 2) can significantly improve the CO_2 footprint of the equipment, especially for the metal sheets introduced to the production process. As the emissions embedded in the scrap make up the highest share, sophisticated material recovery processes should be complemetary to the production process. Sorting and shredding high-quality scrap to recyclers could be performed at the place of production to provide high quality to recyclers. Increasing the secondary materials ratio in metal sheets can provide significant reductions of embedded emissions.

EaaS 1.0: deep dive insights from optimizing the product and operating model

EXHIBIT 29

Equipment-as-a-Service (EaaS 1.0) can decarbonize the lifecycle emissions of the equipment by 37%.



	BAU	Maximize utilization	Optimize material throughput	Material recovery
LEVERS	N/A	**Increasing the machine capacity in terms of processed metal sheets per machine**	**Optimizing material throughput by decreasing share (%) of scrap through AI optimization and lifetime resource efficiency**	**Increasing secondary materials share in the machinery and use phase metal sheets by closed loop recycling**
LEVER ASSUMPTIONS	N/A	• Volume of metal sheets processed increases by x2 compared to BAU	• 5% less scrap • Lifecycle energy efficiency improvement by 7%	• End-of-life machine: 25% material recovery as secondary material input • Use-phase metal sheets: 40% of production scrap as closed loop recycling
MAIN EFFECTS	Lifecycle footprint of the machine is mainly determined by scrap in use phase; electricity consumption and use of operating materials as well as emissions in the construction phase per machine are relatively low.	Compared to BAU (10 machines), only 5 machines are required to provide the baseline utility. Total fleet-wide reduction: **-2.1 kt CO_2e**	Only 4 machines are required to provide the baseline utility. Decreasing use-phase scrap has a significant impact, the total fleet-wide reduction increases to **-24 kt CO_2e**	Increasing the share of secondary materials leads to total fleet-wide reduction to **-43 kt CO_2e**

[1] BAU: Metal laser cutting machine offered in traditional sales model; material composition and direct emissions from production relevant for build phase; electricity, operating materials and scrap from usage of machine as use-phase emissions. Baseline machine fleet: 10.
[2] A sample metal sheet equals ~100 kg and is mainly composed of steel in two different grades and alloys.

Source: SYSTEMIQ and TRUMPF analysis.

In the EaaS 1.0 scenario, the sheet metal laser cutting machine is offered in a Pay-per-Part business model. The EaaS provider retains lifecycle access to the machine and includes performance-enhancing support services and maintenance in the EaaS offer. The customer only pays for the functional part produced from the cutting and sorting process.

Switching from BAU to EaaS 1.0 enables a saving of 37% of CO_2 emissions which corresponds to 68 kg CO_2 per metal sheet processed to functional parts. As illustrated in Exhibit 29, this is achieved by maximizing the utilization, optimizing material throughput and improving material recovery (the levers are applied cumulatively).

Maximizing the utilization of the machine entails that twice as many metal sheets can be processed to functional parts per year. Eventually, fewer machines are required to meet the BAU demand in sheets processed to parts. The relative effects are small, as only the lifecycle footprint in the build phase improves. However, depending on the number of machines, absolute emissions become significant with the build-phase CO_2 footprint being 1,795 tonnes of CO_2. The following underlying lever effects contribute to the increased utilization and the overall equipment effectiveness over the machine's lifetime:

- **Per design** (lever 1): The technical development of the machine is optimized for use phase control and optimization. It has built-in technological features and corresponding advanced services that enhance the utilization (e.g. remote operations of the machine in underemployed shifts). At the same time, the machine is built such that core technology can be replaced once technological progress offers more efficient technology (e.g. more energy-efficient laser).

- Due to access to the machine and corresponding improved **servicing and maintenance** (lever 3), it operates in an as-new condition over the lifetime. Core technology can be updated and replaced while maintenance and data analytics optimize the machine's use-phase efficiency (e.g. over-the-air updates).

- The machine's increasing capacity in terms of lifetime metal sheets processed to parts is enabled by **refurbishing and reusing** the machine and related core parts and technology (lever 6).

Combining the higher utilization with an improved cutting and nesting process leads to an optimized material throughput (lever 5) and a 20% decrease in CO_2 emissions per metal sheet. The AI-optimized cutting process yields a 5% reduction of scrap from each metal sheet, thus increasing the overall utility provision per machine. This is enabled by continuous data-driven process optimization per design and improved machine access (servicing/maintenance) in the use phase. Optimizing the utilization and material throughput leads to fewer machines required to meet the BAU demand: instead of 10 machines in the BAU scenario, only five are required to provide the same utility.

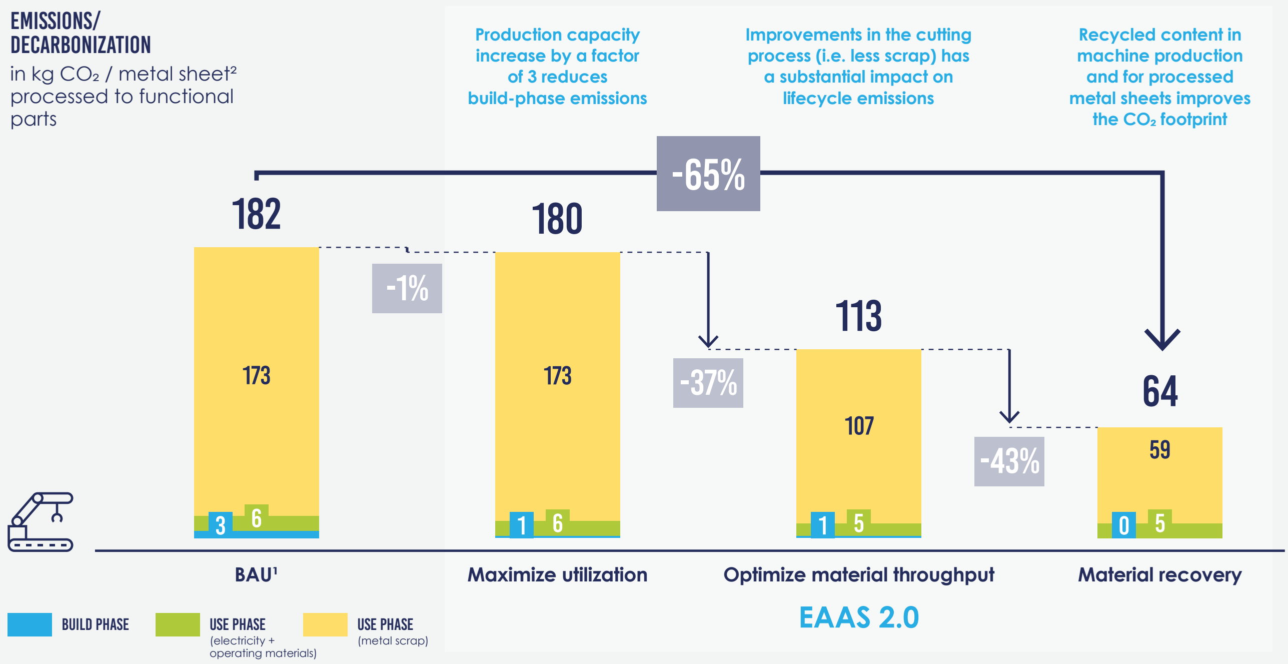
Improving the CO_2 footprint of materials employed can yield significant CO_2 reductions: increasing the content of recycled materials in the build phase of the machine to 25% and 40% of the metal sheets in the use phase reduces CO_2 emissions by 22% (lever 2 combined with lever 7, i.e. closed loop recycling). Construction steel is particularly suitable for recycling. The CO_2 intensity of secondary steel is ~1/6 compared to primary steel (primary Blast Furnace-Basic Oxygen Furnace (BF-BOF) average: 2.3 tonnes CO_2e/tonne versus scrap-based Electric Arc Furnace (EAF): 0.4 tonnes CO_2e/tonne).[100,101]

Therefore, using the steel scrap from production (the skeleton/rest grid) and end-of-life steel from the machines can yield significant contributions in decarbonizing the build and use phase. Over the lifetime of the machine, this amounts to ~5 kt CO_2 per machine. The modelling does not yet include prospective green steel applications in build and use phase, or potential renewable energy contracts within EaaS bundles. This would further eliminate significant shares of use- and build-phase emissions.

EaaS 2.0: deep dive insights from optimizing the product and operating model

EXHIBIT 30

Equipment-as-a-Service connected to a platform solution (EaaS 2.0) can decarbonize sheet metal processing by 65%.



	BAU	Maximize utilization	Optimize material throughput	Material recovery
LEVERS	N/A	**Increasing the machine capacity in terms of metal sheets processed per machine**	**Optimizing material throughput by decreasing share (%) of scrap through AI optimization and lifetime resource efficiency**	**Increasing secondary materials share in the machinery and use phase metal sheets by closed loop recycling**
LEVER ASSUMPTIONS	N/A	• Volume of metal sheets processed increases by x3 compared to BAU	• 10% less scrap • Lifecycle energy efficiency improvement by 7%	• End-of-life machine: 50% material recovery as secondary material input • Use phase metal sheets: 80% of production scrap as closed loop recycling
MAIN EFFECTS	Lifecycle footprint of the machine is mostly determined by scrap in use phase; electricity and additional operating materials as well as build-phase emissions per machine are relatively low.	Compared to BAU (10 machines), only 3 machines are required to provide the baseline utility. Total fleet-wide reduction: **-2.3 kt CO_2e**	Only 3 machines are required to provide the baseline utility. Decreasing use-phase scrap has a significant impact, the total fleet-wide reduction increases to **-43 kt CO_2e**	Increasing the share of secondary materials leads to total fleet-wide reduction of **-73 kt CO_2e**

[1] BAU: Metal laser cutting machine offered in traditional sales model; material composition and direct emissions from production relevant for build phase; electricity, operating materials and scrap from usage of machine as use-phase emissions. Baseline machine fleet: 10.
[2] A sample metal sheet equals ~100 kg and is mainly composed of steel in two different grades and alloys.

Source: SYSTEMIQ and TRUMPF analysis.

