On Track to Circularity

Assessment of Circular Strategies for On

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On has partnered with our team of five graduate students from the University of Michigan to assist in becoming a leader of circularity in the athletic footwear and apparel industry. Our report discusses the status of circularity at On and in the industry at large, and offers strategies for the company to move towards a fully circular business model by 2030. To advise On on how to achieve the company's ambitious circularity goals, the project creates a road map that defines feasible strategies across the six stages of the value chain (materials, design, manufacturing and assembly, logistics, use, and end of life) to guide On and its products towards circularity.

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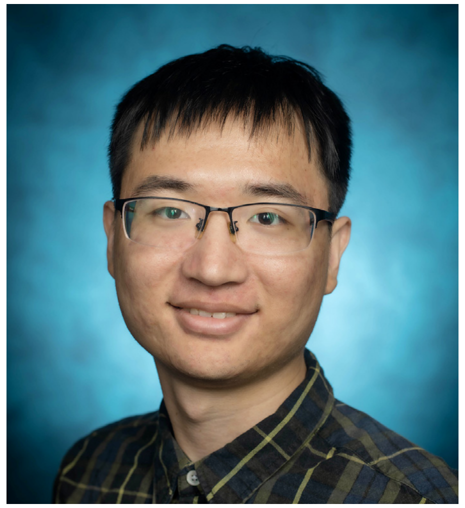

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A SPECIAL THANK YOU TO:

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And thank you to all the experts at On, within the athletic footwear and apparel industry, at the University of Michigan, and beyond, who supported our research and project through providing their expertise, participating in interviews, answering our surveys, and countless other ways.

This project was submitted in partial fulfillment of the requirements for the degree of Masters of Science in the University of Michigan School for Environment and Sustainability.

Executive Summary

This report focuses on ways that On Holdings AG (On) can advance their initiative to be circular by 2030 across their value chain. The strategies and findings in this report are based on an extensive literature review of the circular economy, a comparative analysis of major athletic footwear companies, and internal surveys and interviews with key personnel at On.

Our key findings are as follows:

- The fashion industry is a vital and influential global industry, that contributes over $2.4 trillion to global manufacturing and employs 300 million people worldwide (UNEP, 2019). By 2025, the sportswear sector of the fashion industry is projected to reach a $479 billion (USD) valuation at a compounded annual growth rate of 10.4% (Grandview Research, 2019). Studies show that the footwear and apparel industry is one of the most polluting and wasteful industries, with an estimated 8.1% of global climate change impact (3,990 million tons CO_2-eq) (Quantis, 2018). Apparel and footwear brands are facing pressure from the public to address their impact, and brands are starting to respond with reports on their products' environmental performance and corporate social responsibility (Cheah et al., 2012). For example, some brands are starting to respond with reports on their products' environmental performance and corporate social responsibility with a heavy focus on calculating their scope 1 greenhouse gas (GHG) emissions, while others are honing in on using alternative materials like recycled plastic or organic cotton.
- A shift from the typical linear supply chain to a circular business model is a solution growing in popularity within many industries and governments. Circularity provides an opportunity for the apparel and footwear industry to address the issues of waste, emissions, and pollution that are prevalent within multiple stages of its value chain.
- However, while circularity is growing in popularity, not many companies within footwear and apparel have explicit goals or key performance indicators (KPIs) related to circularity. The lack of standardization and agreement on what circularity means provides a challenge for companies to accurately track their environmental impact, avoid green-washing, and compare their progress on reaching sustainability and circularity goals to competitors.
- There is great potential for circular advancements through collaboration with innovative companies within textiles and recycling, the use of certification, and creative solutions within design and development, as well as consumer engagement.
- Enabling circularity will require collaboration and involvement of partners at every step of the value chain for a business in the apparel and footwear industry.
- There are several challenges that will need to be addressed within businesses and in the industry at large to enable circularity. For example, many of the technologies that could advance circular systems for athletic footwear and apparel are not scaled large enough to be economically or physically feasible.
- There are multiple areas of future study needed to fully understand the impacts and implications of the transition to a circular model. It's estimated that the transition to circular systems and reduced manufacturing could cause a shift in the location and types of jobs in the fashion industry. This could result in more jobs being created in more economically developed countries and less jobs in countries that rely heavily on clothing manufacturing (Repp et al., 2021).

On Specific Findings:

- On has made progress towards circularity through multiple projects and innovative experiments with circular processes, such as their Cyclon™ and the Cloudprime™ products. However, work is needed to scale these efforts across the company and value chain.
- On employees believe it is possible for the company to become circular.
- Employees have worked on projects related to circularity, but there is opportunity for these efforts to be more connected across teams and departments.
- On works with manufacturing partners across its value chain that share similar values of innovation and advancement in the athletic footwear and apparel space. However, On will need to expand its partnerships and influence farther within its value chain to specifically touch raw materials, consumer engagement, and end of life to enable circularity.
- On is working to track all of their energy used, the type of energy, the waste generated, and where waste ends up, but there is still room for improvement in being more detailed and consistent with internal data.

Utilizing these findings we developed over 32 strategies that were edited to the best 29 strategies. We then used a multi-criteria decision analysis to allow a select focus group of On experts to rank our strategies based on their strengths and weaknesses. As a result, we recommend the following 29 ranked strategies, broken down by the value chain, to assist On in reaching its ambitious circularity goals and provide guidance on how to manifest their vision.

Materials:

Invest in and scale up innovative sustainable materials and practices for synthetic materials

Invest in and require energy efficiency and renewable energy supply for materials partners

Prioritize less intensive pretreatment, dyeing, and finishing processes for material production

Utilize materials from pre-consumer and post- consumer textile waste

Product Design and Development:

Prioritize mono-material products

Design for disassembly

Provide training for design and product development teams on circular design principles

Implement better process design, modeling, and simulation tools in the design and development process

Implement modular design

Manufacturing and Assembly:

Use Power Purchasing Agreements (PPA) and International Renewable Energy Certificates (I-REC)

Leverage government incentives to invest in joint or on-site renewable projects

Low-cost substitutions: Address lighting and on-site fuel uses

High-cost substitutions: Invest in new, efficient equipment

Utilize waste through Waste-to-Energy

Logistics and Distribution:

Create or join a standard sustainable supply chain assessment framework

Redesign shoe packaging to be lighter, smaller, and use fewer resources to increase the number of shoes per master carton

Choose distribution center locations based on On's current evaluating standards, but also consider distribution center's locations by their location's estimated climate resiliency

Partner with retailers to create parcel pick-up stations instead of only providing home deliveries

Further invest in On's advanced analytics and IT infrastructure to track and enact system-wide changes more efficiently throughout On's supply chain

Use and Consumer Engagement:

Create care and wash instructions for all products

Organize a donation program for products

Identify repair partners and create a repairability index

Develop a shoe registration program

Communicate product norms on labels

End of Life:

Invest in improving current end of life (EoL) process/ techniques

Cooperate closely with recycling companies to have an efficient EoL process

Seek partnerships with competitors to share ideas and resources for EoL management

Create key metrics to track EoL performance to make sure On is in the right direction, including non-Cyclon™ products

Develop an effective take-back program and ensure end of life shoes will be returned for recycling/donation

This report will serve not only as a guide for On as they transition to be fully circular, but also as a framework in complex decision-making for other businesses within the larger footwear and apparel industry to consider when transitioning to a circular business model.

Introduction

Background on the Athletic Footwear and Apparel Industry

In 2015, the global athletic sportswear market (both footwear and apparel) was valued at $44.6 billion USD (Grandview Research, 2019). Footwear makes up one-third of the sportswear industry, while the other two-thirds are represented by clothing and apparel. By 2025, the industry is projected to reach a $479 billion (USD) valuation at a compounded annual growth rate of 10.4% (Grandview Research, 2019).

There are several trends in the sportswear subset of the footwear and apparel industry that are catalyzing significant growth in terms of market valuation, such as a substantial increase in women's participation in sports and athletics. This growth is especially apparent in rapidly growing countries like China and India. Increased female participation expands the overall market to a relatively new customer base. Another factor influencing the demand for products in the sportswear industry is increasing sentiments of health consciousness. As people reckon with their personal health struggles, many have embraced physical activity to improve their well-being. This has caused a concurrent rise in sportswear and footwear demand. Additionally, consumers increasingly demand multi-use and comfortable products that they can wear for various functions, causing an increase in the demand for athleisure apparel (Linchpin, 2022). Along with a general rise in passion for sports and outdoor activities, athleisure and sportswear apparel are seeing a general increase in consumption, benefiting the entire sportswear industry.

However, this growth is not without a cost. Overproduction, overconsumption, and high turnover rate of clothes in the fashion industry are generating a significant proportion of global material waste and environmental pollution, and the industry is central to many environmental justice and labor rights issues.

Environmental Impacts from Footwear/Apparel[1]

According to the United Nations, the apparel and footwear industry is responsible for 8-10% of global carbon emissions (2007). Accordingly, a second report indicates 1.4% (or 700 million metric tons of CO_2-eq) of emissions are directly attributed to shoes (Quantis, 2018). Comparatively, the air-travel industry represents a 2.4% share of global greenhouse gas emissions (GHG) (Ritchie, 2020). These statistics show the often-overlooked importance of the impact of global footwear and apparel consumption relative to other sources of GHG emissions, such as air travel.

Many industries including footwear and apparel contribute to a large list of environmental concerns, in addition to CO_2-eq emissions, and these industries are the ones that choose what concerns are measured and focused on. The life cycle of global shoe production, from material extraction to disposal, withdraws around 29.5 billion cubic meters of freshwater (Quantis, 2018). Evaluated per capita, one person's annual shoe consumption is the equivalent of taking 21 baths per year. For the apparel industry, freshwater withdrawal amounts to about 215 billion cubic meters over a year (Quantis, 2018). Quantis (2018) estimates that the apparel sector has the potential impact of the loss of 2.25 million daily-adjusted life years (DALY) and footwear has the potential impact of 514,000 DALY lost. DALY is an estimate of potential health impacts, expressed in the years lost due to morbidity and mortality from multiple causes (Golsteijn, 2016). The fashion industry cumulatively represents 2.75 million DALY due to a heavy reliance on fossil fuels and toxic chemicals throughout a product's life cycle (Quantis, 2018). These impacts disproportionately affect populations in low and middle income countries where most manufacturing and production occurs. Additionally, the footwear and apparel industry uses 50,000 billion mega joules (MJ) of resources over a year (Quantis, 2018). Each of these metrics indicates an annual effect from the footwear and apparel industry, and each number is projected to grow with the industry itself. This is a partial list of the categories that we studied to illustrate the environmental impacts from the footwear and apparel industry.

Environmental Impact Categories Associated with Footwear and Apparel

- **Greenhouse Gas Emissions (GHG)**
- **Energy Use and Type**
- **Resource Use**
- **Water Use and Quality**
- **Air Quality**
- **Chemical Toxicity**
- **Acidification**
- **Eutrophication**

1 This section addressed the total environmental impact from the fashion industries for which sportswear is a subset of. Unfortunately due to limited information, we are not able to provide data relevant to just the sportswear sector of the industry.

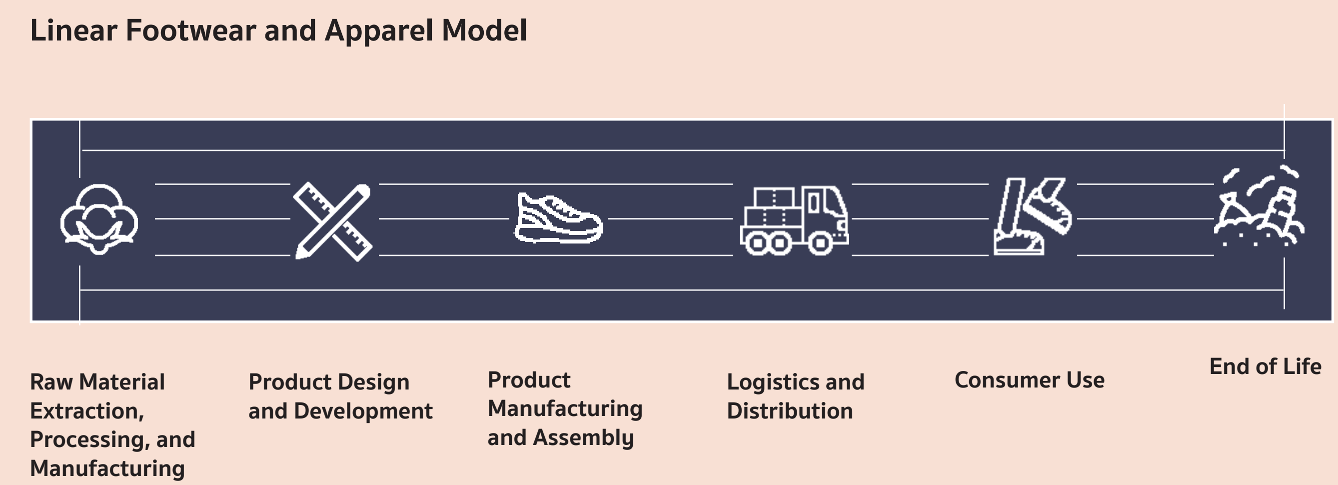

Fig. 1 Linear Footwear and Apparel Supply Chain Model.

The rise of fast fashion is often determined to be the major culprit when it comes to the increasing environmental and social impacts of the apparel and footwear industry (Dottle & Gu, 2022). Fast fashion has accompanied drastic changes in how consumers buy and use products. The apparel and footwear industry has largely moved away from the seasonal launch of clothes in favor of the constant production and development of new products. This has exacerbated a drive for products to be created at the lowest price and in the fastest manner possible. These rapid manufacturing criteria have created conditions where workers are being paid sub-minimal wages, exposed to toxic chemicals, and exploited with excessive and unsafe working conditions (Assoune, 2021).

On the consumption side; fast fashion has created a norm for people to consume more and wear clothes fewer times because of the availability of cheaper and new clothes. The average consumer in the U.S. only wears 20% of their clothes 80% of the time and landfills an average of 81 pounds annually (Igini, 2022). This leads to about 91 million tons of textile clothing waste being landfilled annually, which amounts to about $500 million in lost value from the prematurely disposed of materials (Igini, 2022). Fast fashion has thus created a system conducive to mass consumption that catalyzes market growth while the industry's environmental and social impact suffers as a consequence.

Life Cycle Stages of the Footwear/Apparel Industry

Currently, the footwear and apparel industry follows a linear model as shown in Fig. 1; materials are extracted from the earth, plants, or animals and processed into a workable material for the production process. The production of a single shoe is complicated, with as many as 65 discrete parts and 360 processing steps for assembly (Cheah et al., 2012). It's then typically sent from factories in low to middle income countries to consumers in high income countries (ILO, 1996).

The apparel and footwear industries have climate intensive material extraction and preparation stages for products that are readily disposed of before they lose functionality. The upstream stages from the manufacturing of the product (material extraction and preparation) account for up to an estimated 67% of the product's total climate change impact (CO_2-eq emissions) in the apparel and footwear industry (McKinsey, 2020). 85% of footwear and apparel products end up in the landfill annually (Igini, 2022). Materials and products are having their life cycles cut short. It's with this knowledge that we recognize a pertinent need to change the way clothes and shoes are produced so that we can conserve resources and replenish material feedstocks in a manner that benefits the greater environment.

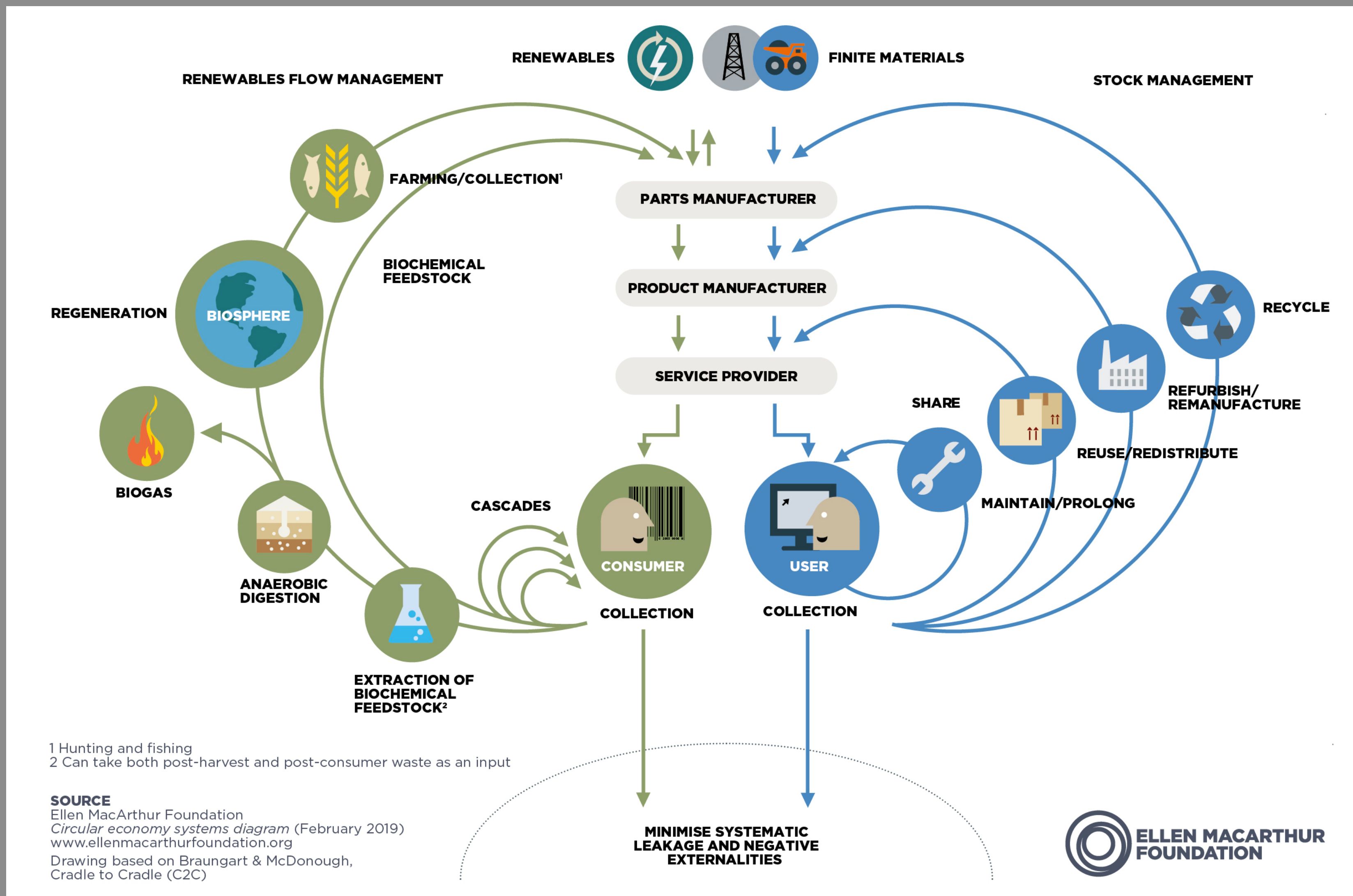

Fig. 2 Circular economy systems diagram from the Ellen MacArthur Foundation. Source: Ellen MacArthur Foundation (2019)

A circular economy decouples economic activity from the consumption of finite resources. It is a resilient system that is good for business, people and the environment. The circular economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. (Ellen MacArthur Foundation)

Background on the Circular Economy

In response to the environmentally degrading linear model that dominates the sportswear industry, many experts and companies have called for a drastic shift to a circular economy (CE) model in the industry. Corporations are starting to shift their business models to decouple economic growth from resource use by emulating ecological cycles for large-scale eco-technical systems and industries. This is a relatively new concept with interest growing rapidly within the last 10 years (Kirchherr et al. 2017), where there is often room for creativity, interpretation, and selection of sub-areas for specific applications of the concept of the CE. Fig. 2 illustrates the variety of paths possible for material flows within a CE.