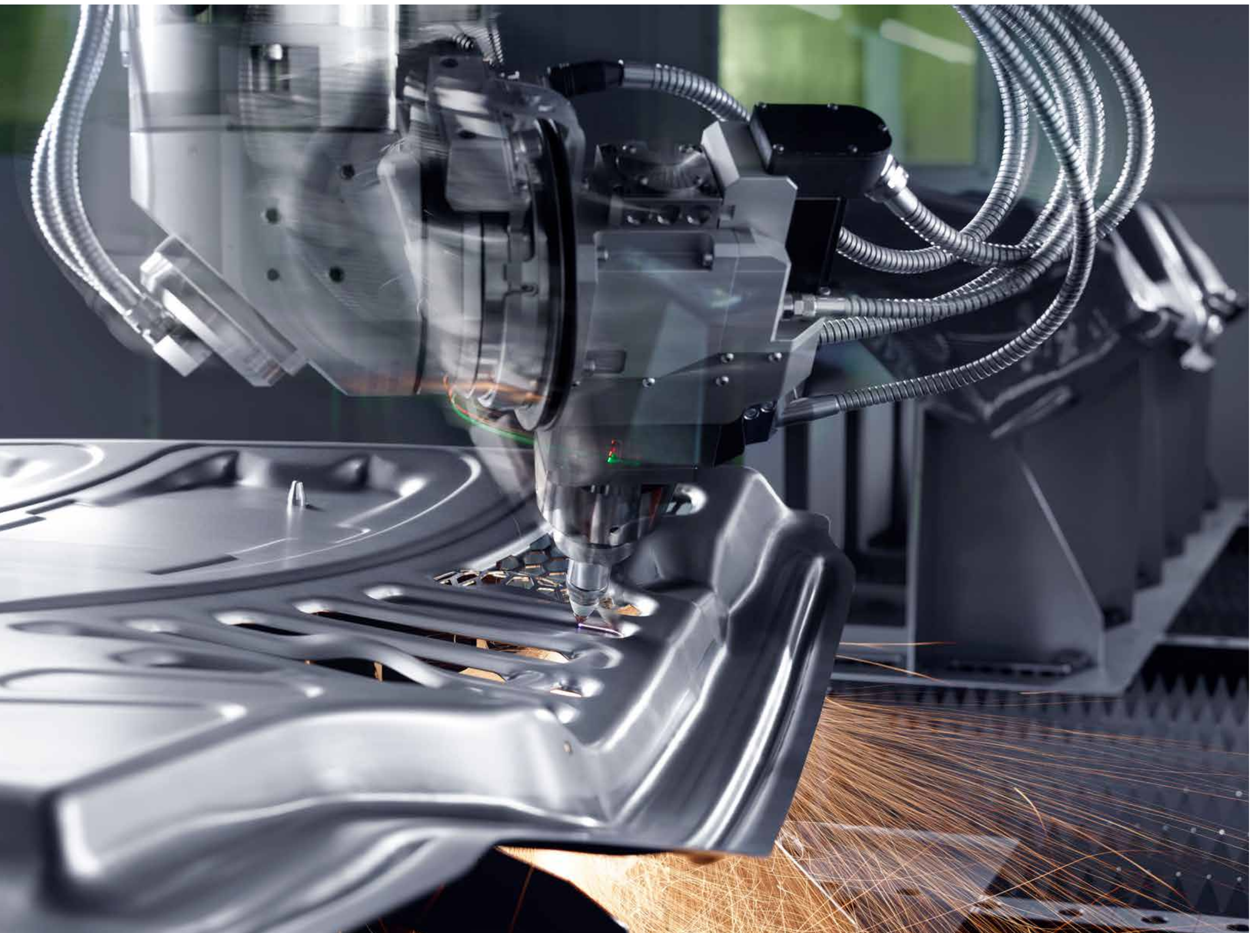
The EaaS 2.0 scenario further enhances the EaaS model by establishing an effective link to a marketplace production platform to achieve an even higher utilization, optimization of material throughput and improved material efficiency. Through demand pooling and smart nesting, the machine's capacity and material throughput can be even further optimized. In total, this scenario decreases 65% of CO_2 emissions which corresponds to 118 kg CO_2 per metal sheet processed to functional parts.

Offering EaaS models linked to a marketplace can maximize the utilization by a factor of three compared to the BAU scenario. Integrating the EaaS model with a marketplace solution can further increase the utilization of the machine, running at an increased capacity as demand is pooled. This would correspond to ongoing trends in consolidations in the laser cutting market. To illustrate, only three machines would be required to meet the baseline production demand of 10 machines. This again only decreasesbuild-phase emissions which are relatively low compared to the use-phase emissions.

Bundling EaaS models with demand from a marketplace platform can further improve the cutting process, thus optimizing the material throughput and decreasing the CO_2 footprint by 37%. Using smart applications to increase nesting efficiency can reduce scrap by an additional 5%. Thus, the metal sheet introduced to the cutting process is optimally used without tilting. Lowering scrap rates even further would result in tilting, with residual grid-free cutting requiring further technological progress.

In absolute terms, together with the increased utilization, the carbon emission reduction corresponds to 69 kg CO_2 per metal sheet processed to functional parts (i.e. ~1,300 tonnes CO_2 per machine per year).

Moving towards closed loop recycling by increasing end-of-life recovery and the share of recycled content in machine production (50%) and use phase metal sheets (80%) yields an additional 43% reduction of the equipment's remaining CO_2 footprint.



Appendix C.3: Deep Dive: White Goods-as-a-Service

The BAU scenario recreates an average WM sold in a traditional business model, reflecting the current market situation in terms of resource efficiency and lifetime.[176] Based on this, the decarbonization effects (measured in g CO_2 per washing cycle) of two scenarios – circular subscription and pooled Pay-per-Wash – are modelled using clustered circularity levers. The respective "lever X" indication in the following sections refers to the circularity levers as presented in Section 3.3 and Exhibit 13.

The first lever cluster: maximizing utilization (lever 4) in this case is expressed in terms of lifecycle washing capacity. Producer ownership in subscription and Pay-per-Wash models increases incentives to design to last (lever 1) and value retention and lifetime extension practices (repair and servicing, lever 3). Because of the long useful life and the standardization of WMs, reuse and refurbishment (lever 6) can become a critical enabler for optimal use of materials and lifetime improvements of the environmental performance (reconditioning and upgrades of core components and up-to-date energy and water saving programmes).

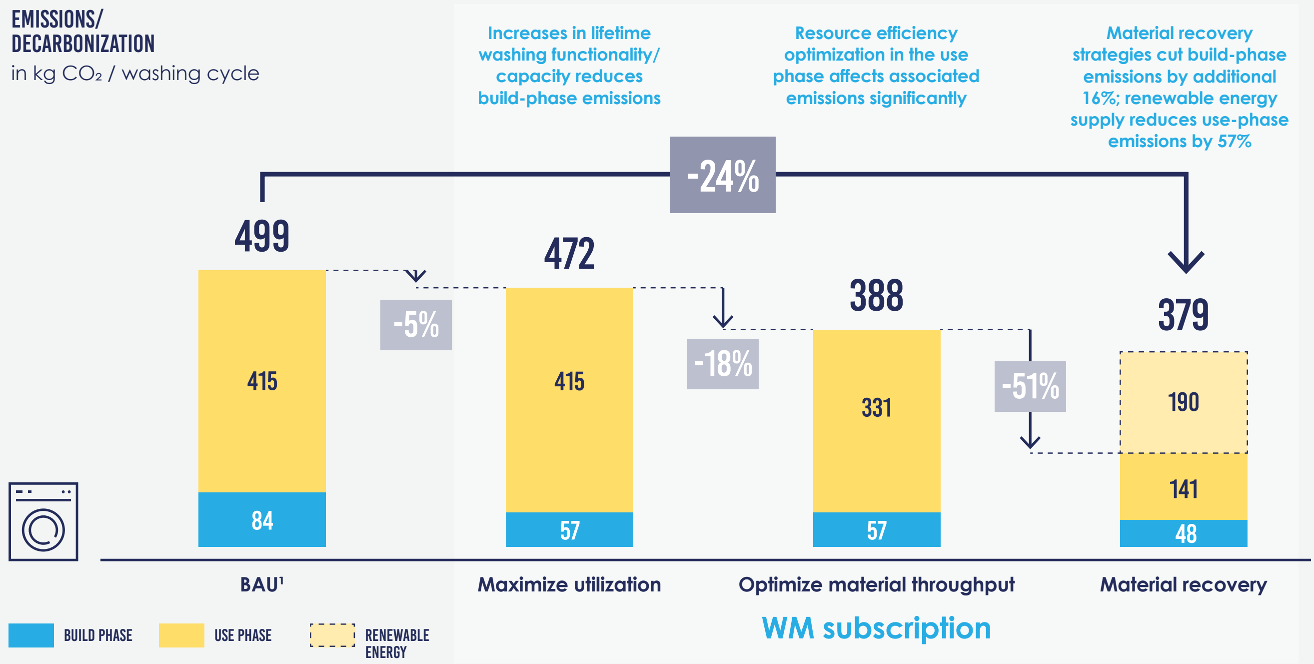
The second lever cluster: optimizing use-phase material throughput (lever 5) results from increased resource efficiency of the WMs. The environmental impact over the lifetime of WMs mainly originates from the use phase, driven by electricity consumption followed by detergent use. This in turn is determined by the efficiency and functionality of the WM as well as the user behaviour (capacity load per washing cycle, water temperature and programme, volume of detergents used). Higher quality WMs with improved energy and water efficiency and technical features such as auto-dosing are made more affordable to customers with high upfront payments being eliminated and shifted over the usage period of the WM. Building in IoT features and offering smart appliances alongside analytics, diagnostics, measuring devices and direct feedback mechanisms to the consumer can further generate positive environmental impacts. Washing with 30°C instead of 60°C can save up to 37% of CO_2 emissions occurring in the laundry of textiles. In addition, CO_2 emissions are reduced by an additional 45% when the WM is fully loaded instead of only half loaded.[177] This is especially relevant in PPW models as washing cycles need to be monitored. But this can also be implemented in WM subscription models.

The third lever cluster: the build-phase emissions are largely determined by the electronic, metal and plastics components; optimizing the reuse of these resources through appropriate end-of-life processes (collection, remanufacturing where possible, closed loop recycling where not; (lever 7)) is facilitated by WGaaS models.

Washing machine subscription: deep dive insights from optimizing the product and operating model

EXHIBIT 31

A circular washing machine subscription model can decarbonize the residential laundry CO_2 footprint by 24%.



LEVERS	N/A	**Improving the lifetime functionality in terms of washing cycles**	**Increasing lifetime energy efficiency, water reduction, and optimized detergent use**	**Enhancing the material recovery and value retention in the loop phase and bundling renewable energy contracts**
LEVER ASSUMPTIONS	N/A	• 4,000 lifetime cycles • 220 cycles p.a. (constant)	• Detergent use: 10.5 kg/year • Water: 10.4 m³/year • Electricity: 0.76 kWh/cycle	• Closed loop recycling: 30% of metals, 10% of plastics • Remanufacturing: 20% of components • [Renewable energy instead of European electricity mix]
MAIN EFFECTS	Electricity and detergent consumption determine use-phase CO_2 emissions; water consumption plays a significant role from a resource use perspective	Compared to BAU (10,000 washing machines), only 6,900 machines are required to provide same utility, saving 720 t CO_2 emissions embedded in the build phase (materials and energy)	Due to higher penetration of high-quality washing machines, energy efficiency, reduced water consumption, and improved detergent use have a significant impact on the lifecycle footprint.	Due to retained ownership of the WM, end-of-life material recovery and value retention can be increased, saving 258 t CO_2 per year. Including renewable energy contracts in the offer reduce use-phase significantly.

[1] BAU: 70 kg washing machine (10,000 washing machines produced p.a. as baseline), 220 washing cycles per year, 2,750 lifetime washing cycles (12.5 years), detergent use: 16.5 kg, electricity: 0.84 kWh/cycle, water: 11.7 m³ per year (Sigüenza et al. 2021)

Source: SYSTEMIQ analysis, Sigüenza et al. (2021), Bocken et al. (2018), BlueMovement (2021).

Designing the product and operating model for circularity can contribute to reducing CO_2 emissions by 120 g per washing cycle (24% of the overall footprint). As illustrated in Exhibit 31, the effects are clustered into three main lever bundles and applied cumulatively: maximize utilization, optimize material throughput, and material recovery.

- **Maximize utilization**: as a result of higher quality WM being offered compared to market average, improved repair-maintenance systems, and value retention strategies, increasing the lifetime capacity reduces the CO_2 footprint by 5%.
- **Optimize material throughput:** resource-efficient WMs and additional use-phase optimization through smart appliances leads to 18% use-phase CO_2 improvements.
- **Material recovery (and renewable energy):** raising closed loop recycling and remanufacturing strategies and switching to renewable energy can decarbonize the washing cycle by a further 51%.

Maximizing the utilization (lever 4) in terms of lifetime washing cycles per WM decreases the amount of WMs used to meet the same demand as in the BAU scenario. The effect results from underlying levers: (a) **Designing for lifetime and quality** (lever 1): subscription models convert one-off sales into revenue generation over the lifecycle, which incentivizes design for lifetime and quality. Lifecycle access to the WM and servicing can lead to additional design for circularity (modularity, repairability) being considered in the design stages. (b) **Improved repair-maintenance systems** (lever 3): subscription model providers can improve the repair maintenance system through predictive and preventive maintenance and upgrades, as well as a more professional handling of transport and installation. (c) **Reuse and refurbish** (lever 6): subscription model providers can establish reuse/refurbishment models, which will extend the lifetime of WMs. Refurbishment and reconditioning upon end of contract can secure the WMs' functionality while keeping the material base.

Optimizing material throughput and energy efficiency (lever 5) has the highest impact on the CO_2 footprint of a WM: electricity and detergent use make up the highest share of use-phase emissions and can be optimized. Top-of-the-line WM models that are made affordable in subscriptions have higher energy efficiency and reduced water consumption which contributes to resource efficiency in the use-phase. Furthermore, built-in technical features such as auto-dosing systems can significantly reduce the amount of detergents used. Energy efficiency per washing cycle improves by 11%, detergent use decreases by 57% p.a., and water consumption by 13% p.a.[176] Further design optimizations with respect to use-phase resource efficiency can be obtained through enhancing the connectivity of WMs with data analytics to advise the customer on use-phase behaviour. Furthermore, WM subscription providers can continuously implement product updates to optimize energy and water savings. Reconditioning WMs to as-new conditions including exchanging worn-out parts and including resource-efficient hard- and software that increases lifetime efficiency can be an additional strategy to decarbonize the use phase.

Increasing the material recovery and value retention in the loop phase through remanufacturing (lever 7) and closed loop recycling (materials are recycled and reintroduced to the production process of a WM (lever 2)) decreases the CO_2 footprint in the build phase by 16% (2% of overall footprint). High and stable WM return rates through retained ownership facilitate the loop phase optimization.

- **Remanufacturing** of parts and components with a high inherent value can decrease energy and material consumption by up to 80% compared with producing new ones.[178] In the model, 20% of electronic components and motors are remanufactured to as-new conditions, saving materials and embedded energy. Technological progress in the components must be reflected in the remanufacturing of parts: only if they achieve a similar lifecycle efficiency to new components does remanufacturing make sense. Design for modularity increases this potential.

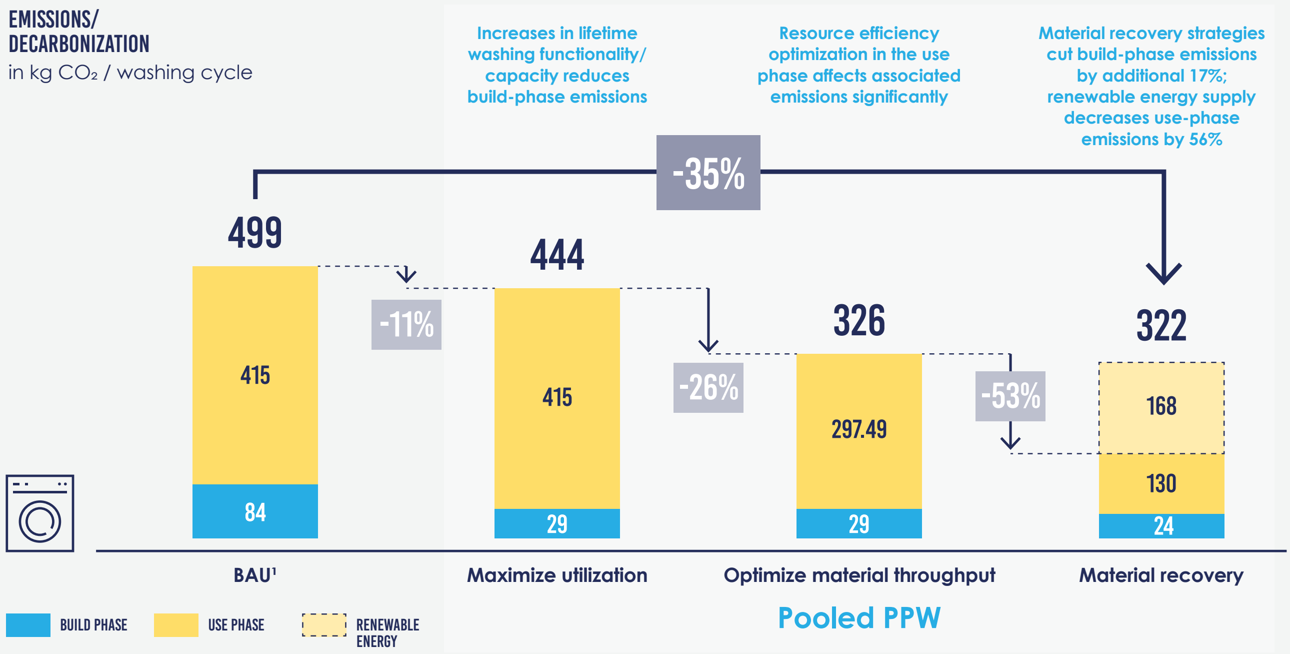
- **Recycling** of end-of-life materials (especially metals and to some extent plastics) and introducing them into closed loops (i.e. secondary materials used in the production of new machines) can decrease the CO_2 footprint. Increasing the share of secondary materials as input factors (metals by 30%, plastics by 10%) reduces the build-phase emissions by 13%.

Additionally, bundling renewable energy in the service offer through cooperation with a green electricity provider could drastically reduce use-phase emissions (57%). Decarbonizing electricity in the use phase is crucial for improving the residential and laundry-related CO_2 footprint. Integrating a renewable energy contract into the subscription service bundle can be a significant lever for contributing to widespread adoption of renewable energy in households.

Pooled Pay-per-Wash (PPW): deep dive insights from optimizing the product and operating model

EXHIBIT 32

A circular Pooled Pay-Per-Wash model can decarbonize the residential laundry CO_2 footprint by 35%.



	BAU	Maximize utilization	Optimize material throughput	Material recovery
LEVERS	N/A	**Increasing the lifetime functionality in terms of washing cycles and pooling five households on one WM**	**Nudging resource-efficient washing behaviour and increasing lifetime energy efficiency, water reduction, and optimized detergent use**	**Enhancing the material recovery and value retention in the loop phase and bundling renewable energy contracts**
LEVER ASSUMPTIONS	N/A	• 8,000 lifetime cycles • 198 cycles p.a. (-10%) Five households access one WM in common residential area	• Detergent use: 9.4 kg/year • Water: 10.4 m³/year • Electricity: 0.66 kWh/cycle	• Closed loop recycling: 30% of metals, 10% of plastics • Remanufacturing: 20% of components • [Renewable energy instead of European electricity mix]
MAIN EFFECTS	Electricity and detergent consumption determine use-phase CO_2 emissions; water consumption plays a significant role from a resource-use perspective	As a result of increasing the lifetime capacity and demand pooling, only 3,400 WMs are required to provide the same baseline utility as 10,000 WM, saving 1,500 t CO_2 emissions embedded in the build phase (materials and energy)	High-quality WMs lead to a more resource-efficient use phase. Smart analytics and consumer behaviour information entails further energy efficiency and improved detergent use.	Due to retained ownership of the WM, end-of-life material recovery and value retention can be increased, saving 118 t CO_2 per year. Including renewable energy contracts in the offer reduces use-phase emissions significantly.

[1] BAU: 70 kg WM (10,000 washing machines produced p.a. as baseline), 220 washing cycles per year, 2,750 lifetime washing cycles (12.5 years), detergent use: 16.5 kg, electricity: 0.84 kWh/cycle, water: 11.7 m³ per year (Sigüenza et al. 2021)

Source: SYSTEMIQ analysis, Sigüenza et al. (2021), Bocken et al. (2018), Homie (2021).

A circular Pooled PPW scenario can decrease emissions per washing cycle by 35% (Exhibit 32). The effects are again clustered into three main lever bundles and applied cumulatively: maximize utilization, optimize material throughput, and material recovery with a renewable energy supply.

- **Maximize utilization:** providing access to high-quality WMs in a common washing area of a residential unit while customers are incentivized by the pricing per cycle to wash more efficiently maximizes the utilization; coupled with lifetime extension strategies (refurbishment, lifecycle servicing) increases the lifetime functionality, this decreases the footprint by 11%.

- **Optimize material throughput:** use-phase resource-efficiency is driven by high-quality WMs connected to smart appliances optimizing the customer's resource consumption, in sum reducing CO_2 emissions per cycle by 26%.

- **Material recovery and renewable energy:** increasing the share of secondary materials from recovered materials and switching to renewable energy can further decarbonize the washing cycle by 53%.

Maximizing the utilization (lever 4) in terms of lifetime washing cycles per WM decreases the amount of WMs used to provide the same washing demand as in the BAU scenario by 66% (3,400 WMs instead of 10,000). This is achieved through more efficient customer usage and pooling five households on one WM coupled with advanced lifecycle servicing.

- **Pay-per-Wash business models incentivize customers through pricing per cycle to wash more efficiently and ultimately less.** It is estimated that a PPW model can decrease washing cycles by up to 20%[iv].[106] Combining PPW schemes with shared laundromats to leverage unused capacities can be facilitated by applications that connect WMs with users – as offered by WeWash, a spin-off by BSH Hausgeräte.[109] Communal laundry rooms are widely applied in Sweden as evidenced by estimated 200,000 shared WMs and the fact that only 75% of households own a WM (EU average is ~90%).[102,179]

- **Designing for lifetime and quality (lever 1)**: Seeing the WM in a PPW model as a revenue-generating asset that maximizes revenue per lifecycle increases incentives for producers to include design-to-last and design-for-modularity principles. Components that limit the useful life of the WM such as the motor, bearings, circuit board, or pump can be built in modularly to be replaced once these show signs of technical failure. Accordingly, cost increases are included in the TCO modelling (section 4.3.2.) by the same factor as the lifetime extension.

- The effects from the WM subscription scenario for improved **repair-maintenance systems** (lever 3) and **reuse and refurbish** (lever 6) apply equally. Additionally, the connectivity of the WM enables analytics that can provide important information on the state of health of the WM. These can be used for diagnostics and predictive maintenance for the WM, extending the useful life.

vi In this modelling scenario, the lower bound of the reduction (10%) is assumed.

As in the WM subscription scenario, optimizing material throughput and energy efficiency (lever 5) has a significant impact on the CO_2 footprint of a WM: an additional 26% of the lifecycle CO_2 can be saved per washing cycle. High-quality WM models with higher energy efficiency and reduced water consumption are employed. An auto-dosing system reduces the amount of detergents used. Energy efficiency per washing cycle improves by 27%, detergent use decreases by 76% p.a., and water consumption by 13% p.a.[176] Pay-per-Wash requires that the WM is connected to a smart metering device at the outlet, which can generate real-time user data to provide insights on more efficient washing behaviour (i.e. reduced wash temperature, optimal wash loads). At the same time, price incentives to nudge customers to use more energy-efficient eco modes can be applied.[108] Providing product updates to optimize energy and water savings and reconditioning WMs to as-new conditions can increase lifetime efficiency.