In a study of 114 CE definitions found in peer-reviewed literature, Kirchherr et al. (2017) found that CE "means many different things to different people," and is typically a combination of reduce, reuse, and recycle activities. This ambiguity implies there is no "cookie-cutter" circularity framework that can be applied throughout the business world. A successful circular model may differ drastically between industries, companies, and geographic locations. Each company seeking a circular business model has a unique set of problems that require tailored solutions. To create a standard definition of CE for the purposes of this research, we identified and evaluated 18 definitions of CE (Appendix A), with direct ties to the apparel and footwear industry. We opted for the Ellen MacArthur Foundation's (EMF) articulation of CE because the EMF circular definition was the most widely referenced in Kirchherr et al.'s (2017) study. Per EMF, the CE can be described by three principles: the elimination of waste and pollution, optimization of product and material circulation at their highest utility, and practices that regenerate natural systems.

Circular Economy and the Apparel / Footwear Industry

Regardless of the ambiguity in the definition and practice of circularity, the CE is quickly growing as a popular solution to the waste and pollution issues associated with the fashion industry. This is illustrated by the increase in recent references to the CE in major industry reports on sustainability in fashion, (examples include McKinsey (2020); Business of Fashion (2022); Apparel Impact Institute (2021)) as well as annual company reports (examples include Deckers (2021); Allbirds (2020)). While companies such as Adidas and Nike have experimented with specific products that utilize a circular model (Fig. 3 and 4, next page), no major company in the athletic industry has incorporated a fully circular business model throughout its entire product line due to the complexity and difficulty of implementation.

Introduction

Companies across the athletic footwear and apparel industry share numerous common challenges in the development of circular models due to their complex, similar value chains. Identification of key leverage points inspired our analysis on how to transition the system to be circular. CE can touch every stage of the product life cycle, so each subsystem and its interactions need to be explored. At the product-level, topics such as material selection, lifetime extension, and functionality need to have more conscious design frameworks to ensure they are suitable for not only consumers but also future partners or customers at the end of a product's useful life. The restructuring of the supply chain will need to give attention to both upstream and downstream activities to keep products within the cycle for reprocessing and re-purposing. Metrics, standards, and observability will be required at every step in the value chain to reduce waste, pollution, and net impacts. Business models will take new forms that follow the function of their processes. Consumers will have different relationships with products and industries alike. Below is a non-exhaustive overview of some key gaps that must be addressed to achieve a circular system in the athletic footwear and apparel industry.

Material Selection

Material selection in athletic footwear and apparel requires a balance between quality, performance, and environmental impact. Sportswear typically utilizes synthetic materials, such as polyesters and polyamides, which are produced from fossil fuels and do not quickly or easily break down at end of life. Raw material extraction, processing, and production are the largest sources of environmental pollution in the footwear industry (Quantis, 2018). The development of high-quality materials with low environmental impact and ease of re-use is fundamental to enabling circularity in the footwear and apparel industry. Furthermore, research and development are needed to investigate the use of biodegradable and bio-based materials that can be easily recycled, broken down, and reincorporated safely back into the environment. 85% of global consumers are making more sustainable purchasing decisions over the last 5 years, resulting in startups and established corporations alike investigating sustainable alternatives (Mass Challenge, 2021). However, scaling sustainable materials remains a challenge across companies.

Design for Circularity

Due to the complexity of many product designs and the use of multiple materials within footwear, it is difficult to efficiently recover raw materials at end of life. A typical sneaker is designed with, on average, 40 distinct materials and 65 different parts (Abu et al., 2017; McLoughlin, 2021).

In the current linear model, the EoL stage of a product is typically not considered in a product's development, though the EoL stage has the longest duration due to the slow decomposition rates of materials in landfills. However, it is estimated that decisions made within the product design and development phase impact approximately 80% or more of the downstream environmental and social impacts of the product within the manufacturing, use, and disposal phases (Charter & Tischner, 2001). To reuse, repair, or recycle a product, it is vital to be able to break the product down to its raw materials. The inability to do so would make recycling nearly impossible, as mixed materials are difficult and expensive to separate and recycle properly. It will be necessary for the design and development process to incorporate EoL considerations to ensure that products can be reincorporated back into the circular cycles.

Material selection in athletic footwear and apparel requires a balance between quality, performance, and environmental impact.

Product Durability

Related to materiality and design, product lifespan and durability are other challenges within the footwear and apparel industry. Oftentimes products are disposed of before they have reached their functional end due to multiple factors, such as part of the shoe or garment wearing out and the inability of the consumer to repair or replace these parts on their own. It is estimated that extending a shoe's life by 9 months, or from 6 months to 15 months, can reduce environmental impacts by 20-30% (Quantis, 2018). An increased durability focus in the product design could increase supply for second-hand products (i.e. thrift stores, garage sales, flea markets). Product lifespan can also potentially be increased via proper care instructions to reduce mistreatment or by accessible repair services to increase a product's functionality despite damages and degrading of materials. Finally, products can be disposed of prematurely due to definitional disparity amongst consumers regarding the desired fit and quality of a shoe (Goonetilleke et al., 2000). Norm setting via communication or product labeling could potentially extend the life of a product by encouraging consumers to use products longer. A combination of changes from both companies and consumers will be necessary to enable longer product life spans.

Shipping

Shipping presents opportunities to be more circular. Leveraging the cooperation of existing sustainable packaging practices in the form of Returnable Transport Items (RTIs) can be expanded to more industries. Further, investment in the standardization and shared ownership of shipping containers and packaging could help simplify the return process within the end of life phase (Meherishi, 2019). Additionally, localized manufacturing could reduce the transport impacts of products.

Fig. 3 Adidas Futurecraft.loop, designed with mono-materials to be easily recycled. Source: Gizmodo (Rutherford, 2019)

Initiating Reverse Logistics

A challenge in any circular system is how to initiate reverse logistics to recover the valuable materials contained in the product. Literature and observational study have found that pro-recycling behavior can be influenced by numerous factors, including cost, market incentives, convenience, infrastructure, environmental awareness, attitudes, culture, social norms, and marketing promotions (Jenkins et al., 2003; Reschovsky & Stone, 1994; Halvorsen, 2008; Ebreo & Vining, 2001; Vining & Ebreo, 1992; Taylor & Todd, 1995; McCarty & Shrum, 2001; Goldstein et al., 2008; Kidwell et al., 2013). There are limited literature or examples to identify which ownership model or recycling intervention works with what product or within what industry. Research is needed by brands to identify how to galvanize people to recycle shoes and apparel, as well as market trials to actualize the research.

The current lack of recycling infrastructure for apparel and footwear remains a prominent barrier to circularity.

End of Life

The above challenges highlight the importance of enabling solutions such as second-hand markets, recycling, or biodegradability to avoid landfill. These technologies at EoL (or end of first use) are critical to the success of a circular model for the athletic footwear and apparel industry. Research and development surrounding EoL solutions, such as textile-to-textile recycling, is a growing activity. However, much of this emerging recycling technology is still in its infancy. The current lack of recycling infrastructure for apparel and footwear remains a prominent barrier to circularity for the industry.

Fig. 4 Nike ISPA Link, designed for disassembly to enable recycling, replacement, or repair of parts. Source: Nike (2022)

Social Equity

The consideration of social impacts is important to incorporate simultaneously with economic and environmental considerations as the CE grows in popularity across industries and countries globally. The athletic footwear and apparel industry operates using a global supply chain and the decision to shift to a CE model will have implications for all employed within a company's product life cycle. It is important that companies incorporate specific social considerations and metrics into their CE framework to ensure a just transition. Understanding what impacts the CE can have on social dimensions such as labor rights, health and safety, and human rights will be necessary as companies explore key partners, metrics, and frameworks for circularity.

Introduction

Background on On

On was founded in 2010 in Zurich, Switzerland, by three friends: Olivier Bernhard, a professional three-time world duathlon champion and multiple Ironman winner; Caspar Coppetti, former sports journalist; and David Alleman, a former chief marketing officer. The one thing they had in common was that they all wanted to "change the world of running" (On, 2022). In their first month after establishing On, their shoe prototypes that focused on providing superior cushioning for running won the ISPO BrandNew Award, one of the most important prizes for innovation in sport (On, 2022). Twelve years later, they have significantly grown their high-end product line and company to include urban all-day shoes like the Roger Centre Courts, hiking boots, and athletic clothes. They have expanded their business by selling On shoes at over 3,500 specialty running stores in over 50 countries; have international offices in the USA, Japan, UK, Australia, Switzerland, and Brazil; and have partnered with athletes competing in their shoes (On, 2022). With all of these accomplishments in the field, the company was recently evaluated to be worth $5.5 billion, nearly three times more than its 2019 value (Killingstad, 2021). In addition to On's rapid growth, they have ambitious goals to be a leader in sustainability within the sportswear sector. They are working towards a circular business model and many other sustainability initiatives.

On predominantly uses a linear business model for its product line, except for the Cyclon™ shoe or, as they nickname it, "the shoe you will never own," which is a subscription-based shoe that users can return to be recycled into another pair of shoes (On, 2022). If On transitioned to being fully circular, the result could significantly decrease environmental impacts while potentially increasing the affordability of its products (Quantis, 2018). In addition to On's work in circularity, they have heavily invested in other sustainable projects like their Clean Cloud project, which led to their Cloudprime shoe made from captured carbon emissions (Fig. 5). The carbon emissions for these shoes are fermented to make liquid ethanol and then the liquid ethanol is dehydrated to make ethylene gas. The gas is turned into ethylene-vinyl acetate (EVA) pellets, which are then engineered into high-performance foam for shoes (On, 2022). In addition, they are continually optimizing packaging, creating life cycle analyses for their products, incorporating more sustainable materials, decreasing and tracking carbon emissions, following an expansive restricted substance list, and ensuring their suppliers have sustainable, just practices. On's environmental commitment is partly pushing their innovation, and this could result in their stake in the footwear industry growing since trends show that one third of current global consumers care about sustainability (Business Wire, 2021).

As a rising leader in the footwear industry with ambitious sustainability and athletic performance goals, they have the goal to transition to a circular model fully (On, 2022). On partnered with the University of Michigan's School of Environment and Sustainability Capstone Program to help meet these goals. Our partnership with On aims to build a road map of how to transition their company to be more circular throughout their value chain. Our hope is that On could serve as an example for the rest of the athletic apparel and footwear industry on how to enable a CE.

Fig. 5 On's Cloudprime, a shoe made from captured carbon emissions. Source: On

Project Timeline

START

Phase 1: Project Planning

- Define project scope and research questions
- Develop project plan

Phase 2: Research and Framework Development

- Literature review into CE
- Comparative analysis of athletic footwear and apparel market
- Build framework for assessing circularity indicators

Phase 3: Case Study of On

- Collect relevant information from On to understand baseline for circularity
- Utilize company data, employee surveys, and employee interviews

Phase 4: Strategy Development

- Deeper research into circular strategies for each value chain stage
- Follow up survey to assess expert opinions within On about selected strategies

Phase 5: Analysis and Synthesis

- MCDA of circular strategies based on survey results
- Synthesis of information into presentation and report for On

Project Complete

FINISH

Definition of the Research Questions

Our project aims to develop a comprehensive and adaptable framework for On to transition towards a circular business model within their value chain. Our framework focuses on assessing multiple strategies within each value chain stage to address the transition between the current linear and circular models. While these strategies address the multitude of environmental consequences associated with the production, distribution, and waste of the traditional linear footwear and apparel life cycle, they additionally address the needs of the business and larger industry in a practical manner. The dichotomy between sustainability and business goals is often a barrier to implementing circular activities. Our project utilized the following research questions to better understand the current state of circularity within the sportswear industry, as well as the gaps and challenges that were considered when building the framework:

(1) What current circularity activities exist within On as well as the athletic footwear and apparel market?

(2) What indicators can be used to measure circularity within the footwear and apparel value chain?

(3) What kind of framework can an athletic footwear and apparel company utilize to track and measure the effectiveness of circular strategies?

Research and Analysis Goals

The project utilizes the following research and analysis methods to answer the research questions:

(1) Create a baseline of circular activities in the athletic footwear and apparel industry and within On

To achieve On's circularity leadership goals, a clear picture of current circular activities in the footwear and apparel industry is necessary to provide a baseline for this project. Relevant information was compiled using both a literature review, as well as a tabular comparative analysis. The comparative analysis additionally helps express the frequency of specific sustainability and circular activities within the industry. Once these references are established, On's comparative position in the industry was then used to focus on where they excel and where there are opportunities for improvement.

(2) Identify challenges and opportunities for circularity within On, with a particular focus on necessary partnerships within the value chain

Literature and industry reports offer insight into the initiatives and challenges within the footwear and apparel industry regarding circularity. However, each company's structure, products, and overall value chains are unique and present their own challenges. Taking the general trends identified through the foundational research, On's various teams and hands-on expertise in implementing existing circularity-focused activities were used to judge the feasibility and efficacy of our proposed strategies. Strong partnerships and supplier relations are key to the success of circularity in the industry. They will need to be considered in parallel, adding the dimensions such as technology readiness level (TRL) and business impact to assess the availability of required technology or processes for enabling circularity.

(3) Determine a framework for On to track and measure the effectiveness of selected circular strategies

To ensure that applied strategies are adding to the company's circularity goals, a framework of key metrics and indicators must be defined. Frequent and broad measures for each product life cycle allow analysts and decision-makers to assess the efficacy and efficiency of activities in the context of circularity. The use of a framework allows for the measurement, analysis, and implementation of candidate strategies in a practical and efficient manner. The framework created gives On circularity metrics to measure and track their progress toward circularity. Strategies as well as a multi-criteria decision analysis (MCDA) provide decision makers at On with an accessible set of variables and considerations based on the information gathered through the literature review and expert interviews. Recommendations for circularity within each step of the value chain are included within the framework. The framework is also flexible to ensure its ability to incorporate and evaluate new strategies and unanticipated challenges that may arise.

Project Deliverable

A report and summarized presentation of findings for On.

The report and presentation covers the results and analysis from Research and Analysis Goals 1-3. The aim of the report and presentation is to provide a condensed, accessible, and clear version of the project's findings and recommendations that can be shared throughout the company.

Using these research objectives and deliverables as a guide, this project assists On in achieving its circularity goal by 2030. The results of this project can be utilized by other athletic footwear and apparel companies to shift from the traditional linear model to a more circular model, as change across the industry is necessary to address its impacts.

Comparative Analysis

Overview of Comparative Analysis

To understand the current state of circularity within the athletic footwear and apparel industry, corporate sustainability reports offer an opportunity to see how companies are approaching sustainability in general, as well as potential plans and existing activities for circularity. Here we sought to identify what comparable companies (e.g., companies that produce athletic footwear and apparel) were doing to make their value chains more sustainable while looking to identify targets or goals that companies were publicly evaluating to drive internal circularity activities. When assessing the landscape of circularity activities currently being employed, the main result was that companies were joining circularity-focused partnerships or pledges which are listed in Appendix C. These commitments signal value for the concept of the CE, but it does not necessarily translate into intent to implement circularity activities. Additionally, with the CE beginning to gain more attention, any new applications or methods may provide companies with a strategic, competitive advantage and thus will not be publicized prematurely. There is a large body of academic literature on the CE, but research specifically for footwear and apparel is limited, non-generalizable to other companies' operations, or theoretical; instead the practical circular economic methods are being pioneered in industry, since the challenges and limitations are of more practical in nature rather than theoretical.

Method

With no existing standard structure for sustainability-related reporting within the apparel and footwear industry (Business of Fashion, 2021), a bottom-up approach was necessary to provide a common structure among the open-end reporting styles of various companies. This required an iterative method that involved reading through several reports, then restructuring how the information was represented to help develop the analysis' categories for common metrics, trends, and activities seen in the reports, and finally, revisiting reports to further extract, refine, and reorganize information (Fig. 6).

Key Takeaways

The qualitative comparative analysis ultimately allowed for the estimation of the key areas where companies were focusing their reporting efforts. Thirteen footwear and apparel brands' sustainability reports were compared. The resulting table can be seen in Appendix B.

General Reporting Trends

- Some companies focused on built environment and Scope 1 greenhouse gas emissions, while others focused on accounting for their entire value chain and products that included Scope 3 emissions (Greenhouse Gas Protocol, 2015).
- This emphasized which companies focused on activities directly under their control and operations, versus which ones extended their accounting to include as much of their value chain as possible, including indirect upstream and downstream activities.
- Companies that have owned several brands typically reported the combination of all their companies' activities into a single aggregate outcome, provided sustainability performance updates for the separate brands within a single report, or the each brand reported individually.

Sustainable Material Focuses

Materials are a core topic of the CE. To classify material focuses, we looked at whether companies focused more on the sustainability of material entering their products (upstream impacts) or the impact of materials at the output of their value chain (downstream impacts). An input-material focused company typically used post-consumer recycled materials, which often reduces the impacts compared to virgin material extraction and processing, and/or bio-based materials, which are materials produced from renewable bio-based sources such as natural fibers and plant-based synthetics. Companies focusing on the impact of materials at the output of their value chain typically chose materials which can be recycled at end of life, or those which can be considered biodegradable, regardless of if recycling or biodegradability is actually currently feasible at end of life for the product.

Companies with input-focused products:

- 62% of companies reviewed use recycled materials
- 46% of companies reviewed use bio-based materials (not necessarily biodegradable)

Companies with output-focused products:

- 23% of companies reviewed use recyclable materials
- 8% of companies reviewed use biodegradable materials

Though companies may focus on using materials that are recyclable or biodegradable, it does not mean that the product will be inherently recycled or biodegrade at end of life. There are still limitations on the collection of the product, the ability to be disassembled, and the ability to recycle or degrade materials at end of life.