Increasing the material recovery and value retention in the loop phase through remanufacturing and closed loop recycling (lever 7) decreases the CO_2 footprint in the build phase by 17% (1% of overall footprint). High and stable return rates facilitate the loop phase optimization. Using returned materials and components for value retention and recovery and ultimately as input (lever 2) can decrease virgin material consumption and associated emissions.

Additionally, using renewable energy could drastically reduce use-phase emissions (by 56%) and the overall footprint by 52%. This highlights the importance of decarbonizing electricity in the use phase. Functionally bundling services within an integrated service offer that aims to decarbonize the use phase of the product is a critical enabler of systematically improving the sustainability of products. Hence, cooperating with a renewable energy provider and integrating a renewable energy contract into the PPW service bundle can significantly decarbonize laundry. The same applies to a potential roll-out of smart meters. Provided that questions surrounding data security are clarified and cooperation between the smart meter provider and the PPW provider enables the set-up, bundling such offers in a smart way can have systemic effects on lifecycle environmental impacts of WMs. Both provider and customer must benefit from the smart meter roll-out as a precondition.

APPENDIX D: SUPPORTING MATERIAL TO CHAPTER 5

Policy measures to support XaaS models and circularity (Section 5.2.2)

Three key policy instruments can support the shift towards circular and sustainable XaaS models: (1) economic and market instruments, (2) regulatory instruments and standards, as well as (3) informational instruments and awareness raising. Table 1 summarizes a set of key policy enablers along the three instruments and corresponding sub-categories. The overview highlights whether these policy actions enable XaaS models in general (e.g. stimulate producer ownership or provide fiscal incentives for Pay-per-Use models), or rather the underlying circularity value levers that help to optimize product and operating models for the circular economy (e.g. recycled content quotas). Several policy actions could be implemented in the relative short term, some in the medium or long term. It is necessary to further evaluate which of these measures could be implemented at European, national and regional policy levels. Some of these instruments could be cross-cutting (e.g. fiscal incentives such as resource taxes) while others could be sector- or product-specific (e.g. EPR systems).

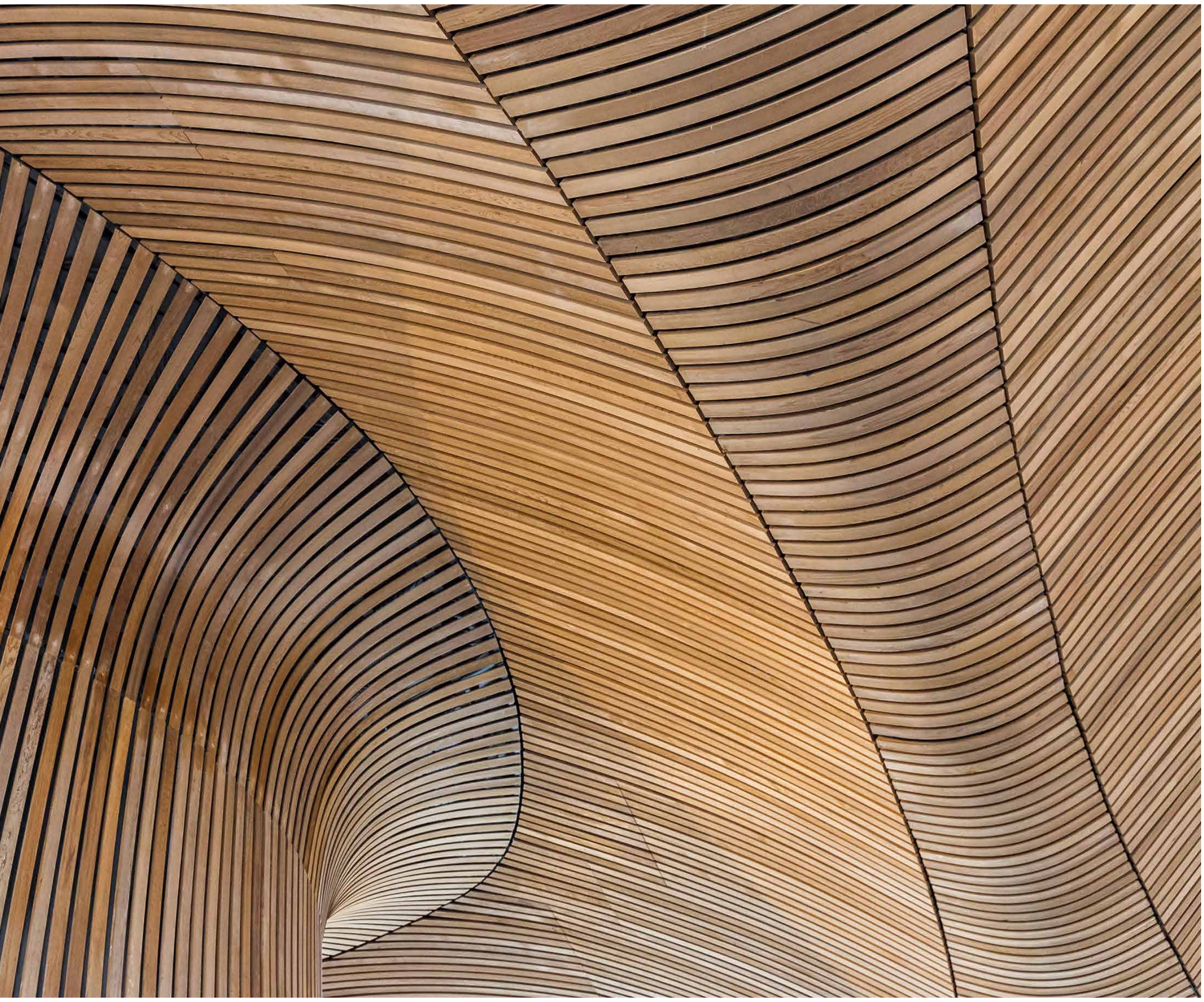


TABLE 1

Potential XaaS policy actions along three policy instruments.

XAAS POLICY ENABLERS	SUB-CATEGORIES	NO.	ELEMENTS	XAAS BUSINESS MODEL (OVERALL)	PRODUCT/OPERATING MODEL (SPECIFIC CIRCULARITY LEVERS)	TIMEFRAME
I. ECONOMIC AND MARKET INSTRUMENTS	FISCAL	1	Improve policy principles to better reflect any costs associated with environmental and health impacts ("externalities"), e.g. through higher carbon pricing or resource taxes. Use the revenues to increase (social) spending.[1]	X		LONG TERM
		2	Adjust value added tax (VAT) requirements to economic conditions of shared services.[2]	X		SHORT TERM
		3	Link value added tax (VAT) rates to environmental characteristics of products and services.[3]	X		MEDIUM TERM
		4	Reduce value added tax (VAT) for labour-intensive repair and maintenance services, and remanufactured goods.[2,4,6]		X	SHORT TERM
		5	Provide tax incentives for consumers to buy or use products which are recycled or certified as fair trade.		X	MEDIUM TERM
		6	Establish partial refund schemes (Repair Bonus) on repair costs.[7]		X	SHORT TERM
		7	Promote reusable systems (e.g. packaging, shipping).[3]		X	SHORT TERM
		8	Disincentivise short-lived goods[8] especially for non-essential products and where substitute materials are available.	X		SHORT TERM
		9	Adjust waste taxes. Examples include landfill and incineration taxes, disposal bans on certain products or materials, packaging taxes and pay-as-you-throw schemes.[9]	X		MEDIUM TERM
		10	Include characteristics of XaaS models with sustainability impacts (e.g. producer ownership) in the CE taxonomy on sustainable finance.	X		SHORT TERM
	FUNDING/ GRANTS & TRAINING	11	Ensure government funding of leasing, sharing, and other XaaS models[3,4,5], also sector-specific (e.g. chemical leasing)[3,10] to help companies innovate at low costs .	X		SHORT TERM
		12	Invest in new corporate and interorganisational innovation spaces for developing, experimenting with, and evaluating radical new service business models linked to circular value creation (e.g. maintenance, upgrading, repair).[8]	X		SHORT TERM
		13	Dedicate financial business support schemes to start-ups/ SMEs to ease initial burden of acquiring high-quality products and provide space to validate the business model. The financial instruments should be linked to specific requirements, such as the purchase of assets with a higher product lifespan, level of durability and potential for reuse, remanufacture.[2]	X		SHORT TERM
		14	Support demonstration projects by companies using track-and-trace and life cycle information about products-in-use to improve take-back services, planning of remanufacturing processes, and replacement of primary production within remanufacturing.[8]	X		SHORT TERM
		15	Provide funding to producers or third-party actors in support of the operation of repair networks with nationwide accessibility.[8]		X	SHORT TERM
		16	Fund repair cafes and facilities (potential XaaS ecosystem partners).[3,11]		X	SHORT TERM
		17	Fund research on and practical implementation of second-life business models.[8]		X	SHORT TERM
	GOVERNMENT PROCUREMENT	18	Support the demonstration and diffusion of digital technologies (e.g. artificial intelligence) in the recovery sector to improve material recognition and sorting as a basis for high-quality recycling and, where necessary, cover necessary adaptations of product designs (e.g. markers as a basis).[8]		X	MEDIUM TERM
		19	Invest in local recycling infrastructure e.g. through grants for the development and demonstration of advanced high-tech collection/sorting technology to improve recycling quality and quantity.[3]		X	SHORT TERM
		20	Adjust tendering rules allowing municipalities to purchase XaaS models.[2]	X		SHORT TERM
		21	Agree on targets/quotas for government procurement regarding used, remanufactured, and recycled products and related preferences for XaaS business model contracts over traditional goods purchases.[5,8]	X		SHORT - MEDIUM TERM
		22	Have a preference or define quota for the procurement of goods with high amounts of certified, high-quality recycled content (i.e. labelled).[3]		X	MEDIUM TERM

Source: SYSTEMIQ collation based on Circular Economy Initiative Deutschland (2021).

XAAS POLICY ENABLERS	SUB-CATEGORIES	NO.		XAAS BUSINESS MODEL (OVERALL)	PRODUCT/OPERATING MODEL (SPECIFIC CIRCULARITY LEVERS)	TIMEFRAME
II. REGULATORY INSTRUMENTS & STANDARDS	WASTE LAW	23	Implement general obligation for producers to take back products (combined with EPR) to prevent waste status.[4,8]	X		MEDIUM - LONG TERM
		24	Extend EPR to further goods categories (e.g. furniture, textiles, construction materials).[12]	X		MEDIUM TERM
		25	Ensure registry of foreign producers active in online marketplaces for ensuring their participation in EPR.[13]	X		MEDIUM TERM
		26	Include eco-modulation fees in EPR systems and evaluate how eco-modulation could be used to incentivise producer ownership.[14]	X		MEDIUM TERM
		27	Set Circular/Electronic Product Passports (product composition incl. toxins; repair, dismantling, and recycling properties/procedures)[8] as extended information requirements for market access.[13]	X		MEDIUM TERM
		28	Redefine definition of waste, when a product becomes waste, and end-of-waste status.[15]	X		MEDIUM TERM
		29	Define guaranteed timeframes for availability of spare parts to 30 years.[8]		X	SHORT TERM
		30	Establish binding quantitative targets for preparation for reuse of products away from recycling.[16]		X	MEDIUM TERM
		31	Integrate definitions and standards to prevent waste status of returned components/cores (i.e returned "cores" are not waste) and distinguish product categories of remanufactured, used, and newly manufactured goods in international trade.[17]		X	MEDIUM TERM
		32	Introduce further material-specific recycling quotas to increase recycling quality.[13]		X	SHORT TERM
	ECODESIGN LAW	33	Strengthen the design for reparability, modularity and upgradability requirements[4,13] also for electronic goods.[10]		X	SHORT TERM
		34	Ensure discrimination-free accessibility of manuals, spare parts, and repair tools, also for third-party repair facilities.[3,4,13]		X	MEDIUM TERM
		35	Define minimum lifetime of goods and critical components.[13]		X	MEDIUM TERM
		36	Regulate the amount of recycled content in products (e.g. packaging), using approaches such as quotas.[8]		X	MEDIUM-LONG TERM
		37	Assess circular criteria (e.g. reparability, recyclability) in EU product registry for market access (i.e. "Conformité Européenne"/CE marking).[8]		X	MEDIUM-LONG TERM
		38	Increase recyclate quality by eliminating/ reducing human and environmental toxicological harmful substances (Design of Lowest Toxicity).[3,4,10]		X	MEDIUM TERM
		39	Extend legal warranties to planned technical lifetime; to three years for all goods, or five years for selected goods[7,13] as incentive for service business models.	X		MEDIUM TERM
		40	Implement warranty statement obligation for manufacturers and extend the limitation period for warranty claims.[3,4]	X		MEDIUM TERM
		41	Prohibit the destruction of returned products from online and offline shopping.[3]		X	SHORT TERM
	STANDARDS	42	Standards ensuring the "right to repair" for users and autonomous repair facilities should also apply to update (obsolete) software and be mandatory for more products (e.g. smartphones and computers).[10]		X	SHORT TERM
		43	Standardise and improve statements on the condition of reused, refurbished, and remanufactured products/components based on traceable data (e.g. product history tracking, product passport) and their quality assurance in order to improve transactions on online platforms and increase the confidence of market participants.[8]	X		SHORT-MEDIUM TERM
		44	Support the development of secure standards for open data formats (e.g. product passports) and related exchange of circularity-related data (e.g. product exchanges/condition, maintenance, repair).	X		SHORT TERM
		45	To prevent a lack of data privacy, producers should only collect and share data that are relevant for carrying out e.g. maintenance or performing the specific function. For this purpose, data should be layered in such a way that they can be categorised.		X	SHORT TERM
		46	Support the development of quality standards for used, remanufactured and refurbished goods by national bodies.[3,5]		X	MEDIUM TERM
		47	Establish binding quality standards for secondary materials and recycled content in end products.[8]		X	SHORT-MEDIUM TERM
		48	Develop new and refer to existing standards and certification systems for high-quality recyclates with transparency regarding physical, chemical, biological properties and quality assurance regarding toxicological properties (e.g. RAL, Cradle to Cradle).[3,10]		X	SHORT-MEDIUM TERM
		49	Implement performance-oriented standards bound by stringent environmental targets.[12]	X		MEDIUM TERM

Source: SYSTEMIQ collation based on Circular Economy Initiative Deutschland (2021).

XAAS POLICY ENABLERS	SUB-CATEGORIES	NO.		XAAS BUSINESS MODEL (OVERALL)	PRODUCT/OPERATING MODEL (SPECIFIC CIRCULARITY LEVERS)	TIMEFRAME
III. INFORMATIONAL INSTRUMENTS & AWARENESS RAISING		50	Educate public and private institutions working in finance, for example the International Accounting Standards Board (IASB) on XaaS models in order to remove barriers (i.e. adjust current depreciation rules of valuation and depreciation of retained assets).	X		MEDIUM TERM
		51	Create a product repair score including physical and digital components (i.e. upgradability) and related (mandatory) product labelling such as a product circularity score.[2] Ensure that labels retain their validity even after the first sales cycle.[8]	X		SHORT - MEDIUM TERM
		52	Foster circular knowledge development and experimentation with access- and result-oriented business models particularly targeting businesses (management and R&D level) as well as consumers.[8]	X		SHORT TERM
		53	Create eco-label for software addressing resource-efficiency and software-based obsolescence of products.[3]	X		MEDIUM TERM
		54	Ensure declaration of average product life at points of sales.[8,10]		X	MEDIUM TERM
		55	Provide information from product passports in a user-friendly way. Ensure possibility for third parties to create data interfaces to inform consumers on sustainability of their choices.		X	MEDIUM TERM

Source: SYSTEMIQ collation based on Circular Economy Initiative Deutschland (2021).

LEGEND

1 SYSTEMIQ & The Club of Rome (2020): A System Change Compass: Implementing the European Green Deal in a Time of Recovery.
2 European Commission (2016): Servitisation - pay-per-use.
3 BMU (2020): Deutsches Ressourceneffizienzprogramm III 2020 – 2023.
4 WWF Deutschland (2020): Stellungnahme des WWF Deutschland zu ProgRess III.
5 Ellen MacArthur Foundation (EMF) (2015): Delivering the circular economy: a toolkit for policymakers.
6 Ex'Tax Project (2016): New era. New plan. Europe: A fiscal strategy for an inclusive, circular economy.
7 Schrack, D., & Hansen, E. G. (2020): SDG 12 - Verantwortungsvolle Konsum- und Produktionsmuster.
8 Circular Economy Initiative Deutschland (2021).
9 Pouikli, K. (2020) Concretising the role of extended producer responsibility in European Union waste law and policy through the lens of the circular economy.
10 European Commission (2020): Circular Economy Action Plan.
11 Beyer, P. & Kopytziok, N. (2005): Abfallvermeidung und -verwertung durch das Prinzip der Produzentenverantwortung.
12 The UCL Green Innovation Policy Commission Innovation for a Green Recovery (2020: Innovation for a Green Recovery: Business and Government in Partnership A Business Perspective on Public Policy and Governance of Green Innovation).
13 Sachverständigenrat Umwelt (SRU) (2020): Kreislaufwirtschaft: Von der Rhetorik zur Praxis.
14 Micheaux H, Aggeri F. (2020) Eco-modulation as a driver for eco-design: A dynamic view of the French collective EPR scheme.
15 European Commission (2020): Circular Economy Action Plan.
16 The Reuse and Recycling EU Social Enterprises network (RREUSE) (2015): Putting re-use and repair at the heart of the EU's Circular Economy Package
17 European Union (2017): Promoting Remanufacturing, Refurbishment, Repair, and Direct Reuse: As a contribution to the G7 Alliance on Resource Efficiency.

ABBREVIATIONS

EPR: Extended Producer Responsibility.
RAL: RAL Deutsches Institut für Gütesicherung und Kennzeichnung – German Institute for Quality Assurance and Certification
REACH: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
SVHC: Substances of Very High Concern (as specified by European REACH regulation).

Source: SYSTEMIQ collation based on Circular Economy Initiative Deutschland (2021).

REFERENCES

EXECUTIVE SUMMARY

1. Stahel W. (2010). The Performance Economy: 2nd Edition. Palgrave Macmillan.
2. Tukker A. (2015). Product services for a resource-efficient and circular economy – A review. Journal of Cleaner Production 97: 76-91.
3. Bocken N, et al. (2016). Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering 33 (5): 308-320.
4. Geissdoerfer M, et al. (2017). The Circular Economy – A new sustainability paradigm? Journal of Cleaner Production 143: 757-768.
5. United Nations Environment Programme (UNEP). (2020). Emissions Gap Report 2020. https://www.unep.org/emissions-gap-report-2020.
6. European Commission (EC). (2021). 2030 Climate Target Plan. https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en, accessed May 2021.
7. The White House. (2021). Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/, accessed May 2021.
8. Norwegian Government: Department for Climate Change. (2020). Norway steps up 2030 climate goal to at least 50 % towards 55 %. https://www.regjeringen.no/en/aktuelt/norge-forsterker-klimamalet-for-2030-til-minst-50-prosent-og-opp-mot-55-prosent/id2689679/, accessed May 2021.
9. International Resource Panel (IRP). (2017). Assessing Global Resource Use: A Systems Approach to Resource Efficiency and Pollution Reduction. https://www.resourcepanel.org/reports/assessing-global-resource-use.
10. IRP. (2019). Global Resources Outlook 2019: Natural Resources for the Future We Want. https://www.resourcepanel.org/reports/global-resources-outlook.
11. Meinrenken C, et al. (2020). Carbon emissions embodied in product value chains and the role of Life Cycle Assessment in curbing them. Scientific Reports 10 (1).
12. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). (2016). Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard - Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. https://ghgprotocol.org/standards/scope-3-standard.
13. MSCI Research. (2020). Scope 3 Carbon Emissions: Seeing the Full Picture. https://www.msci.com/www/blog-posts/scope-3-carbon-emissions-seeing/02092372761, accessed May 2021.
14. McKinsey & Company. (2020). How COVID-19 has pushed companies over the technology tipping point—and transformed business forever. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever, accessed May 2021.
15. Domenech T, et al. (2019). Making Materials Work for Life – Introducing Producer Ownership. https://www.systemiq.earth/resource-category/materials/.
16. EC. (2018). Study on the Potential of Servitisation and Other Forms of Product-Service Provision for EU Small and Medium-Sized Enterprises. https://ec.europa.eu/growth/content/study-potential-servitisation-and-other-forms-product-service-provision-eu-small-and-medium_en.
17. McKinsey & Company. (2020). Customer Centricity as Key for the Digital Breakthrough: What End-Customer Industries Expect from Mechanical Engineering Companies on Platforms and Apps. https://www.mckinsey.com/industries/advanced-electronics/our-insights/digitization-how-machinery-companies-can-meet-customers-expectations.
18. IoT Analytics. (2020). Entering the Decade of Equipment as a Service – Characteristics of the Machine Outcome Economy. https://iot-analytics.com/entering-the-decade-of-equipment-as-a-service/.

19. Arbib J & Seba T. (2017). Rethinking Transportation 2020-2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries. https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/591a2e4be6f2e1c13df930c5/1494888038959/RethinkX+Report_051517.pdf.

20. Siemens AG. (2021). Siemens to introduce sustainable and flexible company car policy. https://press.siemens.com/global/en/pressrelease/siemens-introduce-sustainable-and-flexible-company-car-policy, accessed June 2021.

21. City of Helsinki. (2020). Smart mobility in Helsinki. https://www.myhelsinki.fi/en/business-and-invest/invest/smart-mobility-in-helsinki, accessed June 2021.

22. Strategy&. (2021). The 2020 Digital Auto Report: Navigating through a Post-Pandemic World. https://www.strategyand.pwc.com/de/de/studie/2020/digital-auto-report-2020.html.

23. Ekins P, et al. (2020). Innovation for a Green Recovery: Business and Government in Partnership. https://www.ucl.ac.uk/bartlett/public-purpose/publications/2021/jan/innovation-green-recovery-business-and-government-partnership.

24. EC. (n.d.). Single market and standards: Public Procurement https://ec.europa.eu/growth/single-market/public-procurement_en, accessed May 2021.