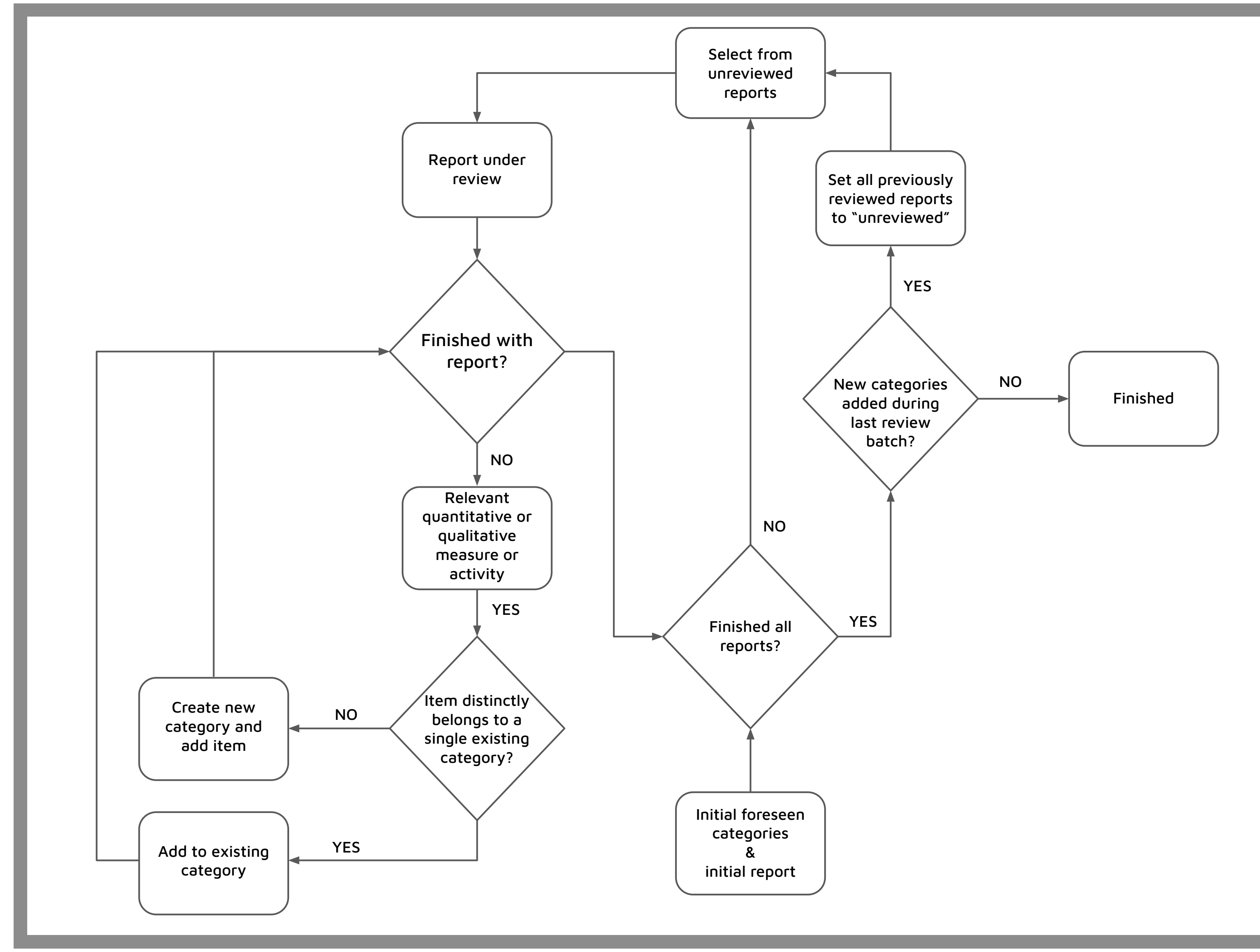

Fig. 6 Decision tree diagram of the iterative process used for the comparative analysis.

Circularity Trends in Reporting

Absence of Circularity

Only one company, Deckers, explicitly stated a target for circularity for all of its brands, which was as follows:

"[By 2030] 100% of all products will be designed with circular economy in mind (e.g., reparable, re-sellable, up-cycling, down-cycling, recycling, natural degradation)." (Deckers, 2021)

Out of 13 brands, only one company explicitly stated a target for circularity.

Quantitative vs. Qualitative Reporting

We identified two general trends in report presentation style. Companies either reported as objectively as possible, leveraging reporting standards, certifications, and partnerships to provide legitimacy to their activities and efforts. Or, companies provided scarce quantitative information or transparency about their activities and instead used storytelling to convey responsible practices.

Emissions Reporting

Companies have options when it comes to reporting emissions. The generally accepted accounting practice (GAAP) involves reporting emissions using Scope 1, Scope 2, and Scope 3 emissions accounting, as developed by the Greenhouse Gas Protocol (Fig. 7). Scope 1 emissions are categorized as the emissions produced directly from company-owned assets activities (e.g., company facility or vehicle energy usages, etc.), Scope 2 emissions are categorized as indirect emissions through the purchase of energy (e.g., emissions from grid power generation), and Scope 3 emissions account for all other indirect emissions in the value chain (transport of goods, customer use of the product, end of life of the product, etc.).

A company with ideal visibility into their value chain and emissions activities would include all three emission scopes in their report, but the reality is that measuring emissions becomes more challenging as the complexity of the value chain increases. It is expected that companies would initially be able to report their Scope 1 emissions (those they have direct control over), then account for Scope 2, and finally, Scope 3 emissions. Though this would be an expected progression, our analysis found that out of the 12 companies that reported emissions, 69% reported Scope 1, 77% reported Scope 2, and 85% reported Scope 3. This is an unusual outcome since some companies are reporting Scope 3 while not reporting Scope 1. One possible explanation is that the Scope 3 emissions are estimated based on the company's supply chain expenditure amount or revenue. This is highlighted by the Greenhouse Gas Protocol's (2011) Scope 3 accounting guidelines, in which an environmentally-extended economic input-output (EEIO) model can be used to assign a monetary unit (e.g., a dollar) a kg CO_2-eq for a particular sector or economic activity.

Unethical Reporting Practices

Not following a regulated set of guidelines or reporting standards affords companies the opportunity to present information in a manner that can minimize a negative public view of the company, or could exaggerate activities to present themselves in a positive manner. This can happen even when the data shows negative outcomes or suggests room for improvement. Misrepresenting information in this way is often termed "green-washing," which is when a company portrays itself as doing more to protect the environment than it really is. The Federal Trade Commission (FTC, 2012) provides guidance on how to avoid these practices. Some common practices seen in these reports, that may be considered green-washing, are listed below:

- Not disclosing how metrics are measured when not adhering to a specific or creditable reporting standard.
- Including subjective measures. An example: rating a material as semi-sustainable, without quantitatively defining what "semi-sustainable" means.
- Providing positive outcomes without offering the total sample set to compare against. An example: Claiming six suppliers are certified, but not providing the total number of suppliers with the supply chain.
- Claiming transparency and traceability, but not providing common information on measures like emissions. An example: Reporting total emissions without providing any further information on allocations and calculations, while often expressing the importance of transparency throughout the report.

Third-Party Accountability

Standards are a set of guidelines which can be followed and applied voluntarily, and do not necessarily guarantee adherence. A list of standards used by the companies in the comparative analysis can be found in Table C1. Certifications require the company and/or product/service to be assessed by a third party; typically the governing body which issues the certification. A list of certifications used by the companies in the comparative analysis can be found in Table C2. Companies leverage third party organizations to help provide external validation of their internal activities. Companies often join partnerships and make pledges to signal their commitment to a specific set of actions. Indices are used to give a single numeric value to the performance of a metric, and allow for organizations to be compared in a simpler manner on a specific metric. A list of commitments and pledges used by the companies in the comparative analysis can be found in Table C3.

Not following a regulated set of guide-lines or reporting standards affords companies to present information in a manner that seeks to minimize a negative view of themselves.

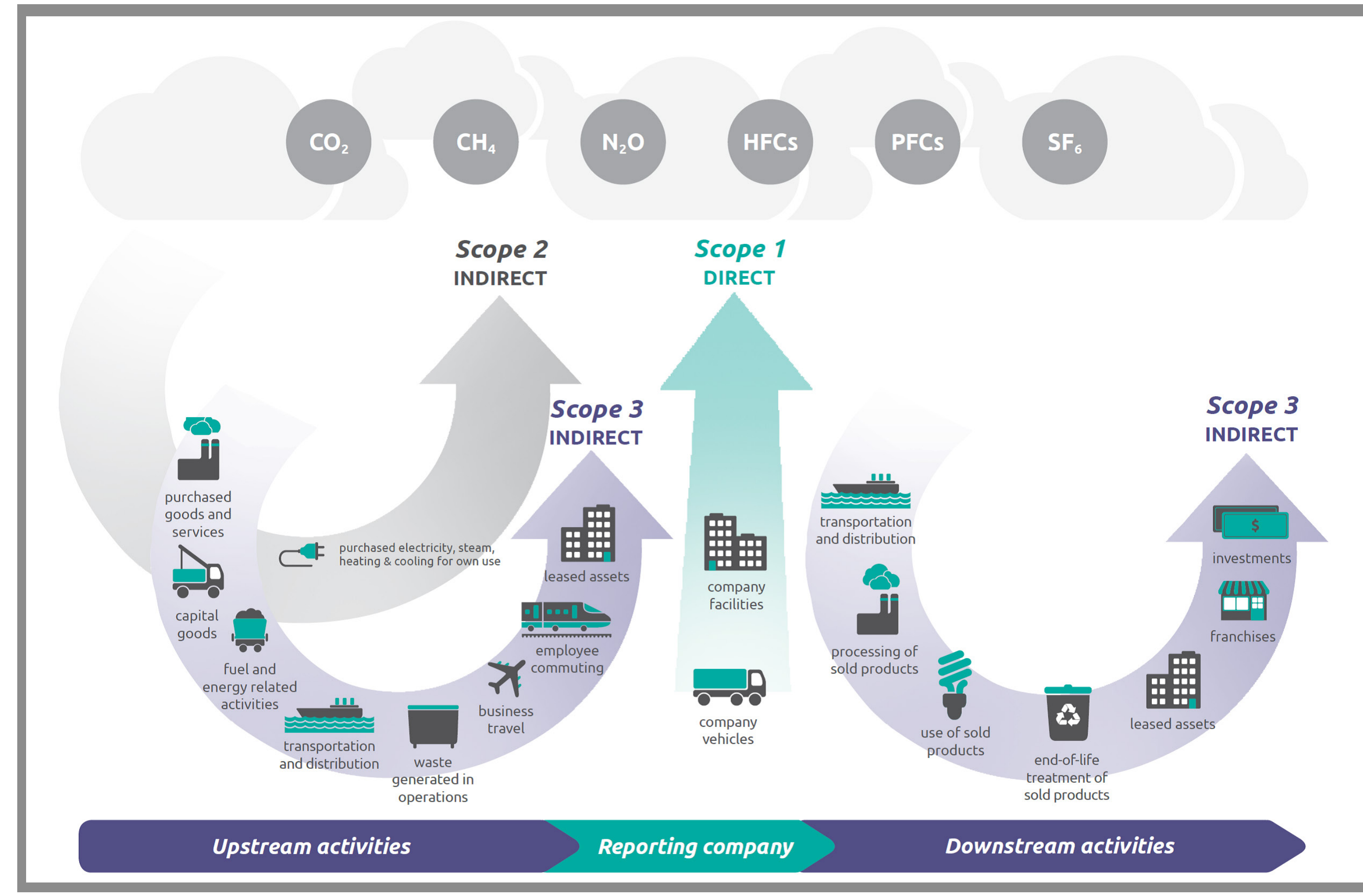

Fig. 7 Definitive examples of Scope 1, Scope 2, and Scope 3 emissions. Source: Greenhouse Gas Protocol (2011)

Limitations

Report Standardization

A lack of standardization in reporting makes it difficult to judge how sustainable a product or service is for consumers and investors. With a current lack of standardization in corporate reporting in this industry, our results from the comparative analysis are also limited by what metrics and activities that companies choose to report. One such metric is that of greenhouse gas emissions reporting. Incorrect emissions scoping or failure to categorize emissions into the scope categories makes it difficult to determine if the reported emissions are truly the full emissions account, or if key large emission activities have been excluded. The lack of regulation on reporting standards affords companies the ability to pick and choose how they report, which can be used to green-wash their activities.

Voluntary Reporting

Reporting offers some amount of insight into a company, but is subjective to what the company is willing to report. On one hand, a company is motivated to report progressive and positive activities, but conversely, they can decide to leave out information that may negatively impact their brand. This could include discovered human rights violations, higher than expected emissions, or a lack of internal visibility into their own supply chain activities.

Absence of Circularity

Only one company, Deckers, explicitly stated a target for circularity. Though not providing more quantitative details on how this is measured or what the final target value(s) is specifically, they do provide categories where existing activities and evidence show progress toward reducing waste, keeping products and materials in use, and supporting regenerative natural systems (Deckers, 2021).

On's Baseline for Circularity

On's Current Circular Engagement

In pursuit of On's ambitious circularity goals, the company has already engaged in projects to promote CE. In addition to the use of recycled materials in products and the use of renewable energy, this section highlights some of On's most notable circular achievements.

Source: On

CleanCloud™ Materials:

In 2022, On released the first ever shoe made from carbon emissions: The Cloudprime shoe, which uses CleanCloud™ Ethylene-Vinyl Acetate (EVA) foam. The CleanCloud™ EVA is produced using carbon emissions and is used for the shoe's midsole. The company LanzaTech captures carbon monoxide emitted from industrial sources and ferments the captured gases to produce an ethanol product. Technip Energies then takes the ethanol and dehydrates it to create an ethylene product. Finally, Borealis polymerizes the ethylene to produce an EVA which On uses to produce the Cloudprime shoe. This process effectively upcycles carbon emissions into new products.

Source: On

Cyclon™ Running Subscription Service:

The Cyclon™ Subscription Service is an industry-leading model to create a subscription-based shoe. Through the Cyclon™ Subscription Service, On has released the Cloudneo shoe which is 100% recyclable and "never technically owned." Instead, consumers pay a subscription for the shoe and can return the product as frequently as every 6 months to receive a fresh pair of shoes. Once shoes are returned they go through a structured supply chain where the products are collected, recycled, and turned into raw materials for the creation of the next batch of Cloudneo shoes. The program illustrates circularity by creating a closed-loop (no new inputs or outputs) for individual product lines.

Source: On

Onward™ Trade-in and Shop Service:

In 2022, On partnered with Trove to create an external interface called Onward™ to resell and trade in pre-owned products. Through Onward™ consumers receive up to a $35 credit to use at On when trading in used and approved good-condition products. On, through their partnership with Trove, take the recovered products and sell them through the site Onward™ (which is owned by On, but operated by Trove). The program extends the functional lifespan of shoes and intends to keep products in circulation for as long as possible.

Defining Indicators for Circularity

The foundations of CE indicators can be found in multiple areas of study, including but not limited to: Life Cycle Analysis, Material Flow Analysis, Input-output Analysis (Corona et al., 2019), Data Envelopment Analysis (DEA), multi-criteria approaches, and system dynamics modeling (Tsalis et al., 2022). Our literature review on circularity indicators demonstrated that there are multiple factors to consider when selecting the most appropriate indicators for a project. Azevedo et al. (2017) emphasize that indicators can be quantitative or qualitative, and may illustrate different categories of evaluation, such as performance versus efficiency. The United Nations (2007) asserts that indicators for a project should be informative, uncomplicated, and provide a foundation for comparison within the study and with other studies.

An analysis of 17 existing Circularity Metric Indexes provides more specific requirements for indicators of circularity (Corona et al., 2019). The following criteria and questions are suggested when choosing metrics:

Validity. Does the metric measure actual progress toward a circular system?

Reliability. Is the metric consistent and robust? Could it be used by different studies or organizations with similar results?

Utility. Is the meaning of the metric clear and easy to measure?

In addition to considering the different areas of study and criteria for creating Circularity Indicators, it is also important to determine the goal of the assessment. Our project aims to measure the potential contribution of circular-enabling strategies toward creating a circular system, which falls into the category "circularity assessment tools" (Corona et al., 2019). We also determined that it will be best to assess strategies using a framework, or multiple assessment indicators, versus a singular score to allow us to investigate multiple CE goals and add more specificity to our project while being adaptable to other companies' unique contexts.

Based on this review, our team decided to adapt the indicators suggested by Corona et al. (2019) for our project as follows:

Resource Use

Resource use, such as water usage and or use of coal for power, is an important aspect of measuring circularity. Reducing the resources being used by a system, especially scarce resources that have a finite limit, is necessary to building a system that can continue to operate on a closed or open loop.

Emissions and Pollutants

For a system to operate in a circular fashion, unusable harmful emissions and toxic pollutants cannot be produced, as these result in negative effects on the environment and human health.

Material Waste

Material waste specifically addresses the potentially reusable waste that an industrial system outputs. For example, at every stage of the production process for apparel and footwear products, there is a potential for material losses, such as from raw material collection or the cutoffs from fabric pattern cutting in production. Measuring and reducing this physical waste maximizes the material's economic utility and value while reducing environmental losses.

Input of Materials

In a circular system, regenerative, renewable, and recycled materials are the optimal materials, as they promote resources that can either be re-utilized or returned safely to the earth, and reduce dependence on finite, harmful resources.

Durability and Longevity

Increased utility of materials/products is highlighted in EMF's definition of CE. This can refer to both the amount of time a product is used as well as the number of times it can be used. Extended use of a product is a first priority in the CE before seeking other solutions such as recycling. This indicator measures a strategy's ability to extend the use of a product beyond its current lifetime.

Business Case

Business case refers to the potential benefits or challenges a strategy may pose from an economic perspective. This indicator is used to determine if a strategy may add economic value for a company to implement, or whether it will require more financial investment to implement.

Technology Readiness Level

Technology and innovation are important parts in enabling the CE throughout the supply chain. New recyclable materials, manufacturing systems, and efficient reverse logistic systems are in research and development across industries. However many remain in their infancy. This indicator will help provide guidance on the technical level of readiness for potential strategies while factoring in the time horizon required to implement the strategies at a practical operational scale. For our project, we suggest the TRL system as defined by the European Union. (Appendix D)

On's Baseline for Circularity

Circular Challenges Facing the Company

On faces several challenges in advancing towards more circular operations. As a comparatively new company founded in 2010, On is actively looking to engage with new partners and companies to advance circularity projects. But scoping and beginning business relationships can be a time-intensive process. The relative youth of On's business also means they are still working towards economies of scale; this is especially relevant because it is not currently feasible to recover and recycle used materials to implement back into production. As On grows these concerns may level out, but in current operations, these scale issues impact pursuits in circularity and sustainability. With regards to manufacturing, On is actively looking to gain more transparency into their suppliers. Here On has limited oversight power to force contractors to adapt to more sustainable conditions. However, On is conducting audits to hold current factories accountable and adding sustainability-related terms to new contracts.

Baseline Assessment

As part of our research method we used On employees as a primary resource and as expert sources in evaluating different circular strategies. Many employees at On are well-versed and active leaders in the transition of clothing and footwear businesses to more circular and sustainable models. Beyond On employees' qualifications, as those in charge of implementing changes, employees are ultimately the final judge of what strategies are practical to implement into On's business strategy. Our research worked with On employees in three specific ways to aid in our research process.

Primary Survey: We sent out a primary survey to staff and divisions at On to collect data regarding On's organizational goals and status about circularity and sustainability initiatives. Through this survey we were able to understand where On currently is in the process of transitioning to a completely circular organization.

Interviews: Following the primary survey, we conducted informational interviews with senior leaders and project managers throughout different segments of On's business. Through structured interviews, our team was able to parse out challenges, successes, and ambitions of On in terms of circularity and sustainability. These interviews provided practical insight about On's transition to circularity.

Follow-up Surveys: Taking information from the company's structure and current initiatives, and combining it with academic literature and market research, our team devised strategies for each of On's respective value chain stages to become more circular. For each strategy we provided a holistic overview and some academic context, and asked employees at On to evaluate how effective they thought each strategy would be in enhancing On's circular mission [See Section: Circular Strategies for On]. These results then guided our final recommendations.

Results from Research on On's Circular Activity, and On's Company-wide Survey and Expert Interviews

Our primary survey evaluated perceptions of circularity and feasibility of On's goals through 17 questions (Table 1) directed to On employees. As it relates to the shared definition of circularity, of the company respondents (n = 22), ~95% agree circulatory requires reducing waste, ~72% agree circulatory requires creating a durable product, ~85% agree circulatory requires reducing environmental pollutants, and 90% agree circularity requires regenerative/renewable materials. Interestingly, ~80% of respondents agree that using material recovered from outside of On's value chain, like waste from a Nike shoe, still constitutes circularity. Only ~18% of respondents agree that off-setting programs, or schemes by companies to fund projects that sequester or reduce CO_2 to offset their own emissions, can factor into circularity.

Circularity Indicator Rankings

In the primary survey, employees (sample size = 27) were also asked to rank five environmental Circularity Indicators (Resource Use, Emissions/Pollutants, Material Waste, Input of Materials, and Utility/Durability) in terms of their relative importance to circularity. However, three outlier responses were removed resulting in an actual sample size of 24.

Survey participants were given 100 points to allocate across each of the five indicators (Fig. 8). Looking at the mean score for each indicator, Emission/Pollutants was deemed the most important indicator, followed by Input of Renewable/Recyclable/Regenerative Materials, Utility/Durability, Material Waste, and Resource Use.