25. Circular Economy Initiative Deutschland (CEID). (2020). Circular Business Models: Overcoming Barriers, Unleashing Potentials. https://static1.squarespace.com/static/5b52037e4611a0606973bc79/t/608a9b723926032d9f74aea2/1619696523596/GM_Gesamtbericht+EN.

26. EC. (n.d.). Green growth and circular economy. https://ec.europa.eu/environment/green-growth/index_en.htm, accessed May 2021.

MAIN REPORT

1. Bundesverband der Deutschen Industrie (BDI). (2020). Global Value Chains under Pressure. https://english.bdi.eu/article/news/global-value-chains-under-pressure/, accessed May 2021.

2. World Trade Organization (WTO). (2015). Germany Trade in Value Added and Global Value Chains. https://www.wto.org/english/res_e/statis_e/miwi_e/DE_e.pdf.

3. Bohn J. (2020). Global supply chain trends and the impact of COVID-19. (2020). https://www.swissre.com/dam/jcr:3d1d496a-16f1-4534-8d4c-e784b719cac8/jeffrey-bohn-presentation-english.pdf.

4. Bentzien H. (2021). Ifo: Lieferengpässe könnten Aufschwung der Industrie bremsen. Dow Jones Newswires. https://www.finanzen.at/nachrichten/aktien/ifo-lieferengpaesse-koennten-aufschwung-der-industrie-bremsen-1030377214, accessed May 2021.

5. McKinsey & Company. (2019) The commercial response to cost volatility: How to protect margins against inflation and tariffs. https://www.mckinsey.com/business-functions/marketing-and-sales/our-insights/the-commercial-response-to-cost-volatility, accessed May 2021.

6. TRACC. (2020). Rising raw material costs – strategies to address its impact. https://traccsolution.com/blog/raw-material-costs/, accessed May 2021.

7. European Commission (EC). (n.d.). Internal Market, Industry, Entrepreneurship and SMEs: The single market strategy. https://ec.europa.eu/growth/single-market/strategy_en, accessed May 2021.

8. Guinea O & Erixon F. (2019). Standing up for Competition: Market Concentration, Regulation, and Europe's Quest for a New Industrial Policy. European Centre for International Political Economy (ECIPE) occasional papers. https://ecipe.org/publications/standing-up-for-competition/.

9. McKinsey & Company. (2017). Digital machinery: How companies can win the changing manufacturing game. https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/digital-machinery-how-companies-can-win-the-changing-manufacturing-game, accessed May 2021.

10. Dorst W, et al. (Plattform Industrie 4.0). (2019). Digital business models for Industrie 4.0. Federal Ministry for Economic Affairs and Energy (BMWi). https://www.bmwi.de/Redaktion/EN/Publikationen/Industry/digital-business-models-industry-4-0.pdf?__blob=publicationFile&v=3.

11. McKinsey & Company. (2020). Industry 4.0: Reimagining manufacturing operations after COVID-19. https://www.mckinsey.com/business-functions/operations/our-insights/industry-40-reimagining-manufacturing-operations-after-covid-19, accessed May 2021.

12. McKinsey & Company. (2020). How COVID-19 has pushed companies over the technology tipping point—and transformed business forever. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever, accessed May 2021.

13. Antikainen M, et al. (2018). Digitalisation as an Enabler of Circular Economy. Procedia CIRP 73, 45–49 (2018).

14. International Energy Agency (IEA). (2021). Global Energy Review 2021. https://www.iea.org/reports/global-energy-review-2021.

15. United Nations Environment Programme (UNEP). (2021). Making Peace With Nature. https://www.unep.org/resources/making-peace-nature.

16. EC. (2021). 2030 Climate Target Plan. https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en, accessed May 2021.

17. The White House. (2021). Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/, accessed May 2021.

18. Norwegian Government: Department for Climate Change. (2020). Norway steps up 2030 climate goal to at least 50 % towards 55 %. https://www.regjeringen.no/en/aktuelt/norgeforsterker-klimamalet-for-2030-til-minst-50-prosent-og-oppmot-55-prosent/id2689679/, accessed May 2021.

19. Eurostat. (2021). Data browser: Air emissions accounts by NACE Rev. 2 activity. https://ec.europa.eu/eurostat/databrowser/view/env_ac_ainah_r2/default/table?lang=en, accessed May 2021.

20. World Economic Forum (WEF). (2021). Circular economy for Net-zero industry transition. https://ceclimate.weforum.org/, accessed May 2021.

21. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). (2016). Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard - Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. https://ghgprotocol.org/standards/scope-3-standard.

22. Meinrenken C, et al. (2020). Carbon emissions embodied in product value chains and the role of Life Cycle Assessment in curbing them. Scientific Reports 10 (1).

23. Jungmichel N, et al. (2017). Umweltatlas Lieferketten: Umweltwirkungen und Hot-Spots in der Lieferkette. adelphi & Systain Consulting GmbH. https://www.adelphi.de/de/system/files/mediathek/bilder/Umweltatlas%20Lieferkette%20-%20adelphi-Systain.pdf.

24. World Economic Forum (WEF). (2021). Circular economy for Net-zero industry transition. https://ceclimate.weforum.org/, accessed May 2021.

25. Potocnik J & Okatz J. (2021). The benefits of a circular economy for effective climate action and society. Green Policy Platform. https://www.greengrowthknowledge.org/blog/benefits-circular-economy-effective-climate-action-and-society, accessed May 2021.

26. The Ellen MacArthur Foundation (EMF). (2015). Towards a Circular Economy - Economic and Business Rationale for an Accelerated Transition. https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf.

27. Aubertin C. (2019). From Product to Product-as-a-Service. Medium. https://medium.com/swlh/from-product-to-product-as-a-service-37baed471cd6, accessed May 2021.

28. Deloitte Insights. (2007). The service revolution: Manufacturing's missing crown jewel. Deloitte Review (1). https://www2.deloitte.com/us/en/insights/deloitte-review/issue-1/the-service-revolution.html.

29. Geissdoerfer M, et al. (2018). Business models and supply chains for the circular economy. Journal of Cleaner Production 190, 712-721.

30. Bocken N, et al. (2016). Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering 33 (5), 308-320.

31. EMF. (2017). The Circular Economy in Detail. https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail, accessed May 2021.

32. Circular Economy Initiative Deutschland (CEID). (2020). Circular Business Models: Overcoming Barriers, Unleashing Potentials. https://static1.squarespace.com/static/5b52037e4611a0606973bc79/t/608a9b723926032d9f74aea2/1619696523596/GM_Gesamtbericht+EN.

33. EC. (n.d.). Green growth and circular economy. https://ec.europa.eu/environment/green-growth/index_en.htm, accessed May 2021.

34. International Resource Panel (IRP). (2019). Global Resources Outlook 2019: Natural Resources for the Future We Want. https://www.resourcepanel.org/reports/global-resources-outlook.

35. Stojkovski I. (2021). Equipment as a service: The transition towards usage-based business models. Available at SSRN: https://ssrn.com/abstract=3763004 or http://dx.doi.org/10.2139/ssrn.3763004.

36. Geissdoerfer M, et al. (2018). Sustainable business model innovation: A review. Journal of Cleaner Production 198, 401–416.

37. ASML. (2021). Circular economy: Minimizing waste, maximizing resources. https://www.asml.com/en/company/sustainability/circular-economy, accessed May 2021.

38. Mitsubishi Elevator Europe. (2021). M-Use®: elevator leasing according to a unique circular model. https://www.mitsubishi-elevators.com/m-use/, accessed May 2021.

39. Patala S, et al. (2016). Sustainable value propositions: Framework and implications for technology suppliers. Industrial Marketing Management 59, 144–156.

40. Drucker P. (1993). Management: Tasks, Responsibilities, Practices. Harper Business.

41. IDEO & EMF. (2017). Service Flip. Circular Design Guide. https://www.circulardesignguide.com/post/service-flip, accessed May 2021.

42. Griffin A & Hauser J. (1993). The Voice of the Customer. Marketing Science 12, 1–27.

43. CWS International GmbH. (2021). CWS Hygiene - Waschräume optimieren. https://www.cws.com/de-DE/hygiene/waschraume-optimieren, accessed May 2021.

44. CWS International GmbH. (2021). CWS Workwear: Mehr Klimaschutz dank Mietkreislauf. https://www.cws.com/de-DE/news/cws-workwear-mehr-klimaschutz-dank-mietkreislauf-2021-05-31, accessed May 2021.

45. Koninklijke Philips N.V. (2021). Decoupling growth from resource consumption. https://www.philips.com/a-w/about/sustainability/circular-economy.html, accessed May 2021.

46. Hilti Group. (n.d.). Ihr bedarfsorientiertes Flottenmangement - viel mehr als ein Werkzeug-Leasing. https://www.hilti.de/content/hilti/E3/DE/de/services/tool-services/elektrowerkzeuge-flottenmanagement.html, accessed May 2021.

47. Stahel W. (2010). The Performance Economy: 2nd Edition. Palgrave Macmillan.

48. Bain & Company. (2019). Choosing the Right Pricing Model for Equipment as a Service. https://www.bain.com/insights/choosing-the-right-pricing-model-for-equipment-as-a-service/, accessed May 2021.

49. Tukker A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment 13, 246–260.

50. Kaeser Kompressoren. (2021). Betreibermodell: SIGMA AIR UTILITY. https://www.kaeser.de/produkte/betreibermodell-sigma-air-utility/, accessed May 2021.

51. PR Newswire. (2020). Global sharing economy revenues could hit $335 billion by 2025. Bloomberg. https://www.bloomberg.com/press-releases/2020-12-07/global-sharing-economy-could-reach-335-billion-by-2025, accessed May 2021.

52. Grover Group GmbH. (2021). Choose. Use. Recirculate. Get the tech you want whenever you need it. Simply, flexibly, sustainably. https://www.grover.com/de-en/how-it-works, accessed May 2021.

53. Circularity Capital LLP. (2021). Grover - circular business model. https://circularitycapital.com/grover-portfolio, accessed May 2021.

54. Lunden I. (2021). Grover raises $71M to grow its consumer electronics subscription business. TechCrunch. https://techcrunch.com/2021/04/12/grover-raises-71m-to-grow-its-consumer-electronics-subscription-business/, accessed May 2021.

55. BNP Paribas. (2018). Leasing: a rental and financing method in line with the circular economy. https://group.bnpparibas/en/news/leasing-rental-financing-method-line-circular-economy, accessed May 2021.

56. Intesa Sanpaolo. (2021). Support to the Circular Economy. https://group.intesasanpaolo.com/en/sustainability/environment/green-products/support-to-circular-economy, accessed May 2021.

57. Intesa Sanpaolo. (n.d.). Nasce Intesa Sanpaolo Rent Foryou. https://www.intesasanpaolo.com/it/business/landing/info/rent-foryou.html, accessed May 2021.

58. Munich Re. (2020). Pay-per-part: TRUMPF and Munich Re plan new business model for the manufacturing industry. https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2020/2020-10-14-pay-per-part.html, accessed May 2021.

59. Siemens. (2021). Deep dive: Discover the full potential of our energy and performance services - Matrin Kruska presenting new business and financing models. https://new.siemens.com/global/en/company/topic-areas/smart-infrastructure/energy-and-performance-services.html, accessed May 2021.

60. Yang M & Evans S. (2019). Product-service system business model archetypes and sustainability. Journal of Cleaner Production 220, 1156–1166.

61. IRP. (2018). Re-defining Value – The Manufacturing Revolution. https://www.resourcepanel.org/reports/re-defining-value-manufacturing-revolution.

62. BMW Group. (2021). A New Era, a New Class: BMW Group steps up technology offensive with comprehensive realignment – uncompromisingly electric, digital and circular. https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2021/bericht/BMW_Group_PR_Annual_Conference_2021.pdf.

63. BCG Henderson Institute. (2019). Do You Need a Business Ecosystem? https://www.bcg.com/publications/2019/do-you-need-business-ecosystem, accessed May 2021.

64. Raddats C, et al. (2019). Servitization: A contemporary thematic review of four major research streams. Industrial Marketing Management 83, 207–223.

65. European Investment Bank (EIB). (2020). Financing the digitalisation of small and medium-sized enterprises: The enabling role of digital innovation hubs. https://www.eib.org/en/publications/financing-the-digitalisation-of-smes-report.

66. Nitrobox GmbH. (2021). Servitization und Equipment-as-a-Service mit Nitrobox. https://www.nitrobox.com/de/loesungen/branchen/industrie-iot/, accessed May 2021.

67. Nitrobox GmbH. (2021). Nitrobox für Mobilitätsanbieter. https://www.nitrobox.com/de/loesungen/branchen/automobil-mobilitaet/, accessed May 2021.

68. Frishammar J & Parida V. (2021). The Four Fatal Mistakes Holding Back Circular Business Models. MIT Sloan Management Review Magazine Spring 2021 Issue. https://sloanreview.mit.edu/article/the-four-fatal-mistakes-holding-back-circular-business-models/.

69. BCG Henderson Institute. (2020). How Do You “Design” a Business Ecosystem? https://www.bcg.com/publications/2020/how-do-you-design-a-business-ecosystem, accessed May 2021.

70. IEA. (2021). Global EV Data Explorer: Projections of European EV stocks in the Sustainable Development Scenario. https://www.iea.org/articles/global-ev-data-explorer, accessed May 2021.

71. The International Council on Clean Transportation. (2021). Transport could burn up the EU's entire carbon budget. https://theicct.org/blog/staff/eu-carbon-budget-apr2021, accessed May 2021.

72. Greenpeace. (2020). Crashing the Climate. How the Car Industry is Driving the Climate Crisis. https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/gp_cleanairnow_carindustryreport_full_v5_0919_72ppi_0.pdf, accessed May 2021.

73. EMF. (2015). Growth Within: A Circular Economy Vision For A Competitive Europe. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf, accessed May 2021.

74. McKinsey & Company. (2020). The zero-carbon car: Abating material emissions is next on the agenda. https://www.mckinsey.com/business-functions/sustainability/our-insights/the-zero-carbon-car-abating-material-emissions-is-next-on-the-agenda, accessed May 2021.

75. Zwiers J, et al. (2021). Wandel des öffentlichen Verkehrs in Deutschland: Veränderung der Wertschöpfungsstrukturen durch neue Mobilitätsdienstleistungen. Eine Transformationsanalyse aus der Multi-Level-Perspektive. https://www.econstor.eu/bitstream/10419/229192/1/1744865892.pdf.

76. Bitkom. (2021). Deutschlands Landbevölkerung will neue Mobilitätsdienste. https://www.bitkom.org/Presse/Presseinformation/Deutschlands-Landbevoelkerung-will-neue-Mobilitaetsdienste, accessed May 2021.

77. Strategy&. (2021). The 2020 Digital Auto Report: Navigating through a Post-Pandemic World. https://www.strategyand.pwc.com/de/de/studie/2020/digital-auto-report-2020.html.

78. IRP. (2020). Resource Efficiency and Climate Change - Material Efficiency Strategies for a Low-Carbon Future. United Nations Environment Programme. https://www.resourcepanel.org/reports/resource-efficiency-and-climate-change.

79. IAA Mobility. (2020). The popular carsharing apps. https://www.iaa.de/en/mobility/newsroom/current-issues/news/the-popular-carsharing-apps, accessed May 2021.

80. Fromm H, et al. (2019). A Study on Free-floating Carsharing in Europe: Impacts of car2go and DriveNow on modal shift, vehicle ownership, vehicle kilometers traveled, and CO_2 emissions in 11 European cities. Karlsruhe Institute of Technology - Working Paper Series in Production and Energy No. 36. https://www.econstor.eu/handle/10419/209622.

81. Transport & Environment. (2017). Does sharing cars really reduce car use? https://www.transportenvironment.org/sites/te/files/publications/Does-sharing-cars-really-reduce-car-use-June%202017.pdf.

82. Riversimple. (2021). Business - Riversimple's purpose and circular economy. https://www.riversimple.com/business-2/, accessed May 2021.

83. WeShare. (2021). 100% elektrisches Carsharing in Berlin und Hamburg. https://www.we-share.io/, accessed May 2021.

84. Octopus Electric Vehicles. (2021). Welcome to Octopus Electric Vehicles. We offer the complete solution. https://www.octopusev.com/, accessed May 2021.

85. Renault Group. (n.d.). Mobilize - Beyond Automotive. https://www.renaultgroup.com/en/our-company/our-brands/mobilize/, accessed May 2021.

86. BloombergNEF. (2020). Electric Vehicle Outlook 2020. https://about.bnef.com/electric-vehicle-outlook/.

87. International Transport Forum (ITF). Transition to Shared Mobility: How large cities can deliver inclusive transport services. https://www.itf-oecd.org/sites/default/files/docs/transition-shared-mobility.pdf.

88. Sono Motors. (2021). Sono App: Mobility and Energy Services. https://sonomotors.com/en/sharing/, accessed May 2021.

89. Greenmove GmbH. (n.d.). Greenmove e-mobility solution. http://www.greenmove.at/, accessed May 2021.

90. EMF & Institute for European Environmental Policy (IEEP). (2021). A low carbon and circular industry for Europe. https://think2030.eu/wp-content/uploads/2021/02/Circular-economy-and-industry-WEB.pdf.

91. Whim Global. (2021). Whim: Experience the seamless way to move around. https://whimapp.com/, accessed May 2021.

92. Whim Global. (2021). Whim: Sustainable development. https://whimapp.com/sustainability/, accessed May 2021.

93. WEF. (2021). Paving the Way: EU Policy Action for Automotive Circularity. http://www3.weforum.org/docs/WEF_Circular_Cars_Initiative_Paving_the_Way_2021.pdf.

94. SYSTEMIQ & The Club of Rome. (2020). A System Change compass: Implementing the European Green Deal in a Time of Recovery. https://www.systemiq.earth/wp-content/uploads/2020/11/System-Change-Compass-full-report_final.pdf.

95. Domenech T, et al. (2019). Making Materials Work for Life – Introducing Producer Ownership. https://www.systemiq.earth/resource-category/materials/.

96. Eurostat. (2021). Data Browser: Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E). https://ec.europa.eu/eurostat/databrowser/view/sbs_na_ind_r2/default/table?lang=en, accessed June 2021.

97. Circle Economy. (2019). The Circularity Gap Report 2019. https://circulareconomy.europa.eu/platform/sites/default/files/circularity_gap_report_2019.pdf.

98. Oliver Wyman. (2020). Ride the Green Wave: Decarbonization will be one of the dominant topics of industrial equipment manufacturers in the next decade. https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2020/august/Oliver-Wyman-Ride-The-Green-Wave.pdf.

99. TRUMPF. (2020). Pay-per-part: TRUMPF and Munich Re plan new business model for the manufacturing industry. https://www.trumpf.com/en_US/press/global-press-releases/press-release-detail-page/Press/pay-per-part-trumpf-and-munich-re-plan-new-business-model-for-the-manufacturing-industry/, accessed June 2021.

100. Ecoinvent. (2020). Ecoinvent Database 3.7.1. https://www.ecoinvent.org/database/ecoinvent-371/ecoinvent-371.html, accessed June 2021.

101. Energy Transition Commisson (ETC). (2018). Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century. https://www.energy-transitions.org/publications/mission-possible/.

102. Wasserbaur R, et al. (2020). What if everyone becomes a sharer? A quantification of the environmental impact of access-based consumption for household laundry activities. Resources, Conservation and Recycling 158.

103. Pakula C & Stamminger R. (2010). Electricity and water consumption for laundry washing by washing machine worldwide. Energy Efficiency 3, 365–382.

104. Bressanelli G, et al. (2017). Reshaping the Washing Machine Industry through Circular Economy and Product-Service System Business Models. Procedia CIRP 64, 43–48.

105. BlueMovement. (2021). Rent Bosch products from €7,99 per month: a subscription to a sustainable household. https://www.bluemovement.com/nl-en, accessed June 2021.

106. Bocken N, et al. (2018). Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE. Journal of Cleaner Production 198, 498–510.

107. Homie. (n.d.). Homie - How it works. https://www.homiepayperuse.com/en/?webpage=4, accessed June 2021.

108. Homie. (n.d.). With Homie you pay per wash. And programmes that use less energy are cheaper. https://homiepayperuse.com/de/?type=5, accessed June 2021.

109. Robert Bosch GmbH. (2021). Laundry gets a new spin. WeWash connects washing machines and dryers with their users. https://www.bosch.com/stories/wewash/, accessed June 2021.

110. EMF. (2012). In-depth - Washing Machines. https://www.ellenmacarthurfoundation.org/news/in-depth-washing-machines, accessed June 2021.

111. Bundles. (2021). Miele washing machine subscriptions. https://bundles.nl/en/miele-washing-machine-subscriptions/, accessed June 2021.

112. Hagiu A & Wright J. (2020). When Data Creates Competitive Advantage. Harvard Business Review. https://hbr.org/2020/01/when-data-creates-competitive-advantage.

113. Bitkom. (2020). Industrie 4.0 – so digital sind Deutschlands Fabriken. https://www.bitkom.org/sites/default/files/2020-05/200519_bitkomprasentation_industrie40_2020_final.pdf.

114. Bauer K, et al. (Plattform Industrie 4.0). (2020). Collaborative data-driven business models: Collaborative Condition Monitoring – How cross-company collaboration can generate added value. Federal Ministry for Economic Affairs and Energy (BMWi). https://www.plattform-i40.de/PI40/Redaktion/DE/Downloads/Publikation/kollaborative-datenbasierte-geschaeftsmodelle.pdf?__blob=publicationFile&v=5.

115. German Federal Government. (2021). What is the German government doing for the climate? https://www.bundesregierung.de/breg-en/issues/climate-action/government-climate-policy-1779414, accessed June 2021.

116. EC. (2021). Sustainable products initiative. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative, accessed June 2021.

117. German Machine Tool Builders' Association (VDW). (n.d.). umati: universal machine technology interface. https://vdw.de/en/technology-and-standardisation/umati-universal-machine-technology-interface/, accessed June 2021.

118. Federal Ministry for Economic Affairs and Energy (BMWi). (n.d.). GAIA-X: A Federated Data Infrastructure for Europe. https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html, accessed June 2021.

119. BMWi. (2021). Industrie und Politik im Dialog zur digitalen Zukunft der Automobilindustrie. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/03/20210302-industrie-und-politik-im-dialog-zur-digitalen-zukunft-der-automobilindustrie.html, accessed June 2021.

120. Bergmann C (Telekom). (2021). The alliance for secure and cross-company data exchange in the automotive industry is picking up speed. https://www.telekom.com/en/media/media-information/archive/catena-x-automotive-network-620638, accessed June 2021.