The standard deviation was high due to extreme outliers in each category. Based on the point allocation, the relevant importance of Material Choice and Emissions, at 22 (SD = 7) and 24 (SD = 11) points respectively, were considered the most important. While at the low end, Resource was only allocated a mean of 16 (SD= 7) points, and Utility/Durability and Material Waste were 21 (SD=12) and 17 (SD= 6) points.

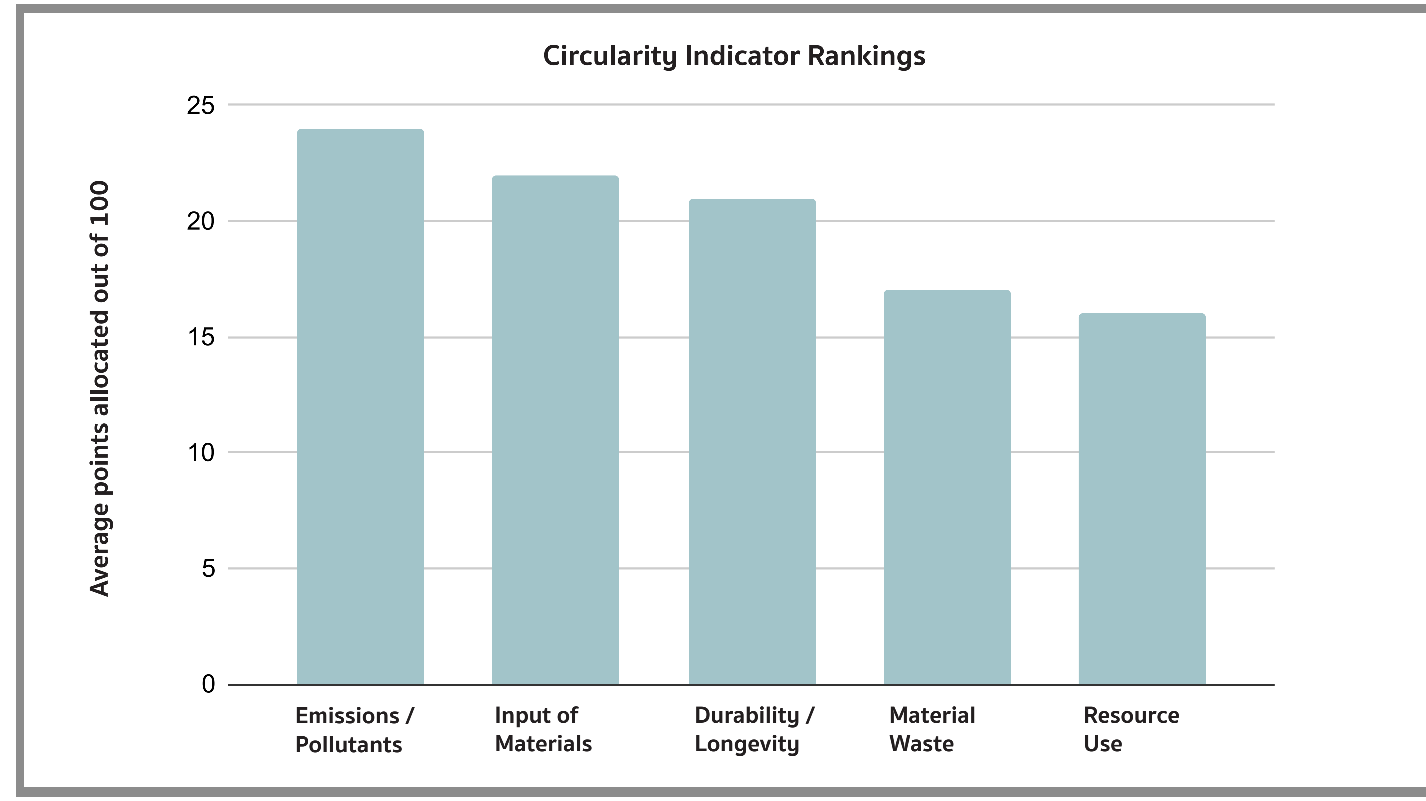

Fig. 8 Circularity Indicators ranked by On employees when allocated 100 points to determine the indicator's importance to circularity.

Circularity requires eliminating or reducing solid waste.	Circularity requires refurbishing or repairing products so they can be reused.
Circularity requires creating a durable, high quality, product.	Circularity requires a product to have multiple value streams (i.e., initial purchase, recycling, reuse).
Circularity requires reducing environmental emissions and pollutants.	Circularity requires use of renewable resources when energy dependence is necessary.
Circularity requires using regenerative / renewable materials.	Offsetting (hand-printing) programs can be used to achieve circularity.
Circularity requires using recyclable materials.	Consumer engagement is critical to circularity.
Circularity requires keeping materials from On products in circulation.	Product design is the most important element of circularity.
Using materials from a Nike shoe to manufacture an On shoe is considered circular.	If all On's products are circular, the company is circular.
Circularity requires second hand uses for products.	A fully circular economy is an achievable ambition.

Table 1. Statements that On employees were asked to "strongly agree; somewhat agree; neither agree nor disagree; somewhat disagree; or strongly disagree" with to gauge company perception of circularity and circular practices. Full survey responses can be found in Appendix E.

Circular Strategies

Multi-Criteria Decision Analysis

Incorporating circularity within an organization requires the consideration of multiple questions, criteria, and opinions of different stakeholders. The goals, feasibility, and evaluation of circular strategies are often complex and not straightforward. The best decision for an organization can be subjective due to the different business models, objectives, and markets that each business occupies. This complexity requires a decision-making process that is inclusive of multiple perspectives, objectives, and considerations. For this project we decided to implement a multi-criteria decision analysis (MCDA) to determine the best strategies for each stage of On's currently linear value chain to assist in transitioning to a circular value chain. MCDA allows for decision makers within an organization to assess possible strategies based on multiple criteria to then rank the options against each other. Decision makers will also rank the importance of the criteria as well, as some criteria may have greater influence on the decision than others. The objective for an MCDA is to identify the strategy that best addresses each of the predetermined criteria and is therefore the desired solution. Fig. 9 illustrates the steps within the MCDA process. More information about the calculations used for the MCDA can be found in Appendix E.

As described in more detail in the earlier section "On's Baseline for Circularity", circular strategies identified for each stage of the value chain were assessed for feasibility and effectiveness by On employees based on their impact on the following Circularity Indicators – resource use, emissions and pollutants, material waste, input of materials, durability and longevity, business case, and technology readiness level (see pg. 13). Employees were asked to rank the strategies for the value chain stage based on their expertise and the information presented. The results from the survey were then used within the MCDA to determine which circular strategies are most effective and feasible for On to implement.

The MCDA allowed us to utilize both literature review as well as company expertise to select and rank strategies for each stage of the value chain. This approach acknowledges the context-specific knowledge of decision-making within a company setting, while also maintaining the research and industry understanding necessary to inform these decisions.

The incorporation of circularity into a business model requires a decision-making process that is inclusive of multiple perspectives, objectives, and considerations.

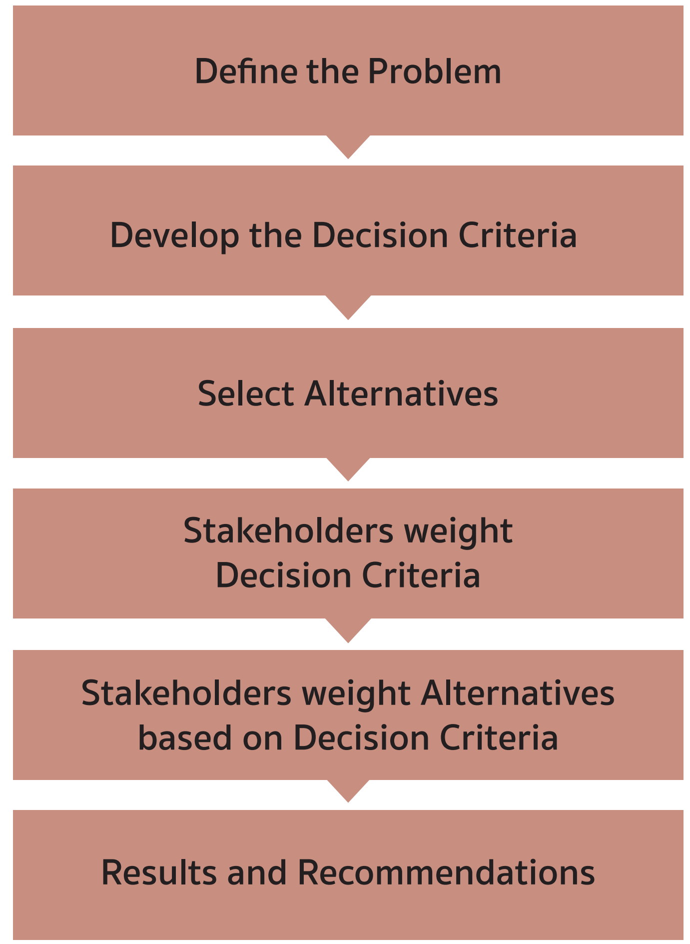

Fig. 9 Basic steps of an MCDA analysis. Steps adapted from 1000minds (n.d.)

Strategies for each value chain stage

Utilizing the key takeaways from our literature review, internal interviews and surveys with On employees, and the results of our MCDA analysis, the following sections outline the strategies determined to have the most potential to enhance circularity within On's currently linear supply chain. With the goal of moving to a circular supply chain in mind (Fig. 10), each stage of the value chain has four to five strategies that our team has determined to be high priority for On to pursue to achieve their circularity goals by 2030. Each section below provides a detailed description of the value chain stage, its unique circularity challenges, and presents the strategies and their evaluated impact on each of the Circularity Indicators based on the MCDA. Table 11 on page 30 provides the ranking for all strategies. Additionally, we have provided potential partnership suggestions and metrics for each stage that may assist in tracking and supporting the circular strategies.

Moving from a linear model to a circular model

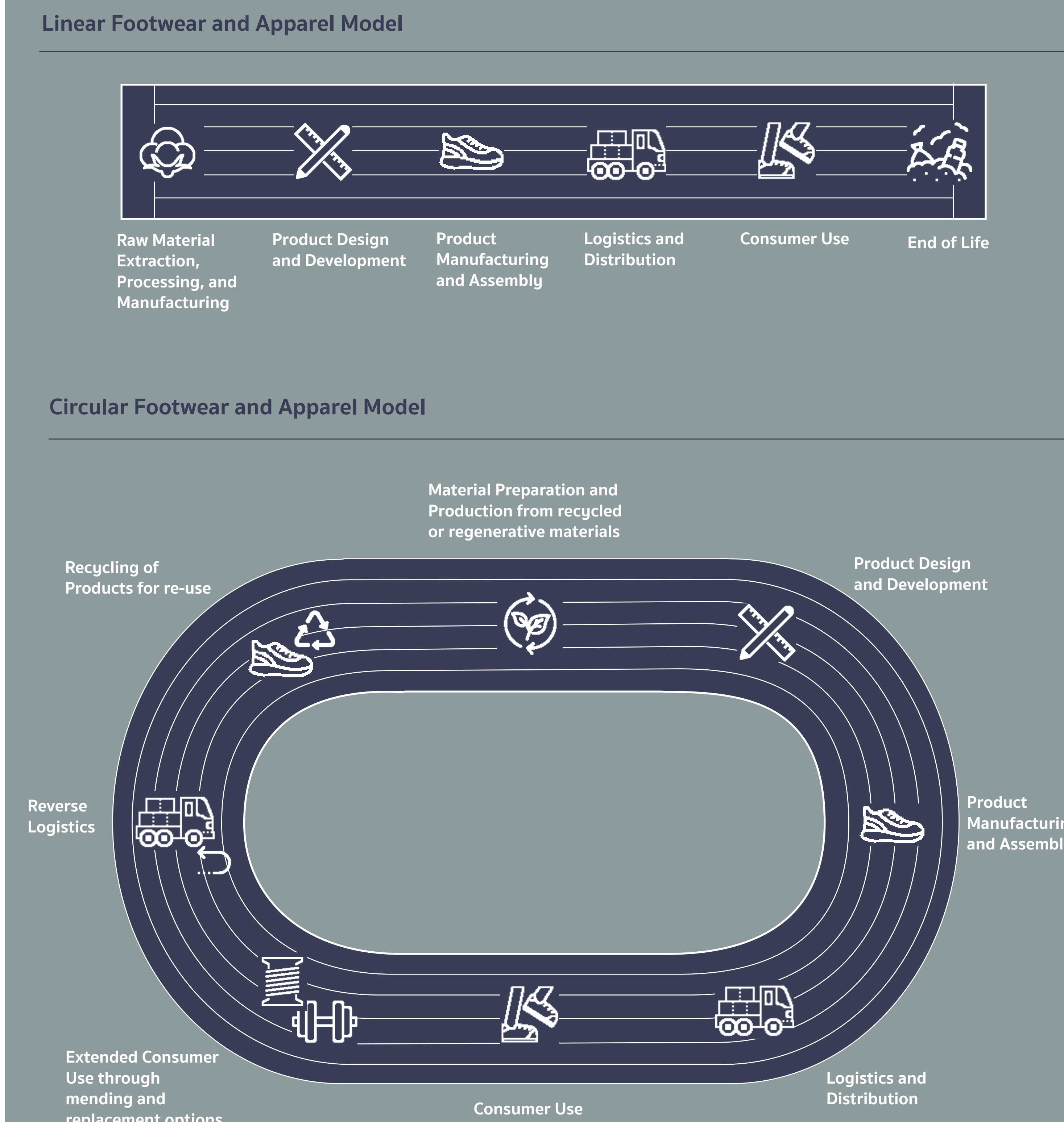

Fig. 10

Materials

The materials stage marks the beginning of the product life cycle. This stage is made up of three smaller steps in the process: extraction, processing, and production. Material extraction, processing, and production accounts for 67% of CO_2-eq emissions from the apparel and footwear industry (McKinsey, 2020; Fig. 11). On's own supply chain emissions aligns with the industry, with about 62% of its 2021 Scope 3 emissions coming from raw material extraction, processing, and manufacturing (On, 2021). Material extraction is the first part of the process, and describes the cultivation and extraction of raw materials from animals, plants, or the earth. Examples of this stage include the cultivation of cotton plants, as well as the extraction of oil from the ground. Within the supply chain, material extraction is considered a Tier 4 partner in most footwear and apparel supply chains, as it is the farthest removed from a company's production process and control. Next, the raw materials are transported to Tier 3 partners for processing. Factories at this step process raw materials into yarns and other usable fiber products. The final step for materials is Tier 2, or the material production step. Here, materials are prepared and finished to be utilized in finished goods manufactured and assembled by Tier 1 supply chain partners. Yarns are knit or woven into fabric yardage, materials are dyed to their desired color, and necessary finishings are added to the fabric. Table 2 details each step in the process for Tier 1-4 suppliers.

System change is necessary for the materials stage, and will serve an essential role in switching to a circular model in any business (Textile Exchange, 2020). In addition to CO_2-eq emissions, the materials stage has significant impacts on resource degradation, deforestation, water and energy usage, as well as use of and contamination from toxic chemicals (Pentatonic, 2022). For example, fabric dyeing and finishing processes within the material production step rely heavily on water, heat, and chemical usage (Pentatonic, 2022). Due to their location, these processes most commonly use coal and thermal energy as their primary energy source, which contributes heavily to its environmental impacts (Sadowski et al., 2021).

Decisions made within the materials stage serve a key role in initiating circular practices through innovation regarding material choices and qualities. The materials chosen must be able to either be recycled to enable them to be reincorporated back into the system at their end of life, or returned safely to the earth. In the current state, most materials are not recyclable, nor is the recycling technology at a stage to support a large textile recycling industry (Pentatonic, 2022). Circular textiles are inhibited by several factors, including toxic finishing techniques, the use of blended materials, potential quality degradation through recycling, and the cost of recycled materials compared to virgin materials (Sadowski et al., 2021; Pentatonic, 2022). Materials popular within athletic footwear and apparel add additional complexities to the topic, as athletic footwear and apparel typically utilizes synthetic fibers for their durability and performance qualities necessary for athletic activities and heavy usage (Jane, 2018). Synthetic fibers are primarily derived from fossil fuels and as a non-renewable and non-biodegradable material, athletic companies must find ways to either remove synthetic materials from their product line, or find alternative, robust recycling methods that decrease their dependence on virgin, finite materials.

The materials stage's dependence on nonrenewable resources and energy sources, as well the waste and inefficiencies associated with it, make it an important stage for On to alter toward more circular practices. Four strategies are presented for On to potentially increase the circularity of the material stage. The following section includes a description of each strategy, a table (Table 3) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity at the Materials stage.

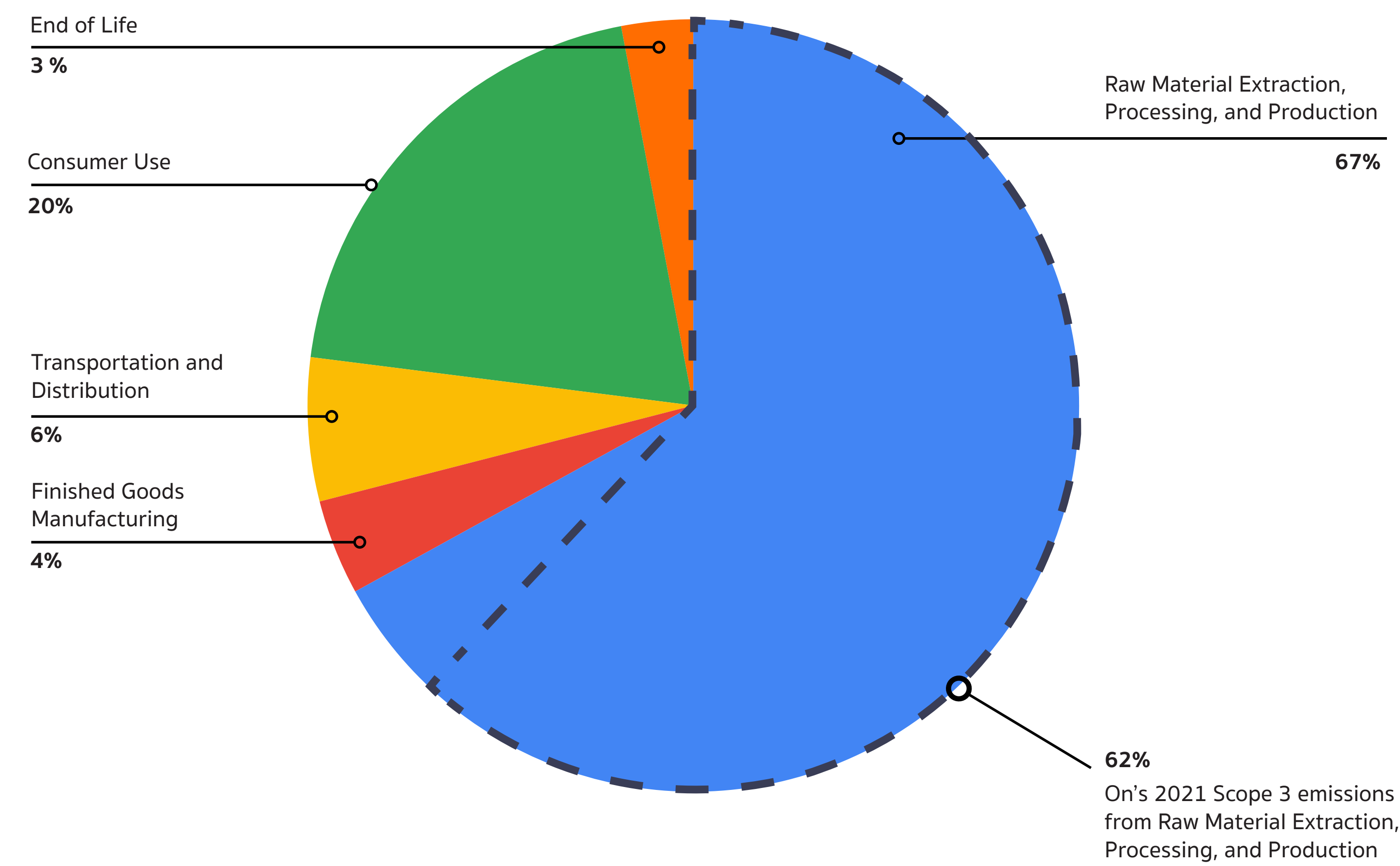

Fig. 11 Pie Chart illustrating the emissions from each part of the value chain based from McKinsey (2020), overlaid with On's 2021 Scope 3 emissions from Raw Material Extraction, Processing, and Production.