121. Ekins P, et al. (2020). Innovation for a Green Recovery: Business and Government in Partnership. https://www.ucl.ac.uk/bartlett/public-purpose/publications/2021/jan/innovation-green-recovery-business-and-government-partnership.

122. Pouikli K. (2020). Concretising the role of extended producer responsibility in European Union waste law and policy through the lens of the circular economy. ERA Forum vol. 20, 491–508.

123. Frenken K & Schor J. (2017). Putting the sharing economy into perspective. Environmental Innovation and Societal Transitions 23, 3–10; Financial Times. (2013). The 'sharing economy' undermines workers' rights. https://www.ft.com/content/92c3021c-34c2-11e3-8148-00144feab7de#axzz2hmOfYAnC, accessed June 2021.

124. Domenech T, et al. (2019). Making Materials Work for Life – Introducing Producer Ownership. https://www.systemiq.earth/resource-category/materials/.

125. Ekins P, et al. (2020). Innovation for a Green Recovery: Business and Government in Partnership. https://www.ucl.ac.uk/bartlett/public-purpose/publications/2021/jan/innovation-green-recovery-business-and-government-partnership.

126. Orasmaa A, et al. (2020). Rethinking Ownership: Producer Ownership Models in a Circular Economy. https://www.sitra.fi/en/publications/rethinking-ownership/.

127. EC. (n.d.). Internal Market, Industry, Entrepreneurship and SMEs: Public Procurement. https://ec.europa.eu/growth/single-market/public-procurement_en, accessed June 2021.

128. The Guardian. (2019). France to ban destruction of unsold consumer products. https://www.theguardian.com/world/2019/jun/04/france-to-ban-the-destruction-of-unsold-consumer-products, accessed June 2021.

129. EC. (2016). Servitisation: Pay-per-use. Business Innovation Observatory. https://ec.europa.eu/docsroom/documents/16595/attachments/1/translations/en/renditions/native, accessed June 2021.

130. EC. (2015). Closing the loop - An EU action plan for the Circular Economy. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN.

131. The Re-use and Recycling EU Social Enterprises network (RREUSE). (2017). Reduced taxation to support re-use and repair. http://www.rreuse.org/wp-content/uploads/RREUSE-position-on-VAT-2017-Final-website_1.pdf.

132. Federal Ministry of the Environment (BMU). (2020). Deutsches Ressourceneffizienzprogramm III 2020-2023. https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Ressourceneffizienz/progress_iii_programm_bf.pdf.

133. Funding London. (n.d.). Greater London Investment Fund. https://glif.co/, accessed June 2021.

134. Groothuis F & Gersen P. (2016). New era. New plan. Europe. A fiscal strategy for an inclusive, circular economy. The Ex'tax Project, Cambridge Econometrics, Trucost, Deloitte, EY, KPMG Meijburg and PwC. http://www.neweranewplan.com/wp-content/uploads/2016/12/New-Era-New-Plan-Europe-Extax-Report-DEF.compressed.pdf.

135. Jalava E, et al. (2021). The EU's Sustainable product policy framework and producer ownership models are key to mainstreaming circular business models. https://www.sitra.fi/en/articles/the-eus-sustainable-product-policy-framework-and-producer-ownership-models-are-key-to-mainstreaming-circular-business-models/, accessed June 2021.

136. EU Policy Lab by Joint Research Center (JRC). A vision for the EU "Sharing Economy". https://blogs.ec.europa.eu/eupolicylab/portfolio/, accessed June 2021.

137. Micheaux H & Aggeri F. (2021). Eco-modulation as a driver for eco-design: A dynamic view of the French collective EPR scheme. Journal of Cleaner Production 289, 125714.

138. European Parliament. (2021). Ecodesign for Circular Economy. https://www.europarl.europa.eu/legislative-train/theme-new-boost-for-jobs-growth-and-investment/file-ecodesign-for-circular-economy, accessed June 2021.

139. European Environmental Bureau (EEB). (2020). A circular economy within ecological limits: Why we need to set targets to reduce EU resource consumption and waste generation in the new Circular Economy Action Plan. https://eeb.org/library/a-circular-economy-within-ecological-limits/.

140. Sigüenza C, et al. (2021). Circular business models of washing machines in the Netherlands: Material and climate change implications toward 2050. Sustainable Production and Consumption 26, 1084–1098.

141. BMU. (2020). Deutsches Ressourceneffizienzprogramm III 2020-2023. https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Ressourceneffizienz/progress_iii_programm_bf.pdf.

142. EC. (2020). Circular Economy Action Plan for a cleaner and more competitive Europe. European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0098&from=EN, accessed June 2021.

143. EC. (2016). Servitisation: Pay-per-use. Business Innovation Observatory. https://ec.europa.eu/docsroom/documents/16595/attachments/1/translations/en/renditions/native, accessed June 2021.

144. Plattform Industrie 4.0. (2021). Working Group on "Digital Business Models in Industrie 4.0". https://www.plattform-i40.de/PI40/Navigation/EN/ThePlatform/Structure-Organization/PlatformWorkingGroups/Business-Models/business-models.html, accessed June 2021.

145. Relayr. (2021). Equipment-as-a-service. https://relayr.io/equipment-as-a-service/, accessed June 2021.

146. Circuly. (2021). Circuly and the circular economy. https://www.circuly.io/circular-economy, accessed June 2021.

147. twist. (n.d.). Sell access to your products. https://www.letstwist.co/, accessed June 2021.

148. TULU. (2021). Own less, live more. https://www.tulu.io/, accessed June 2021.

149. Omocom. (n.d.). Insurance, on demand. https://www.omocom.insurance/?lang=en, accessed June 2021.

150. Hofstetter J, et al. (2021). From Sustainable Global Value Chains to Circular Economy—Different Silos, Different Perspectives, but Many Opportunities to Build Bridges. Circular Economy and Sustainability 1, 21-47.

151. Schröder P. (2020). Promoting a just transition to an inclusive circular economy. Chatham House. https://www.chathamhouse.org/2020/04/promoting-just-transition-inclusive-circular-economy.

152. International Labour Organization. (2018). World Employment and Social Outlook 2018 – Greening with jobs. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_628654.pdf.

153. CEID. (2021). Circular Economy Roadmap für Deutschland. https://www.acatech.de/publikation/circular-economy-roadmap-fuer-deutschland/.

154. Platform for Accelerating the Circular Economy. (2021). Actions Working Toward Circularity for Capital Equipment: Capital Equipment Coalition - Europe and North America. https://pacecircular.org/capital-equipment-coalition, accessed June 2021.

155. CEID. (2021). Circular Economy: A way forward. https://www.circular-economy-initiative.de/english, accessed June 2021.

156. SITRA. (2021). Strategy: Towards a fair, sustainable and inspiring future. https://www.sitra.fi/en/topics/strategy-2/, accessed June 2021.

157. Kemp R & Waybright J. (2015). Financial Accounting, Global Edition. Pearson.

158. Kirchherr J, et al. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling 127, 221–232.

159. IRP. (n.d.). Glossary. https://www.resourcepanel.org/glossary, accessed June 2021.

160. Organisation for Economic Co-operation and Development (OECD). (n.d.). Extended producer responsibility. https://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm, accessed June 2021.

161. Plattform Industrie 4.0. (2021). What is Industrie 4.0? https://www.plattform-i40.de/PI40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html, accessed June 2021.

162. EC DG for Research and Innovation. (2021). Industry 5.0: Human-centric, sustainable and resilient. https://op.europa.eu/en/publication-detail/-/publication/aed3280d-70fe-11eb-9ac9-01aa75ed71a1/language-en/format-PDF/source-search.

163. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). (2016). Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard - Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. https://ghgprotocol.org/standards/scope-3-standard.

164. MSCI Research. (2020). Scope 3 Carbon Emissions: Seeing the Full Picture. https://www.msci.com/www/blog-posts/scope-3-carbon-emissions-seeing/02092372761, accessed May 2021.

165. Coenenberg A, et al. (2016). Kostenrechnung und Kostenanalyse. Schäffer Poeschel.

166. Tukker A. (2015). Product services for a resource-efficient and circular economy – A review. Journal of Cleaner Production 97: 76-91.

167. IDEO. (n.d.). IDEO: Design thinking - resources. https://designthinking.ideo.com/resources, accessed June 2021.

168. TU Delft. (2020). Hot off the press! Delft Design Guide 2.0. https://www.tudelft.nl/en/2020/io/february/hot-off-the-press-delft-design-guide-20, accessed June 2021.

169. Stojkovski I. (2021). Equipment as a service: The transition towards usage-based business models. Available at SSRN: https://ssrn.com/abstract=3763004 or http://dx.doi.org/10.2139/ssrn.3763004.

170. KPMG AG WPG. (2017). Der neue IFRS 16. Paradigmenwechsel in der Leasingbilanzierung - in vier Schritten zur Lösung. https://assets.kpmg/content/dam/kpmg/de/pdf/Themen/2017/kpmg-ifrs-16.pdf.

171. SüdLeasing. (n.d.). IFRS 16: Next steps. https://www.suedleasing.de/fileadmin/shared/Bilder/01_Unternehmen/01_Aktuelles/IFRS_Next_Steps.pdf.

172. PricewaterhouseCoopers AG WPG. (2016). IFRS 16 – a new era of lease accounting! https://www.pwc.de/de/newsletter/kapitalmarkt/assets/in-depth-ifrs-16-a-new-era-of-lease-accounting.pdf.

173. ConnectedValue GmbH. (2020). Perspectives: Industrial Users & CFOs – Pay per use – providing machines & equipment as a Service. https://www.charge-per-use.com/?page_id=87.

174. CEID. (2020). Circular Business Models: Overcoming Barriers, Unleashing Potentials. https://static1.squarespace.com/static/5b52037e4611a0606973bc79/t/608a9b723926032d9f74aea2/1619696523596/GM_Gesamtbericht+EN.

175. Material Economics. (2018). The Circular Economy - a Powerful Force for Climate Mitigation. https://materialeconomics.com/publications/the-circular-economy-a-powerful-force-for-climate-mitigation-1.

176. Sigüenza C, et al. (2021). Circular business models of washing machines in the Netherlands: Material and climate change implications toward 2050. Sustainable Production and Consumption 26, 1084–1098.

177. Lehmann A, et al. (2019). Ökobilanzielle Bewertung des Lebensweges eines handelsüblichen weißen Baumwolle T-Shirts in Deutschland. https://www.ikw.org/fileadmin/ikw/downloads/Haushaltspflege/20190415_Oekobilanz_T-Shirt.pdf.

178. OECD. (2019). Business Models for the Circular Economy - Opportunities and Challenges For Policy. https://www.oecd-ilibrary.org/sites/e59f8dd6-en/index.html?itemId=/content/component/e59f8dd6-en.

179. Electrolux. (n.d.). A uniquely Swedish way of washing your clothes. https://www.electroluxgroup.com/en/a-uniquely-swedish-way-of-washing-your-clothes-29699/, accessed June 2021.

180. Hertwich E, et al. (2019). Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics - A review. Environmental Research Letters 14 (4).

EVERYTHING-AS-A-SERVICE XAAS

HOW BUSINESSES CAN THRIVE IN THE AGE OF CLIMATE CHANGE AND DIGITALIZATION

September 2021
Version 1.1

Conducted by

SYSTEMIQ

On behalf of

SUN Institute
Environment & Sustainability
Initiated by Deutsche Post Foundation