Tier 4	Tier 3	Tier 2	Tier 1
Material Extraction	Material Processing	Material Production	Finished Production
The cultivation and extraction of raw materials from plants, animals, and the earth	Process raw materials in to yarn and other usable fiber-based products	Finishing of the materials. This includes making fabric from yarns, dyeing of materials, and adding trims or finishing details	Assembly and production of final products

Table 2. Breakdown of Apparel and Footwear Industry's Materials stage, including the Tier of supplier associated with each step.

Materials

Strategies

Material Strategy 1: Invest in and scale-up innovative sustainable materials and practices for synthetic materials

On has developed specific goals to use 100% recycled polyester and polyamide, and cotton sourced from 100% organic, petrol-free sources by 2024 (On, 2021). On's largest material purchases include polyester at 46% and polyamide at 27% of their Fall/Winter 2021 collection. Within those percentages, recycled material was 23% of On's polyester purchases and 49% of polyamide purchases (On, 2021). As the largest categories for On's materials and also the most difficult to dispose of or re-utilize at end of life, On will need to focus on finding sustainable solutions for polyester and polyamide specifically. To achieve goals of circularity within these material categories, one potential option is to transition fully to recyclable options for polyester and polyamides.

Chemical[2] and mechanical recycling represent two options for recycling polyester and polyamides, both of which have considerable potential as well as challenges. Currently, options for textile-to-textile recycling for synthetic materials are limited, with many operations remaining in the research and development stage. While chemical recycling processes are working to maintain the virgin quality and highest yield of recycled materials over multiple recycling rounds, the environmental impacts are still relatively unknown at a larger scale due to its infancy. Some organizations such as the Natural Resource Defense Council have expressed concerns about the potential for hazardous waste in the chemical recycling process as well as environmental justice issues with the placement of chemical recycling plants in proximity to low income communities and communities of color in the United States (Singla, 2022). In comparison with chemical recycling's current form, mechanical recycling may be a less environmentally impactful option, but quality of the materials will degrade over multiple recycling rounds (Radhakrishnan et al., 2019). With these current unknowns in mind, our team suggests that On utilize mechanical recycling where feasible for its current product line, and make the switch to chemical recycling incrementally as more information is understood about its impacts on a larger scale.

While On could also potentially develop or utilize alternative materials for its synthetics, research and development has shown that alternatives like performance-enhanced natural materials do not currently live up to the quality and performance of synthetic materials (Lee et al., 2021).

Therefore, it makes sense for On to invest in the development of a recycling infrastructure for its synthetic materials. While there is limited research on textile recycling at scale, the organization Textile Exchange has been gathering information on the sustainability of preferred textiles and fibers through their Material Change Index. As of 2021, the program includes 149 participating companies within the footwear and apparel industry that are tracking their transition to preferred materials (Textile Exchange, 2021). Textile Exchange defines a preferred fiber or material (recycled or bio-based) as, "one which results in improved environmental and/or social sustainability outcomes and impacts in comparison to conventional production" (Textile Exchange, n.d.). The information collected for their program shows the opportunity for environmental impact through the switch to alternative materials.

Less than 1% of clothing is recycled into new clothing each year. (EMF, 2017)

Material Strategy 2: Utilize materials from pre-consumer and post-consumer textile waste

To reduce the amount of virgin materials in On's feedstocks, On should utilize resources from pre-consumer and post-consumer textile waste. Each year clothing and footwear is thrown away or goes unsold, causing not only a large amount of wasted materials to be sent to landfill but a costly loss for businesses as well (Pentatonic, 2022). For example, it is estimated that less than 1% of clothing is recycled into new clothing each year (Ellen MacArthur Foundation, 2017), and $500 billion of value is lost every year by throwing away unsold clothing (UNEP, 2019). By participating in building a more comprehensive textile recycling infrastructure globally, On could recoup both pre- and post-consumer textile waste to be re-incorporated into its production feedstocks. Utilizing recycled materials can reduce waste, emissions, and resource use associated with virgin materials (Textile Exchange, 2020). On could also benefit financially from being both a seller and consumer of textile waste. This could be done on a closed or open loop basis, as there is opportunity for companies with like-materials to share waste streams. However, as previously mentioned, textile-to-textile recycling is still in a development stage, meaning that the scaling of this industry will take time and funding. There are also concerns related to the quality, durability, and eventual end of life of recycled materials that must be addressed in this stage as well.

Material Strategy 3: Prioritize less intensive pretreatment, dyeing, and finishing processes for material production

Tier 2, material production, is responsible for 52% of the apparel and footwear industry's CO_2-eq emissions (Sadowski et al., 2021). Tier 2 includes the dyeing and finishing processes for materials, which tend to be heat, water, and chemically intensive processes. For example, some estimates show that one ton of dyed fabric can use up to 200 tons of fresh water (Fashion Revolution, 2020). Additionally, many textile mills are heavily dependent on coal as an energy source for heating the water necessary for the dye processes (Ley et al., 2021). This is a significant opportunity to reduce emissions, pollutants, and wasted material within On's supply chain. On should phase out traditional wet dyeing methods in favor of less intensive treatments such as dry processing, dope dyeing, and solution dyeing for all of its products (Kant, 2012; Intertrek, 2019).

Material Strategy 4: Invest in and require energy efficiency and renewable energy supply for materials partners

There is great potential to reduce resource use and emissions within Tier 1-4 production partners through updating facility machinery and processes to ones that are more energy and resource efficient, or supported by renewable energy where available (Sadowski et al., 2021; Pentatonic, 2022; Ley et al., 2021; Quantis, 2018). Research has found that machinery and processes within textile mills as well as garment factories are typically outdated and heavily dependent on fossil fuels (Ley et al., 2021). Simple fixes, such as those laid out by the Apparel Impact Institute's Clean by Design program (right), are effective in reducing the water and energy usage of many processes as well as operational costs (Ley et al., 2021). By investing in and working together on these updates with supply partners, On could significantly reduce emissions and resource use associated with the material and manufacturing stages, while also strengthening relationships with partners around a common goal of efficiency and sustainability.

Clean by Design's Best Practices

- Metering and Leak Detection
- Cooling Water Reuse
- Recover Heat and Hot Water
- Maintain Steam Traps and System
- Recover Heat from Exhaust Gas and Heating Oil
- Condensate Collection and Recovery
- Process Wastewater Reuse
- Improve Boiler Efficiency
- Improve Insulation
- Optimize Compressed Air

2 The term chemical recycling is used to describe a wide range of chemical processes and pathways to get from "waste" to virgin quality materials. Each pathway has different inputs, yields, and emissions associated with them. Examples include pyrolysis, gasification, and depolyermization.

Materials

Key partners to help enable circularity within the Material stage

- Material innovators, at company or academic and laboratory stages
- Material companies working on unique dye processes
- Material recyclers, fiber mills + manufacturers to recoup material waste
- Organizations like the NRDC or IFC that are connecting mills to programs to enhance efficiency
- Other companies within athletic footwear and apparel to invest in and support research and development needed for scaling sustainable materials and recycling across industry

Suggested Metrics for Material Stage

- Percent of product line using recyclable materials
- Percent of product line using preferred materials
- Percent of product line using pre-consumer and post-consumer textile waste
- Percent of water recycled from textile processes
- Percent of wastewater in textile processes
- Energy consumed [MJ] per process type
- Emissions [CO_2-eq] per process type

Table Key

○	Potential for positive impact on the Circularity Indicator
–	Potential for neutral/ no impact on the Circularity Indicator
✗	Potential for negative impact on the Circularity Indicator

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Material Strategy 1: Invest in and scale-up innovative sustainable materials and practices for synthetic materials	○	○	○	○	–	✗	✗
Material Strategy 2: Utilize materials from pre-consumer and post-consumer textile waste	○	○	○	○	–	✗	–
Material Strategy 3: Prioritize less intensive pretreatment, dyeing, and finishing processes for material production	○	○	○	○	○	○	○
Material Strategy 4: Invest in and require energy efficiency and renewable energy supply for materials partners	○	○	○	○	○	–	–

Table 3. MCDA survey results on the impact of Material Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F1.

Design and Product Development

The design stage details the conception of a product, in which the product idea and its specifications are developed and tested before the product enters manufacturing. Though design can impact many decisions made during the manufacturing and assembly stage, this stage focuses on the prep work of the design and product development teams. Design requires an ideation and testing period to help finalize the product. Within this period of the product's life cycle, there are many opportunities for designers and product developers to impact circularity later in the life cycle. It is estimated that choices made within the product design and development stage can influence up to 80% of the environmental and social impacts that occur within the aforementioned downstream processes (Charter & Tischner, 2001). It will be necessary to prioritize circularity within the initial design of products; choices made on product aesthetic, fit, and materials start with the design stage and will impact the way the product will be made, used, and recycled or disposed of.

Currently, designers are not always aware of the implications of their product choices upstream and downstream of the design stage (Sadowski et al., 2021). As evidenced by the previous stage, popular material selections like mixed materials or synthetics can reduce the ability for a product to be recycled or to be biodegradable at the end of its life cycle. Certain choices in the materials stage pose the trade-off between quality, performance, and durability, and the design stage confronts similar trade-offs. Designers and product developers must determine the right balance between aesthetic, cost, and performance within athletic products, which can lead to design decisions that may not benefit circularity. For example, the use of glues to piece together an athletic shoe may prohibit the ease of recycling at end of life, as certain parts may be difficult to separate. A designer may also decide to create a shoe with multiple parts and seams as an unique aesthetic choice. However, this decision can lead to multiple, complex pattern pieces and additional steps in the manufacturing process to piece the shoe together, which can increase emissions and the potential for wasted material yardage from production.

With the design stage's significant potential for impact on the circularity of a product, it is essential to prioritize design choices that better enable circularity and also support design and development teams in determining the best solutions for each product. The following presents five strategies for On to increase the circularity of the design stage. This section includes a description of each strategy, a table (Table 4) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity in the design stage.

Fig. 12 Nike Considered Boot, made to be disassembled at EoL utilizing materials and joining techniques that avoid glues and permanent seams. Source: Nike (2007)

Fig. 13 Adidas Futurecraft.loop, all parts made with the same material for minimal need for separation and ease of recycling. Source: Gizmodo (Rutherford, 2019)

Strategies

Design Strategy 1: Provide training for design and product development teams on circular design principles

Circularity must be a leading principle from the very beginning of the design process to enable its success (Amed, 2022). However, circularity can be achieved in multiple ways, allowing designers to incorporate other goals for a product in their decision-making as well. The first strategy we suggest is for On to implement training for all of its design and product development teams on circularity principles. This will help ensure that circularity is top of mind for all products, not just special projects. This training could also be offered to production partners to strengthen circularity goals throughout On's supply chain. The Ellen MacArthur Foundation provides circularity guidelines for designers to help ensure that circularity is ingrained in the design process (Ellen MacArthur Foundation, 2020). EMF recognizes that circularity will not necessarily look the same for every industry, let alone company or product, and therefore its guidelines provide multiple strategies and options that designers can incorporate into their work. Following guidelines such as those put forth by EMF, or working to create internal circularity principles for the On design team, ensure that circularity is incorporated more quickly and robustly into newer products and revisions to the product line.

While our team has determined that it is important for circular design suggestions to not be prescriptive, the following strategies investigate three circular design principles that may be particularly important to the circular challenges of the athletic footwear and apparel industry.

Design Strategy 2: Design for disassembly

Design products that allow for products to be easily taken apart (Mestre and Cooper, 2017). This can assist in enabling modularity as well as easier end of life processing. Easily disassembled products include modularity, lessening the use of mixed materials, as well as reducing or eliminating the use of glues and adhesives that would negatively impact the reuse, compostability, or recyclability of other parts. Nike's Considered Boot (Fig. 12) serves as a case study for the impact of designing for disassembly, by eliminating adhesives, selecting sustainable materials, and utilizing zero waste principles. The boot is estimated to reduce product energy consumption by 35%, and reduce manufacturing waste by 61% (Warn, 2021).

Design Strategy 3: Prioritize mono-material products

Design mono-material products that use only one material throughout (Mestre and Cooper, 2017). This aids in simplifying recycling options, such as whole shoe recycling, in comparison to the time and labor costs of separating multiple materials for multiple waste streams. On's own Cyclon and Adidas's Futurecraft.loop (Fig. 13) represents the possibility for a mono-material product, which requires minimal separation for recycling.

Design Strategy 4: Implement modular design

Design products to allow for parts of the product to be easily replaced or fixed by customers (Mestre and Cooper, 2017). This allows for longer usage of the product by switching out only the pieces that may wear out faster, such as the soles of running shoes. Combined with other design choices, like incorporating recyclable or compostable materials, implementing modular designs will ensure that worn out pieces do not end up in the landfill. Nike's ISPA Link (Fig. 4) is an example of modular design, as the parts of the shoe are designed to be easily taken apart and switched out. Not only does this serve a circular function, but it also allows for unique aesthetic choices that may be appealing for designers and consumers.

Design Strategy 5: Implement better process design, modeling, and simulation tools in the design and development process

In addition to incorporating circularity in the initial ideation phase, there are also design technologies and techniques that can reduce material waste, emissions, and resource use within assembly and manufacturing (Sadowski et al., 2021). By utilizing digital visual aids like patterning programs, 3D computer-aided design and manufacturing (CAD/CAM) programs such as Modo and ShoeMaster, and simulation in the prototyping phase, designers and product development teams can reduce waste and unnecessary seams or parts before even creating a physical product. Pattern programs and zero waste cutting techniques can also help designers identify best practices for laying out pattern pieces on fabric yardage to avoid unnecessary waste typical in the cutting process. On should implement digital programs within both its design and manufacturing process for more efficient, sustainable prototype development and pattern planning for mass production.

Design and Development

Key partners to help enable circularity within the Design Stage

- Design and product teams
- Organizations like Ellen MacArthur Foundation that provide guides to design thinking for the circular economy
- Companies working on innovative process and modeling tools

Suggested Metrics for Design Stage

- Percentage of product line incorporating circular design principles
- Percent material efficiency in development phase by mass [Kg]
- Percent material efficiency of product patterns by mass waste yardage [kg]
- Emissions [CO_2-eq] saved per product designs or re-designs for circularity
- Material waste [kg] per product design or re-design of product

Table Key

○	Potential for positive impact on the Circularity Indicator
—	Potential for neutral/ no impact on the Circularity Indicator
✕	Potential for negative impact on the Circularity Indicator

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Design Strategy 1: Provide training for design and product development teams on circular design principles	—	—	○	—	—	—	—
Design Strategy 2: Design for disassembly	○	○	—	○	—	○	—
Design Strategy 3: Prioritize mono-material products	○	○	○	○	—	✕	—
Design Strategy 4: Implement modular design	—	—	—	—	✕	✕	✕
Design Strategy 5: Implement better process design, modeling, and simulation tools in the design and development process	—	—	○	—	—	—	—

Table 4. MCDA survey results on the impact of Design Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F2.

Manufacturing and Assembly

Athletic footwear manufacturing and assembly is estimated to account for about 31% of all energy used throughout the industry's typical value chain.

The manufacturing and assembly stage for the footwear industry involves the construction of the shoes from sourced material components, such as the fabric upper and the sole from Tier 2+ suppliers. This stage is almost solely performed by contract manufacturers in developing countries; China, India, and Vietnam are the top three producers respectively (Smith, 2022).

It is estimated that for athletic footwear (synthetic-material-based), manufacturing and assembly account for about 31% of all energy used throughout the industry's typical value chain, excluding the use phase (Quantis, 2018)[3]. This energy consumption is primarily from facility operations (e.g., lights, appliances) and machinery use (e.g., sewing machines). Similarly, it is estimated that for athletic footwear (synthetic-material-based), manufacturing and assembly account for about 32% of all CO_2-eq emissions throughout the value chain, excluding the use phase[4]. Emissions during this stage are driven by primary energy sources such as supplied electricity generation from the grid and in-facility heating processes (e.g., heating boilers for steam, and Heating, Ventilation, and Air Conditioning (HVAC). For material waste, there is a lack of literature on the typical amount of waste generated during the manufacturing process, e.g., scrap rate, but a McKinsey (2020) report assumes about a 14% waste rate for apparel and footwear total during this stage. Though this is not specific to footwear, it gives an idea of the impact of material waste in this phase. 29% of all freshwater withdrawal throughout the overall value chain is also estimated to take place during manufacturing (Quantis, 2018)[5].

In addition to the following five strategies presented, a set of meta-strategies are suggested to better inform what other strategies might provide specific benefits. These meta-strategies involve increasing supplier visibility to allow for better measure-ability and controllability when the brand looks to identify an area of improvement, develop a strategy, and implement a mechanism to achieve the designed outcome. By increasing the visibility and having instrumentation for direct measurement of processes and quantities, models can be formulated to help identify root causes as well as allow new methods to be simulated prior to implementation. This section includes a description of each strategy, a table (Table 7) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity in the Manufacturing stage.

3 Footwear manufacturing (38%) and assembly (19%) stages account for 57% of total energy usage [MJ] in the value chain (excluding use stage), and synthetic material footwear is 54% of energy usage out of 3 types of footwear types (leather, textile, and synthetics) (Quantis, 2018). Allocation calculated by: [M&A is 57% value chain energy usage] x [54% of impact comes from synthetics] ≈ 31%.

4 Footwear manufacturing (43%) and assembly (20%) stages account for 63% of total emissions [CO_2-eq] in the value chain (excluding use stage), and synthetic material footwear is 50% of total emissions out of 3 types of footwear types (leather, textile, and synthetics) (Quantis, 2018). Allocation calculated by: [M&A is 63% value chain emissions] x [50% of impact comes from synthetics] ≈ 32%.

5 Footwear manufacturing (41%) and assembly (20%) stages account for 61% of total freshwater withdrawal [m3] in the value chain (excluding use stage), and synthetic material footwear is 48% of freshwater withdrawal out of 3 types of footwear types (leather, textile, and synthetics) (Quantis, 2018). Allocation calculated by: [M&A is 61% value chain freshwater withdrawal] x [48% of impact comes from synthetics] ≈ 29%.

Strategies

Manufacturing Strategy 1: Use Power Purchasing Agreements and International Renewable Energy Certificates

Most footwear suppliers assemble footwear in China, India, and Vietnam, whose grids rely on an average of over 50% coal and above 20% oil for energy sources (IEA, 2020a, 2020b, 2020c). Specifically for where On's suppliers primarily operate, Vietnam's majority grid sources are approximately 50% coal, which is mostly imported and increasing in share, and 25% oil. Working with utility companies or municipalities to arrange Power Purchasing Agreements (PPA) to secure renewable energy from the grid is key to reducing scope 2 emissions for the manufacturing activities. As most popular manufacturing countries are still developing their renewable energy capacity, PPAs might not be available or may be limited, but Renewable Energy Certificates (RECs), which allow for the indirect purchasing of renewable energy, can be the next best option when working at the grid level. For countries that do not have much renewable energy overall, International RECs (I-RECs) offer a more available option, but through a more removed method (Fig. 14). Though RECs do not provide a facility with direct renewable energy and are not typically acceptable for LCAs, RECs show a commitment and allow for the indirect investment in overall renewable energy capacity while allowing for potential scope 2 indirect emission offsets. This signaling of commitment shows consumers and investors that the brand is willing to invest in renewable energy in the short term, regardless of local availability.

Energy Source	% of Vietnam energy mix supplied by source
Coal	52.3%
Natural Gas	7.6%
Hydro	6.5%
Biofuels and waste	7.7%
Oil	25.0%
Wind, solar, etc.	0.9%

Table 5. Total energy supply by source for Vietnam energy grid, 2020 (IEA)

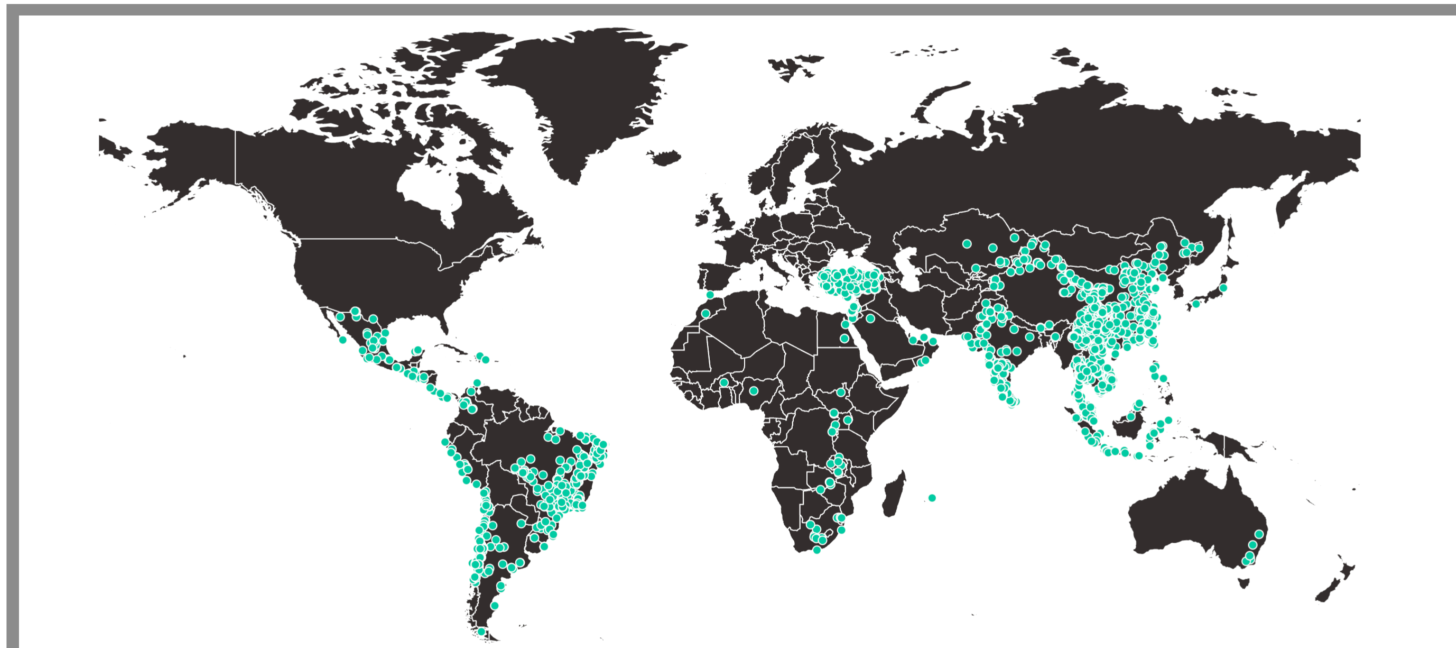

Fig. 14 I-REC Generation Device Registration Map. Source: Evident (n.d.)

Manufacturing and Assembly

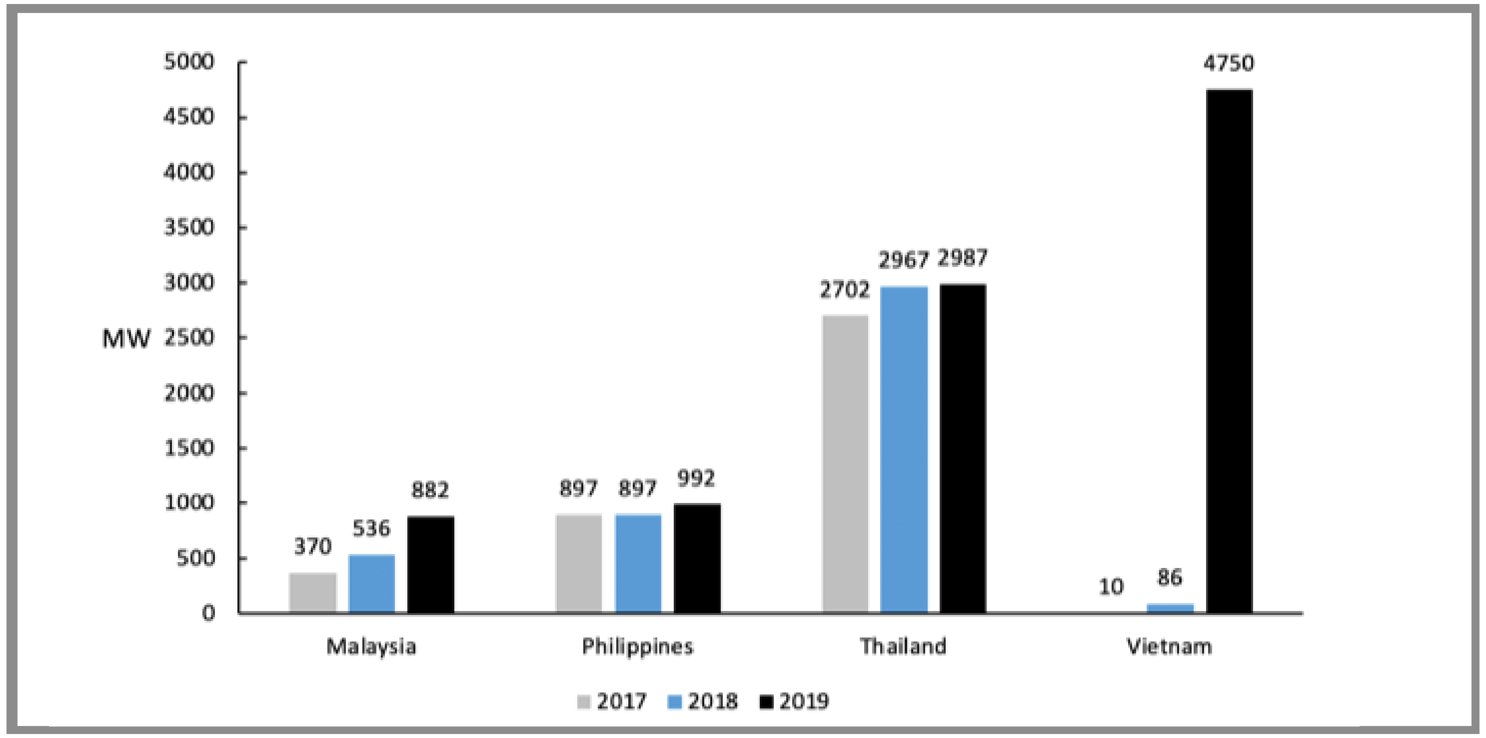

Fig. 15 Vietnam Solar Capacity overtime compared to other countries in Southeast Asia, 2017-2019 Source: Do, T. N., & Burke, P. J. (2021)

Manufacturing Strategy 2: Leverage government incentives to invest in joint or on-site renewable projects

When renewable energy is not an option from the local grid utility, countries like Vietnam often have incentives for companies to invest in renewable energy generation projects or install roof-top solar. Investing in a local renewable energy project with other investors could offer clean energy to suppliers while also allowing the sale of clean energy to other companies. Installing third-party renewable energy generators like rooftop solar is a low-cost and low-risk alternative to a joint venture for offsetting some grid emissions. Both options are heavily supported by incentives such as lower energy costs and reduced taxes.

Currently, Vietnam has the fastest-growing renewable energy market in Southeast Asia, due to regulatory policy to incentivize investment in renewable energy within the country (Fig. 15). Vietnam has had a Feed-in-Tariff (FIT) between 2021 and 2023 – a policy designed to specifically support the development of renewable energy projects by guaranteeing above-market prices for energy producers, as well as a guaranteed amount of purchased energy by the local utility for installations such as rooftop solar.

Vietnam has additional incentives such as allowing 100% foreign ownership in renewable energy projects, reduced corporate taxes or tax-exemption, tax-free imports, and free land leases for specific energy projects (Teo et al., 2020).

Though Vietnam, among other developing countries, is looking to grow its grid using renewable energy, limitations have presented themselves in the form of limited transmission capacity. A challenge that often occurs is the utility having to shut down sections of the grid due to inability to support high energy demand periods that co-occur with the peak generation times for renewables like solar. These forced shutdowns have caused renewable energy projects to lose income, reducing the overall return on investment (Le et al., 2022).

Though producing On's entire product line with 100% renewable energy such as solar would be an impressive task from a local installation or complete ownership standpoint, On can still consider investing in a joint venture or equity in renewable projects to offset the energy consumed during the manufacturing stage.

Manufacturing Strategy 3: Low-cost substitutions: Address lighting and on-site fuel uses

While companies cannot easily change their grid emissions, they can improve their operations' energy use through efficiency upgrades. Suppliers are often cost-sensitive, so asking a supplier to make large retrofits to improve sustainability for the client brand will require the brand to financially invest more to see those changes. Simple substitutes such as switching from fluorescent systems to LEDs can reduce lighting-related emissions by 41-50%, while also reducing operating costs (Principi et al., 2014). For thermal processes such as the production of steam for forming, boilers currently use fossil fuels that can be swapped out for less carbon-intensive fuels with potentially minor retrofits. Overall this cost will be passed onto client brands, but will help improve their products' overall transition toward circularity.

Athletic footwear and apparel industry manufacturers primarily use liquified petroleum gas (LPG) for their heating processes. Though LPG has among the lowest CO_2-eq emissions per million BTU (MMBTU) out of standard fuel alternatives, natural gas and biogases can provide an emissions reduction per MMBTU of 14% to 24%. Alternative gaseous fuels that provide an emissions reduction from LPG can be seen in Table 6 (EPA, 2014).

Fuel Type	kg CO_2-eq emissions per MMBTU	Emissions reduction from current LPG Fuel (%)
Liquified petroleum gas (LPG)	61.71	N/A
Propane	61.46	< 1%
Natural Gas	53.06	14%
Landfill Gas	52.07	16%
Other Biogases	52.07	16%
Coke Oven Gas	46.85	24%

Table 6. Fuel alternatives to LPG for lower CO_2-eq emissions per MMBTU (EPA, 2014).

Manufacturing Strategy 4: High-cost substitutions: Invest in new, efficient equipment

Significant investments in updated equipment will be required if brands are willing to support suppliers to make operations more sustainable and if suppliers begin to compete for contracts based on sustainable manufacturing capabilities. For example, investing in a HVAC system that is 30% more efficient, and switching to sewing machines that are 20% more efficient can reduce emissions by 9% (McKinsey, 2020). Replacing a fuel-based boiler for thermal manufacturing processes with an electric boiler can reduce emissions by 16% (McKinsey, 2020) where an additional 1-7% boiler efficiency can be achieved with a waste heat recovery system (ETSAP, 2010). Switching over to fuel-less processes also reduces the workers' exposure to pollution.

Though these systems require a large upfront cost, leasing is a potential option to save on operating costs. For a full-load steam system (86%-94% utilization), the fuel cost accounts for 96% of the system's total life-cycle cost, while the upfront investment and maintenance cost account for the remaining 4% (ETSAP, 2010). Switching to a more efficient boiler alone will heavily reduce operating costs, while an electric boiler can reduce costs further while also eliminating related onsite emissions. This strategy is analogous to Strategy 4 in the Materials strategy section, which focuses on methods for increasing efficiency within a material production setting.

Manufacturing Strategy 5: Utilize waste through Waste-to-Energy

Waste-to-energy (WTE) is a controversial topic within the context of the CE (Rada et al., 2018). However, if the waste that is incinerated has no chance of being reused, such as hazardous waste, it may be a short-term strategy to extract some benefit. An article by The American Society of Mechanical Engineers (ASME) puts forth the comparison of WTE having an annual capacity rate of approximately 85% compared to the solar and wind rate of 15-45% due to climate-based availability.

Partnering with a WTE producer provides an immediate reduction in unutilized waste, while generating energy that is often cleaner than alternative combustion-based forms of generation due to its advanced recovery processes (Covanta, 2021). Though reducing waste through better design and processes is the preferred path, this strategy is a short-term solution that aims to utilize current waste streams while better practices are being designed and implemented.

Manufacturing and Assembly

Key partners to help enable circularity within the Manufacturing Stage

- Contracted manufacturers (CMs)
- Local government
- Local utilities
- Other brands with local manufacturing operations

Suggested Metrics for Manufacturing Stage

- Percentage renewable energy
- Energy consumed [MJ] per process type
- Percent energy efficiency per process
- Emissions [CO_2-eq] per process type
- Emissions [CO_2-eq] per unit manufactured
- Percent material efficiency by mass [Kg]
- Percent material efficiency per unit manufactured
- Percent of circular outflow = (% recovery potential x % actual recovery) (WBCSD, 2022)
- Recovery percent includes biodegradability percentage
- Mass [Kg] and impact of hazardous waste produced [DALYs, acidification, eutrophication, human and eco-toxicity] (Hillege, 2019)
- Local water scarcity footprint per unit manufactured (Boulay et al., 2017)
- Percent of water recycled
- Percent of discharged water

Table Key

○	Potential for positive impact on the Circularity Indicator
—	Potential for neutral/ no impact on the Circularity Indicator
✕	Potential for negative impact on the Circularity Indicator

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Mfg Strategy 1: Use Power Purchasing Agreements and International Renewable Energy Certificates	○	○	—	—	—	○	—
Mfg Strategy 2: Leverage government incentives to invest in joint or on-site renewable projects							
Mfg Strategy 3: Low-cost substitutions: Address lighting and on-site fuel uses							
Mfg Strategy 4: High-cost substitutions: Invest in new, efficient equipment							
Mfg Strategy 5: Utilize waste through Waste-to-Energy							

Table 7. MCDA survey results on the impact of Manufacturing Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F3. Please note: The only recorded response for the Manufacturing stage chose to appraise one strategy. More results would be needed to correctly conduct the MCDA for this stage.

Logistics and Distribution

The main function of the logistics stage is to deliver a good or service from its origin point to the point of consumption (Michigan State University, 2022). However, it is a complex stage that includes multiple considerations such as warehouse design and management, packaging formation and design, working with international suppliers and customs, and lastly transportation. The result is that the logistics stage is sensitive to disruptions like weather events, labor strikes, pandemics, and poor inventory planning, which could result in overstock, understock, and damaged, lost, or stolen products (Devinder, 2022). If optimized, logistics and distribution have the potential to save a company a lot of time and money (Devinder, 2022). Converting logistics to a circular system will require a high level of transparency to ensure that a company can track its waste, carbon emissions, and social impact.

One of the greatest obstacles we identified was the lack of transparency in this stage, which impaired the ability to collect data about waste generation, energy use, and working conditions. The lack of information in this stage made it difficult to find leverage points to make this system circular as well as track sustainability progress (Amed, 2019). Additionally, there is not a standardized, widely accepted framework that companies can use to accurately compare their logistics to their competitors, resulting in a challenge to assess how progressive and ambitious a company's sustainability activities are (DiNapoli, 2022). In addition, logistics can be energy and resource intensive, as increased expectations and competition for providing next-day or same-day shipping has led to more last-mile shipping emissions (Bennett, 2021). Consumer behavior has also shifted to overbuying products online with the intention of returning items due to free return shipping, which in turn has increased last-mile emissions and packaging (Bennet, 2021). For the logistics phase to become circular, there will need to be a major shift in logistic planning and accounting for the trends in the way customers interface with products.

In an ideal circular system, the logistics stage would operate very differently than current conditions. The logistics stage would be able to maximize the number of products shipped per trip with minimal overstock in a shared warehouse to avoid throwing out unsold products (Zheng, 2003). The shipping crates would be durable, compact, and easily stripped of bar codes to allow for the crates to be used for future shipments. Everything would be powered by renewable energy. In addition, packages that are being sent directly to the consumer would be on the most fuel/resource-efficient path, and products would never need to be returned. However, the logistics stage is quite far from that impressive vision. The following are five strategies that can help the logistics stage get closer to that goal. This section includes a description of each strategy, a table (Table 8) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity in the Logistics and Distribution stage.

Strategies

Logistics Strategy 1: Further invest in On's advanced analytics and IT infrastructure to track and enact system-wide changes more efficiently throughout On's supply chain

Resilient and reliable information technology (IT) infrastructures help to decrease operating costs, automate and synchronize tasks, secure sensitive information, improve customer/partner relationships and allow for easier outsourcing and collaboration (Vitez, 2019). Infrastructures like this could help On meet its sustainability goals faster by supporting the ability to track data like CO_2 emissions and implement system-wide changes faster, like discontinuing the use of pre-paid shipping labels. In addition, advanced analytics like advanced sizing tools could decrease resource consumption and emissions. Advanced sizing tools can help a consumer buy better fitting clothes when shopping online.

An average 181g of CO_2eq is emitted when a single item is shipped using a standard courier system like FedEx (Bennet, 2021). In addition, it's been studied that 30% of online shoppers deliberately over-purchase and then return items, resulting in unnecessary emissions generated and wasted resources from shipping and manufacturing (Bennet, 2021). In addition, when customers over-buy, it inflates what manufacturers think they need to produce, resulting in overstocked warehouses where old products could then end up in a landfill. If On implemented the use of advanced sizing tools, it could decrease the amount of product shipments that are returned – which would also decrease costs, CO_2 emissions, and put less stress on On's logistics teams and partners. When interviewing On employees working in logistics, they mentioned time, volume of products, and not being able to make system-wide changes to shipping processes internationally as challenges to circularity and sustainability.

For these reasons, implementing a more robust IT infrastructure could help reduce the logistics stage's carbon footprint. In addition, advanced sizing tools could decrease On's scope 2-3 emissions as it is estimated that advanced sizing tools can decrease in product returns by 25-30% (Smith, 2022). Additional satisfaction from customers being able to accurately choose their sizes online could also lead to increased customer retention (Smith, 2022). A 5% increase in customer retention has been linked to companies' profits increasing by 25-95% (Smith, 2022).

This is an extremely feasible strategy that could be integrated into On's company by investing resources into On's existing IT department, or outsourcing this project to an existing company that specializes in helping build robust IT systems or advanced analytics. The biggest challenge would be the upfront cost and training of employees on the updated system.

Logistics Strategy 2: Partner with retailers to create parcel pick-up stations instead of only providing home deliveries

Online shopping makes up a seventh of all retail purchases worldwide, adding the need for companies to have a last-mile delivery plan (Flueger, 2021). "Last-mile" emissions references the emissions generated during the delivery process to get a product to its final destination (Flueger, 2021). However, 60% of home deliveries can fail the first time because of slow identification of handover points, long walking distances, and the customer not being home. This results in delivery services needing to make a second run during this "last mile" (Flueger, 2021; Peppel, 2022). By utilizing parcel pick-up points instead of typical home deliveries it is estimated that two thirds of the CO_2-eq generated can be saved because it consolidates parcel drop off and leads to less miles driven (Peppel, 2022). Through consolidation, fleet size could be decreased to reduce road congestion (Peppel, 2022). Parcel pick-ups work best in densely populated areas, but even rural and suburban areas can have a 40% saving in CO_2-eq emissions (Peppel, 2022). Parcel pickup could have an even smaller CO_2-eq impact if the consumer trip-chains – a person completes multiple tasks and walks, bikes, or takes public transit to get to a parcel pick-up location (Flueger, 2021). Parcel pick-ups are often safer, resulting in less tampered with or stolen packages and provide flexibility for the customer (Pasholok, 2021).

If On partnered with local retailers who sell On products to build secure pick-up locations, it could decrease "last mile" delivery emissions (Pasholok, 2021). This strategy could complement current freight provider objectives, like those of Cargocare, Kühne+Nagel (Fig. 16, next page), and Forto. In addition, as courier systems like FedEx electrify their fleets or partner with companies like Quickpak, On will be able to continue to decrease its environmental impact from last-mile shipping. Also, parcel pick-up partnerships could positively affect the retail partners because of the heightened likelihood of compulsive consumption – the effect of customers being overcome by the urge to buy more products since they are in a store. However, this also negatively affects the idea of slowing down the speed of consumption (Green Whereabouts-360, 2023 and Pasholok, 2021).

Shipping a single item emits an average of 181g CO_2-eq. (Bennett, 2021)

Logistics Strategy 3: Create or join a standard sustainable supply chain assessment framework

Sustainable supply chain assessment frameworks help companies to aggregate and assess sustainability data through the use of qualitative and quantitative indicators, which could result in well-informed strategic decision-making by management through greater system transparency (Prabodhika, 2021). In addition, it would help customers be able to assess companies' sustainability initiatives and environmental impact better (Ellen MacArthur Foundation, 2023). Examples of sustainable supply chain frameworks are; Supply Chain Operations Reference Model (SCOR Model), Global Logistics Emissions Council (GLEC), and Higg: The Sustainability Insights Platform. Examples of criteria that could be assessed in-depth are; work conditions, human rights, corruption risk, sourcing, use of resources, GHG emissions, use of hazardous materials, fuel use/type and transportation costs. One of the barriers to analyzing On's environmental impact and ways to assess how the company can become more sustainable is the lack of data. Data availability about the emissions produced from the various forms of freight transportation and electricity use proves to be a challenge in understanding the impact of the logistics and distribution stage. Utilizing an established framework or creating a more stringent framework to track supply chain data could advance On's sustainability goals.

This strategy would be one of the more difficult ones to implement since data collection has shown to be quite difficult in the fashion industry based on our literature review. However, On must continue to build a detailed picture of its logistics' environmental impact to be able to assess how to decrease emissions and provide insights on how to proceed with current and future partners.

Logistics Strategy 4: Redesign shoe packaging to be lighter, smaller, and use fewer resources to increase the number of shoes per master carton

Green packaging design is a design method that aims to reduce, reuse, and recycle materials to make packaging (Zavodna, 2021). This strategy supports On's current work in innovating its product packaging to be more sustainable by decreasing the amount of materials needed and changing material types. For example, On has innovated their packaging by using 100% recycled materials for packaging, discontinuing the use of plastic kimble on socks, using silk-based tissue, and using water-based inks. On dramatically decreased the amount of ink needed for their shoe packaging by rebranding their shoe boxes to be the natural cardboard color compared to their original majority black shoe box design. However, there are still more ways that the packaging of shoes could be optimized to be able to fit more pairs in the master cartons. If the box size per shoe decreased, then more shoes could fit per master carton. In addition, another challenge includes removing old shipping labels on master cartons, which is very important for a successful delivery but can be very labor intensive. These are some of the challenges that block the creation of a closed loop system for master cartons. In theory, companies like Datalase could help On overcome these obstacles and decrease the CO_2-eq generated from these processes. Datalase has been able to reduce 16.8% of CO_2-eq generated from making shipping labels through the invention of an inkless solution that uses photonic printing to make shipping labels (Datalase, 2020).

Technological advancements in packaging design has the ability to reduce emissions, material use, and enable more materials to be re-purposed instead of landfilled. For instance, there have been industry advancements where shoe packaging has been created that only requires 10% of the total amount of materials that an average shoe box and bag would require (Zavodna, 2021).

Based on our research, it seems that there is a heavy focus on innovating individual product packaging, but there is an opportunity for a larger focus on innovating packaging for master cartons and last-mile shipping options. If On could increase the number of packages shipped per container, then the individual product's carbon footprint would decrease.

Fig. 16 Küehne+Nagel shipping crate being prepared for transport. Source: Kuehne + Nagel (Freightwaves, 2019)

Logistics Strategy 5: Choose distribution center locations based on On's current evaluating standards, but also consider distribution center locations by their location's estimated climate resiliency

Assessing climate resiliency helps businesses and people consider their local exposure to climate-related hazards. The EU has spent an estimated EUR 487 billion, while the US has spent an estimated $2.295 trillion from 1980-2020 because of climate-related events (Christophers, 2021). Major climate hazards exacerbated by climate change include drought, wildfires, inland flooding, sea level rise, and extreme heat. After natural disasters strike, many businesses need to recover because of direct losses like fatalities or costly infrastructure damage. Even if a business isn't directly damaged, the rippling effect of the disaster could impact business or supply chains. By weighing environmental factors when choosing routes and factory locations, businesses can make their company more climate resilient, resulting in saved lives and durable, climate-resilient infrastructure.

Since On is partnered with companies that have warehouses across the globe, On could compare their current locations to possible locations offered by their partners. Then they could study climate projections to see if there are current warehouse options by their providers that are more climate resilient.

While warehouse locations are traditionally chosen based on cost, facility size, and route on transportation path, evaluating a warehouse's vulnerability to environmental disasters is also a way to improve climate adaptability and resilience. In the long-term perspective, the less money and resources used to rebuild after natural disasters will have a positive impact because reducing the use of resources is one of the best ways to be more sustainable and support circular activities. Reducing resource use generates less waste in a system, ultimately resulting in less energy and CO_2 being emitted (Ellen MacArthur Foundation, 2023). There are many climate projections focusing on different parts of the world that can help assess the best locations to place warehouses and offices.

Logistics and Distribution

Key partners to help enable circularity within the Logistics Stage

- Package printing companies, e.g., DataLase, inkless printing solutions for products and packaging
- Electric freight companies e.g., Fleetzero, building a fleet of electric ships to deliver cargo for their customers
- Packaging material companies, e.g., Viupax, footwear packaging company
- Parcel locker pick-up providers, e.g., Alfred24, parcel pick-up locker provider
- Climate resiliency mapping tools and companies that track this data, e.g., Climate Mapping for Resilience and Adaptation or the European Environmental Agency

Suggested Metrics for Logistics Stage

- Percentage of partnered last-mile fleet that are electrified
- Percentage mix of types of freight used and their energy source
- Percentage of factories and warehouses that are located in high risk climate change and natural disaster zones
- Increase number of products shipped per master carton
- Amount of online returns per year
- Track which cities sell the most On products to identify possible parcel pick-up station locations
- Percentage of renewable/clean resource used in the entire logistic stage
- Total amount of energy and materials needed to package individual On products
- CO_2-eq from transportation per unit

Table Key

○	Potential for positive impact on the Circularity Indicator
—	Potential for neutral/ no impact on the Circularity Indicator
✕	Potential for negative impact on the Circularity Indicator

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Logistics Strategy 1: Further invest in On's advanced analytics and IT infrastructure to track and enact system-wide changes more efficiently throughout On's supply chain	✕	✕	○	—	—	○	○
Logistics Strategy 2: Partner with retailers to create parcel pick-up stations instead of only providing home deliveries	○	○	—	—	—	○	—
Logistics Strategy 3: Create or join a standard sustainable supply chain assessment framework	○	○	○	○	—	✕	—
Logistics Strategy 4: Redesign shoe packaging to be lighter, smaller, and use fewer resources to increase the number of shoes per master carton	○	○	○	○	—	○	○
Logistics Strategy 5: Choose distribution center locations based on On's current evaluating standards, but also consider distribution center's locations by their location's estimated climate resiliency	○	○	○	○	○	○	—

Table 8. MCDA survey results on the impact of Logistics Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F4.

Use and Consumer Engagement

A product's use phase is the period of time that a consumer physically engages with the product. This phase encompasses the time from when a consumer purchases a product to the ultimate end of life decision for the product made by the consumer. The total consumer engagement period is typically 6 months for a pair of running shoes (Fleet Feet, 2022). While the use phase of shoes contributes to only 1.7% of the product's total carbon emissions, extending a product lifespan by three times can reduce the total carbon emissions by 65% and water use by 66% by preventing the need to manufacture a new replacement product (MistraFuture, 2017). The use phase is a small part of the product's life cycle impacts, but very important in the prevention of new product loops that are environmentally intensive. Currently, On provides a trade-in option for users through the platform Onward, but more circular strategies for use are complicated and untested. Company-level interventions at this phase are complicated because the company ultimately does not have ownership of the product after the point of purchase. Therefore, circular initiatives require communicating with consumers through marketing campaigns or providing outlets for consumers to engage in sustainable behaviors (i.e. shoe repair). These initiatives are largely uncorroborated because there is not any significant consumer research into how consumers react to specific marketing and communication pertaining to circularity and extended product use. However, specific case studies can supplement data to provide evidence for specific strategies. This section includes a description of five strategies, a table (Table 9) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity at the Use stage.

Fig. 17 Allbirds Shoes, designed with materials that can be easily washed in a washing machine, as well as separated when insoles or laces need to be replaced. Source: Sanja Kostic for The Spruce (Leverette, 2023)

Strategies

Use Strategy 1: Create care and wash instructions for all products

Circularity requires materials and products to stay in use for as long as possible. The promotion of proper wash and care instructions for footwear and apparel products can help maintain materials at their highest value and lengthen a product's life cycle. For footwear, cleaning can enhance material function and increase aesthetic value, each of which lengthens a product's lifespan. While clothing is often over-washed, more efficient and reduced washing can prevent material aging and mitigate microfiber waste. The instructions should accompany the purchase of any product from On.

In the case of Allbirds, the company has innovated their footwear product line to accommodate the everyday dirt and stink that accompanies frequent uses of a product (Allbirds, 2023). Allbirds has simplified the cleaning process, by changing product design to allow shoes to simply be thrown in the washing machine like everyday clothes (Fig. 17). This attribute of the product allows shoes to look cleaner and smell better longer. Because dirt and smell are two of the primary determinants of when a shoe should be thrown away, washing helps elongate the life of a product.

Instructions to wash shoes are readily available online and On even has steps to wash shoes on their website, but these processes can be time intensive. Simplified options to wash shoes are necessary to engage the larger consumer base who may be unwilling to engage in time intensive maintenance. The difficulties in implementing machine washable shoes are multi fold; the wash process can age the shoe due to the submerging in water and the exposure to high temperatures. To allow for washing, materials need to be tolerant to washing conditions which would require changes in the material composition of the shoe. Other treatments and wash options should be evaluated to enhance the aesthetics and reduce the smell of shoes.

Use Strategy 2: Develop a shoe registration program

To ensure proper product use and disposal, On needs to remain engaged with a consumer as they use a product. Once a product is purchased from On, the company loses direct engagement with the customer. Without a streamlined form of communication, On cannot communicate with consumers at key milestones in a products life cycle (like at the 6-month point, when shoes are typically disposed of) or engage with consumers to ensure they are properly using the product. A shoe registration program can allow On to track use, engage with consumers, and provide relevant product updates at key intervals. A survey at the University of Michigan found that consumers want to register products, but often don't like putting in the effort (Schoettle et al., 2015). However, the researchers proposed that creating exclusivity by registering the product can increase engagement. Therefore, the product registration can be accompanied with access to an exclusive social community of On runners to track miles ran, engage with other users, and gamify the use of shoes (e.g. a customer leader board of miles ran). A further advantage of shoe registration is access to reliable customer data that can be leveraged to provide more sustainable and consumer-influenced shoes. From a technical standpoint, all the resources and tools are available to create product registration, while companies like Registria, Tavant, and Modyo sell registration services.

Use Strategy 3: Communicate product norms on labels

There are a number of social norms when it comes to running shoes, like the recommendation to replace running shoes every 6 months or 300 miles. Misinterpreting norms for product use can often lead to a product not fully being utilized, which reduces the use time of the product. On can place labels on products to relay suggested use information and give indications of when it's time for a new pair of shoes. This information can promote a more standardized lifespan for shoes and reduce uncertainty about when it's time for a new pair. This strategy echoes the studies on peer comparison in the energy sector. When users were presented on their energy bill with their neighborhoods average energy usage there was a regression to the mean by all users in the neighborhood (NBER). The practice of correctly communicating norms to create a more standardized use can be implemented into the footwear industry to minimize variability in consumer use and prevent premature disposal. From a technical standpoint, relevant research is needed to determine the functional lifespan of a shoe, and because use is not homogeneous among users, there are limitations to this approach because it could potentially lead to disposal of a still useful shoe.

Use Strategy 4: Organize a donation program for products

On already has created Onward in partnership with Trove to collect used shoes and recirculate them, but Onward is restricted to only selling high-quality products. This leaves a subset of the shoes that still have life in them, but are not high enough quality to be resold. These mid-quality products can stay in circulation by being donated to disadvantaged communities. On can additionally collect used products at retail stores or at local collection points to be donated to new communities and thus extend the functional life of a product. From a conceptual standpoint, all of the pieces are in place. On would just need to organize collection points and identify charities who can properly distribute the shoes to disadvantaged communities. It is also important for there to be a checks system to make sure that all donated shoes are still functional.

Use Strategy 5: Identify repair partners and create a repairability index

Repair models can extend a product's life by 1.35x and create a reduction in emissions and resource use (McKinsey, 2020). Companies like Birkenstock and Veja have worked with cobblers to create local repair options for their products. Veja's repair operation has repaired over 5,000 shoes, while unrepairable shoes are collected and "given a second life" according to the company's website (Veja, 2021). By creating repair instructions and working with local cobblers and experts, On can create a repair model for their products to increase a product's life span. On can additionally create a repair-ability index for their products, a 1-10 labeling system to indicate how repairable a product may be, to encourage consumers to repair their products. To enable repair options for shoes, On would need to create a repair manual for the product and provide third parties access to individual parts of the shoe to allow for repair and replacement of damaged or old parts. A repair model would likely require a simplification of the manufacturing and assembly process.

Key partners to help enable circularity within the Use Stage

- Shoe repair companies, either local cobblers or companies to help with modular design
- Product registration manager companies, such as After, INC or Registria
- Material manufactures to help create washable products
- Donation centers to handle large volume, such as Salvation Army or Goodwill
- Research / University systems to measure and standardize functional use of a product

Suggested Metrics for Use Stage

- Average lifespan of product's use phase
- Average miles-used per shoe product
- Percent of products repaired over total sold
- Average use of shoes as compared to competitor brands
- Number of repairs per product life cycle
- Number of products registered
- Number of consumers engaged at use phase via registration platform
- Number of shoes donated
- Extended use time for shoes after use by primary consumer (i.e. length of use in the next iteration of life cycle)
- Average number of use loops/cycles per product

Table Key

- ○ **Potential for positive impact on the Circularity Indicator**
- – **Potential for neutral/ no impact on the Circularity Indicator**
- ✕ **Potential for negative impact on the Circularity Indicator**

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Use Strategy 1: Create care and wash instructions for all products	○	○	○	○	○	○	○
Use Strategy 2: Develop a shoe registration program	–	○	○	○	○	○	–
Use Strategy 3: Communicate product norms on labels	–	○	○	–	○	✕	–
Use Strategy 4: Organize a donation program for products	○	○	○	○	○	○	–
Use Strategy 5: Identify repair partners and create a repair-ability index	○	○	○	○	○	–	–

Table 9. MCDA survey results on the impact of Use Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F5.

End of Life

End of Life is considered the last stage of a product's existence and it is viewed as a reactive approach toward waste management, focusing on how waste can be used once the product has reached the end of its lifespan. (Staikos & Rahimifard, 2007). In the world of footwear and apparel, there are four common options when a product enters this stage; reuse, recycle, incineration, and landfill (Staikos & Rahimifard, 2007). Within these four options, reuse is often considered the best choice for EoL management, followed by recycling, incineration, and landfilling (Munasinghe et al., 2021). Reusing shoes is commonly performed through repairing shoes, donations to non-profit organizations or charity shops, and redistribution to developing countries (Rahimifard et al., 2007). Recycling EoL shoes is the process through which materials are collected, sorted, deconstructed, and reprocessed into new usable products (Albers et al., 2008). Incineration involves the combustion of organic materials, which can be used to generate heat and electricity (de Titto & Savino, 2019). Disposal to landfill is the most common end of life option for this stage of shoes (Gottfridsson & Zhang, 2015).

Landfilling shoes is considered to have the greatest environmental impact because landfilling of natural and bio-based fibers can emit GHGs while synthetics can remain in the soil for centuries without decomposing (Muthu, 2014), causing environmental pollution of rivers and groundwater supplies, predominantly by landfill leachate (Staikos & Rahimifard, 2007), and more. Landfilling is the most common method because it is the easiest, cheapest, and most convenient way for individuals, companies, and cities to dispose of solid wastes. 85% of footwear and apparel end up in landfills (Igini, 2022), and for shoes specifically, the number is around 90% to 95% (DiNapoli, 2022; Hoskins, 2020). This creates a huge gap between the ideal state (reuse or recycle) and the actual end of life scenario for most footwear and apparel.

The vision for EoL in a circular model is to take back all the product from consumers and to have solutions in place for a given material to keep it in a closed-loop, or to put it into the recycling stream to minimize waste from products. It is essential to the CE to prioritize reducing the percentage of landfilled materials, by increasing the amount recycled through partnerships with other companies and end of life partners. The following are five strategies for On to potentially increase the circularity of the EoL phase. These strategies are based on research as well as review of industry standards and suggestions for improvement. This section includes a description of each strategy, a table (Table 10) describing their ranked impact on each Circularity Indicator, as well as metrics and key partnerships for measuring and enabling circularity at the End of Life stage.

Strategies

EoL Strategy 1: Cooperate closely with recycling companies to have an efficient EoL process

Recycling is an end of life strategy that could protect humans and the environment from pollution concerns associated with landfills while also more efficiently using resources. Recycling often requires external partnerships. On will need to work closely and cooperate well with external recycling services providers. To fulfill this strategy, On would need to make sure the recycling process is highly transparent, not only about the resource usage during the recycling process, but also about the output, material efficiency, wastes, and emissions. Within this strategy, On should launch several test programs to explore more recycling options for EoL products with external partners, make sure that each major market has at least one major recycling service partner, and ensure the capacity of their recycling service grows as sales grow.

EoL Strategy 2: Invest in improving current EoL process/techniques

Previous research (Staikos & Rahimifard, 2007) indicates that the recycling process for shoes might be problematic and inefficient given their complexity of mixed materials. On should work with their recycling partners to improve current EoL processes and technologies to increase the efficiency of the entire EoL stage. To fulfill this strategy, On would need to identify which kinds of material cannot be properly recycled, but are essential for the performance of a running shoe, and partner with technology companies focusing on circularity, such as On's partnership with Carbios, to explore more efficient solutions on recyclable material. Additionally, exploring new options for currently unrecyclable materials, optimizing the current EoL process and reverse logistics, efficient classification of products based on the level of wear, and cooperating with more recycling service providers to reduce the shipping distance are all feasible approaches to increase the efficiency of On's EoL stage.

EoL Strategy 3: Develop an effective take-back program and ensure end of life shoes will be returned for recycling/donation

The fraction of shoes that end up in landfills is extremely high, which leads to a lot of environmental problems and waste of resources. However, many customers are not aware of an easy or convenient way to recycle their shoes. Even if they understand that their shoes should be recycled, customers may still throw them away due to the inconvenience of recycling. This strategy can help to provide a convenient way for On's customers to recycle their shoes by shipping them back to On. On needs to develop a take-back program which gives customers an opportunity to take EoL shoes back. The practice of this program could be putting a return label in the box, including a web page link or a QR code that indicates where consumers can send back their shoes, or expanding the current Cyclon™ subscription model to more products. On currently has a take-back program in partnership with Trove that extends the lifespan of On's product through secondhand purchases. On could evaluate the benefit of that program financially and environmentally to see if it is financially feasible to launch a pilot take-back program for end of life products. This strategy could potentially address increasing external expectations of Extended Producer Responsibility across different countries in which On sell products as well.

EoL Strategy 4: Create several key metrics to track EoL performance to make sure On is in the right direction, including non-Cyclon™ products

It is essential to make sure all products have metrics to track the performance of EoL processes to approach circularity. We defined 10 different metrics (next page) based on sustainability reports from the comparative analysis and literature review that might not only help On to track performance, but also identify which areas in the EoL stage could be improved upon.

EoL Strategy 5: Seek partnerships with competitors to share ideas and resources for EoL management

From our experience with On's employees, On likes to learn from others and is open for cooperation. On should seek out those with similar circularity goals within the industry and cooperate with them to share ideas and resources for EoL management. This could include sharing the same factory/recycling service providers for recycling shoes. By sharing recycling resources, both brands could benefit from a larger pooled material supply as well as help support recycling facilities that require a larger supply to operate efficiently. If the outcome of recycling shoes is usable for new shoes, it can be co-branded with the other collaborating brands. This might not only promote relationships with the partner brands, but also could have the added commercial benefit of selling co-branded shoes. This strategy also includes sharing ideas with talented colleagues in other brands and learning from each other on end of life management. This strategy might play a role in terms of improving and optimizing the current EoL process.

End of Life

Key partners to help enable circularity within the End of Life Stage

- Companies focusing on reuse, e.g., TERSUS, which focuses on closing the loop for textile by providing services such as deep cleaning, repair, up-cycling, and recycling. Soles4Souls, which donates shoes for entrepreneurs in developing areas to utilize for parts and up-cycling
- Companies focusing on recycling technology, e.g., FastFeetGrinded, which is currently working on machinery that can easily transform a shoe to raw material for new shoes and other products. On could also expand current partnership with Carbios or similar companies like Wolkat, Kvadrat Really, and DenimX

Suggested Metrics for End of Life Stage

- Percentage of returned products
- Percentage of shoes ending up in landfill
- Total amount of finished product waste collected, recycled, or donated
- Total amount of waste produced during the entire EoL stage
- Waste per unit of production
- Total amount of CO_2-eq emissions during the entire EoL stage
- CO_2-eq emissions per unit
- Waste and CO_2-eq reduction per unit per year
- Chemical management index ("Chemical Management 2022," n.d.)
- Percentage of renewable/clean resource used in the entire EoL stage

Table Key

○	**Potential for positive impact on the Circularity Indicator**
—	**Potential for neutral/ no impact on the Circularity Indicator**
✗	**Potential for negative impact on the Circularity Indicator**

	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
EoL Strategy 1: Cooperate closely with recycling companies to have an efficient EoL process	○	—	○	○	—	—	—
EoL Strategy 2: Invest in improving current EoL process/techniques	○	○	○	○	✗	✗	—
EoL Strategy 3: Develop an effective takeback program and ensure end of life shoes will be returned for recycling/donation	—	○	○	—	✗	○	—
EoL Strategy 4: Create key metrics to track EoL performance to make sure On is in the right direction, including non-Cyclon™ products	○	—	○	—	—	✗	✗
EoL Strategy 5: Seek partnerships with competitors to share ideas and resources for EoL management	○	○	○	—	✗	—	✗

Table 10. MCDA survey results on the impact of End of Life Strategies on Circularity Indicators. More information that was provided for the MCDA survey can be found in Appendix F, Table F6.

Circular Strategies

Higher Priority ↑ / ↓ Lower Priority

Raw Material Extraction, Processing, and Manufacturing	Product Design and Development	Product Manufacturing and Assembly*	Logistics and Distribution	Consumer Use and Engagement	End of Life
Invest in and scale-up innovative sustainable materials and practices for synthetic materials	Prioritize mono-material products	Use Power Purchasing Agreements and International Renewable Energy Certificates	Choose distribution center locations based on On's current evaluating standards, but also consider distribution center's locations by their location's estimated climate resiliency	Create care and wash instructions for all products	Invest in improving current EoL process/ techniques
Invest in and require energy efficiency and renewable energy supply for materials partners	Design for disassembly	Leverage government incentives to invest in joint or on-site renewable projects	Create or join a standard sustainable supply chain assessment framework	Organize a donation program for products	Cooperate closely with recycling companies to have an efficient EoL process
Prioritize less intensive pretreatment, dyeing, and finishing processes for material production	Provide training for design and product development teams on circular design principles	Low-cost substitutions: Address lighting and on-site fuel uses	Redesign shoe packaging to be lighter, smaller, and use fewer resources to increase the number of shoes per master carton	Identify repair partners and create a repairability index	Seek partnerships with competitors to share ideas and resources for EoL management
Utilize materials from pre-consumer and post-consumer textile waste	Implement better process design, modeling, and simulation tools in design and development	High-cost substitutions: Invest in new, efficient equipment	Partner with retailers to create parcel pick-up stations instead of only providing home deliveries	Develop a shoe registration program	Create key metrics to track EoL performance to make sure On is in the right direction, including non-Cyclon™ products
	Implement modular design	Utilize waste through Waste-to-Energy	Further invest in On's advanced analytics and IT infrastructure to track and enact system-wide changes more efficiently throughout On's supply chain	Communicate product norms on labels	Develop an effective take-back program and ensure end of life shoes will be returned for recycling/donation

* The only recorded response for the Manufacturing stage chose to appraise one strategy. More results would be needed to correctly conduct the MCDA for this stage.

Table 11. MCDA results aggregated to show strategies for each stage of the value chain ordered from Higher Priority to Lower Priority based on the rankings from employee survey.

Limitations of Analysis

Lack of Impact-related Information for Athletic Footwear

The athletic footwear and apparel industry posed challenges to finding existing research on the CE. Some research, such as LCAs, exist for athletic footwear specifically. However, these results are unique to the product and the company's supply chain and operations setup, and is not easily generalizable to all athletic footwear. We extracted the key areas which are general to all athletic footwear and apparel life cycle stages and provide general considerations rather than exact solutions to challenges. There is available information on the apparel industry as a whole and the individual life cycle stages, but there is scarce information on footwear alone, or specifically athletic footwear. Given this limitation, specific material and process LCAs and their impacts are allocated for footwear given these more broad available literature. Additionally, the subjectivity of LCAs and other metric-producing methods present challenges on how to represent sustainability-related measures as a reduced set of quantitative metrics.

While a lack of information and evaluation metrics make product and process impact assessment challenging at a unit level, the unstandardized nature of current reporting practices further makes information challenging to gather and analyze. Without enforceable reporting standards in place, brands and organizations are afforded the opportunity to report information in any way they find is suitable. From here two challenges arose for the project: the comparison of companies and their product lines, and the verifiability of reported information. Each company often reported different sustainability-related metrics in different ways while using different methods to produce those metrics. Additionally a companies' ability to choose how they represent their reported information makes it challenging to verify what information is represented in a complete-as-possible and ethical manner, and how the information can be fairly compared against other companies without the given underlying assumptions and models.

Current State of Technology to Achieve Circularity

A few challenges with implementing circular economic systems are that for a system to be circular, each value chain stage needs to be able to support the process of waste minimization, while also being economically and technologically feasible for the business. When investigating potential strategies, solutions, such as chemical recycling, provided promising answers to large challenges for a circular system implementation within the footwear industry, but are currently not feasible at scale and require impactful tradeoffs such as high energy intensity. The use stage posed a different challenge in terms of having both scarce information on consumer behavior specifically for the product type in focus, while also having limited solutions that provide significant quantitative evidence supporting any particular benefit. Though solutions can be theorized, such as reward programs or using mobile applications to gather user usage data, it is not clear if the anticipated benefits will truly be realized without prior evaluations or experimentation. So with great technical solutions starting to be applied to the realm of circular footwear, more time and research is needed to determine which solutions will end up proving practical.

Value Chain Measureability for Life Cycle and Impact Assessment

A challenge that is reflected both in research and in practice is low measureability of current value chain activities and processes, and low visibility into areas such as supplier operations. For footwear and apparel, brands heavily rely on their suppliers and the extended supply chain to produce and distribute their products, which has limited brands' visibility into potential negatively impactful activities. As seen in the comparative analysis, companies are still working to add accounting processes and audits within their supply chain, which will be a fundamental first step in being able to comprehensively analyze the sustainability of their businesses. Without these processes currently in place, publicly available information is not widely available or representative of the true state of sustainability of the industry.

Ranking and Strategy Limitations

The strategies proposed for each life cycle stage are limited due to the specificity of the challenges they are trying to address for a single company. Though the strategies' prioritization is informed by the overall industry's baseline statistics and research literature, these strategies are qualitatively chosen based on the company's current needs and weighted by employees who are currently working on the related challenges. Not having direct access to all the information that an internal employee has, these individuals were presented with potential top-level options that could be used to generate solutions that can then be implemented. Ideally these strategies would be piloted in a practical method, mechanism, or process with the company and its partners to collect data and assess utility, but based on the time and proximity limitations the strategies can only be presented in the form of recommendations. The MCDA ideally would be ranked by more industry experts for additional insight, but we decided to focus on a specific companies' specific situation for the purposes of this project.

Source: On

Future Areas of Focus

Our project focused on a broad analysis of how circularity and sustainability could be further integrated into On's value chain. To better understand how On can further their circularity journey, there are key areas that we have noted that will be impactful. Specifically, social considerations; consumer engagement; reverse logistics; and national and international policy are key areas that require increased attention to promote a CE and help On become fully circular.

Social Dimensions

Many supporters of circular systems promote that CE is a sustainable development tool that will advance social equity due to its promise of economic prosperity and reduction of resource exploitation and waste (Repp et al., 2021). Through an analysis of 114 definitions for CE, Kirchherr et al. (2017) determined that while there are many existing interpretations of CE, it is most often described as an economic and environmental model with little mention of the social impact. For example, Kirchherr et al.'s (2017) and Padilla-Rivera et al.'s (2020) analyses found that most definitions within the literature do not include or expand upon social considerations aside from employment, leaving a gap in research about CE's impact on sustainable development. Moreau et al. (2017) emphasize this point as well, stating that the social and institutional dimensions of the CE are under-researched and underdeveloped. They argue that the CE's current emphasis on economic prosperity does not go far enough to address the underlying social issues of the current linear system and could reinforce these inequalities.

However, supporters of CE state that incorporating circular practices will support social aspects of sustainable development due to a projected increase in employment and job opportunities based on circular activities such as recycling or refurbishing (Repp et al., 2021). Repp et al. (2021) analyzed this assumption, focusing on the predicted impact that CE would have on the EU apparel industry. The study found that while there may be an increase in jobs in the recycling and waste management sectors, there will be a decrease in manufacturing and resource extraction sectors globally. While this may initially seem beneficial from an environmental perspective, the context of these industries is important. This shift in employment will favor wealthier countries of the Global North and discriminate against middle- and lower-income countries whose economies largely depend on resource extraction and manufacturing. Research shows that people will migrate in search of job opportunities which could lead to greater international migration and a greater division between income classes (Yuko, 2021). Viewing the impacts of the CE model from this global perspective raises concerns about how a just transition would be managed.

Another key topic within the social dimensions of CE is the quantitative measurement of social equity within the apparel and product-based industries. Both Gonçalves and Silva (2021) and Gold and Heikkurinen (2018) explore this topic, commenting on the lack of standardization and regulation across the industry.

Most companies create their own internal reporting, leading to differing boundaries, assessments, and units across the industry. Gold and Heikkurinen (2018) call the current industry emphasis on corporate transparency into question, emphasizing that corporate responsibility is a limiting model that cannot sufficiently self-govern on issues of sustainability and ethics due to the opaque nature of corporations. This lack of standardization and transparency can easily cause green-washing, mislead heads of companies and consumers, and lead to corrupt systems (Generation Climate Europe, Task Force on Textiles, 2021). Without deliberate actions or standardized measurements related to social equity, CE could be another economic tool that perpetuates inequalities and injustice globally.

On will need to continue to focus on how CE in their company and industry will impact social conditions such as labor rights, health and safety, and human rights since the footwear industry spans across the globe. While less common than environmental measurements, there are emerging tools that assess the social impact of a company's supply chains which could help On evaluate their social impact. For example, the ISO-14040 framework for a Life Cycle Assessment (LCA), allows for companies to conduct a Social Life Cycle Assessment (S-LCA). The S-LCA works to identify hot spots for social impact across a company's supply chain and helps evaluate potential changes in producers and manufacturers. While S-LCAs is a developing area, they provide just one example of how On can incorporate data-driven social metrics into their CE and sustainability initiatives.

Consumer Engagement

The role consumers play in influencing corporate sustainability is debated by economists and business professionals. Another topic debated is whose responsibility is it to push this adoption of circular products. Should it be the company's responsibility or is it dependent on the customers' wants?

In this case, our report suggests both companies and consumers need to change their behavior for the successful adoption of circularity. Companies like On need to build their products and design their operations to be circular and responsibly manage their waste. Customers need to change their consumption behaviors. For example, we believe it is critical that On continues to build out their end of life plan for their products. In turn, customers need to use that plan and slow their overall consumption of products. One of the main reasons we identified why the fashion industry is so wasteful is because of the high turnover rates of clothing and footwear (Jacobs, 2022). Running sneakers in particular have a fast turnover rate with a typical lifespan of 6 months (300-500 miles) before their performance starts to degrade (Matsumoto, 2022). To extend the lifespan of shoes and enable circularity, On will need to rethink how they design shoes, but consumers are also going to need to want to repair and/or wash shoes instead of buying new. On will also need to consider how to ensure they do not perpetuate the phenomenon of fast fashion. Fast fashion has exacerbated the phenomenon of overbuying, as people buy cheap clothes and wear the garment a handful of times before throwing it away or donating it.

However, many donated clothes end up abroad in other markets that cannot compete with clothes being sold in more economically developed countries, incarcerated for energy, or landfilled (Jacobs, 2020). If an individual slowed their consumption of products and the way they dispose of clothes such as shopping second-hand or renting clothes, this could dramatically affect the annual generation of clothes in a landfill (Jacobs, 2020).

Overall, for companies' sustainability initiatives to be successful there will need to be a large amount of consumer engagement in these programs and a cultural shift in the way people consume goods and services. In addition, there will need to be more consumer research to understand the best practices to encourage consumer engagement in sustainability initiatives as well as make these initiatives accessible to all demographics. Companies from all sectors will need to evaluate how to spur circularity in their fields, as a successful CE will require cross-sectoral collaboration.

Reverse Logistics for the Circular Economy

Designing a successful reverse logistics plan for a company greatly depends on the industry itself, effectively engaging the customer, and government regulation. Reverse logistics will vary depending on the location of operations based on a country's policies, the size, the assets of the company, and a multitude of other factors. However, increased transparency and data collection on the supply chain will allow companies to build a plan for their reverse logistics, which is a vital part of closing the loop in their operations.

Some of the most crucial components to be aware of when creating a reverse logistic design is understanding the use of the product/service and what outputs will be left at the end. This will dictate the best course of action for an end of life plan. At this point, it's important to build a plan of action to address the logistics of getting the discarded product from the customer back into the custody of the company that originally sold the product/service. Once the logistic chain is mapped out there needs to be a use for this material within its industry for this process to be considered circular. Though using this waste product as an input for another industry is better than it being a landfill, it is not considered circular in some policy definitions. For example, it is not a circular practice by the EU's Circular Economy Action Plan to send old shoes to a waste-to-energy or sold to less economically developed countries at a decreased price (Business of Fashion, McKinsey & Company, 2022). An example of a successful reverse logistic design would be for old shoes to be collected from the consumer and then broken down to be made into new shoes that could be sold to a new customer. Increased focus on reverse logistics and evaluation of the available options will be necessary for companies to become circular.

Circular Economy Enabling Policies and Companies' Role in Policy

As companies work to define their own closed-loop processes individually and within their industry, their work is impacted by the local and international policies they operate within. The Climate Crisis, a situation characterized by the threat of highly dangerous, irreversible changes to the global climate, has informed the reformation of traditional company operations toward less environmentally harmful practices (Oxford Languages, 2023). However, companies are currently making their own definitions for what circularity and sustainability means to them. Non-profit organizations like Greenbiz and the Ellen MacArthur Foundation are conducting research about the CE to be able to build a comprehensive, universal, and broadly accepted definition of CE that can guide companies on their transition to be circular. In addition, governments are working to regulate and analyze policies that may enable or inhibit the creation of circular systems across sectors, industries, and country lines. For example, non-compete laws, health and safety regulations, waste management policies, and subsidies will all need to be assessed on the global and local level to determine unexpected impacts on the viability of implementing circular practices. There will need to be considerable research conducted to assess how policies and regulations can support stakeholders working together for the shared goal of creating a sustainable CE.

Implications for the Broader Industry

Industries and the companies within each industry vary so much based on their products or services, business model, location, and customer demographic, meaning that it is vital to build a specific action plan to reach circularity. There is no one-size-fits-all road map to circularity and claims like that could lead to negative unintended results. When approaching how to transition from an linear business model to a circular model, it is crucial to evaluate how this transition will impact every part of the value chain. The MCDA process for assessing strategies for circularity presents just one method for companies to make sense of the multiple, complex criteria associated with enabling circularity.

This study recommends strategies that can help On become more circular as well as more generalizable ways that a company in the athletic footwear and apparel industry can transition to circularity. This report can be used to inspire other companies on how to examine their own supply chain to transition to a circular model.

Appendices

Appendix A: Circular Economy Definitions collected and their sources

Circular Economy [CE] Definition	Source
"The environmental objective of [CE] is to reduce the production-consumption system of virgin material and energy inputs and waste and emissions outputs (physical throughput) by application of material cycles and renewables-based energy cascades. The economic objective of [CE] is to reduce the economic production-consumption system's raw material and energy costs, waste management and emissions control costs, risks from (environmental) legislation/taxation and public image as well as to innovate new product designs and market opportunities for businesses. The social objective is the sharing economy, increased employment, participative democratic decision-making and more efficient use of the existing physical material capacity through a cooperative and community user (user groups using the value, service and function) as opposed to a consumer (individuals consuming physical products)	Korhonen, 2017
"A circular economy decouples economic activity from the consumption of finite resources. It is a resilient system that is good for business, people and the environment. The circular economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution." (Ellen MacArthur Foundation).	Ellen MacArthur Foundation, n.d
"The circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimizing negative impacts. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital (Ellen MacArthur Foundation 2015)."	Sadowski, 2021
"Focuses on stock optimization. Has a structure of three loops: reuse and re-marketing for goods, product-life extensions for goods and a recycling loop for molecules (secondary resources) (Stahel, 2013)."	Kalmykova, 2018
"A general term for reducing, reusing and recycling activities conducted in the process of production, circulation and consumption (Government of People's Republic of China, 2008)."	Kalmykova, 2018
"In the circular economy the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized (EC, 2015a, EC, 2015b)."	Kalmykova, 2018
"An alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life (WRAP, 2016)."	Kalmykova, 2018
"An economic and industrial system based on the reusability of products and raw materials, and the restorative capacity of natural resources, which also attempts to minimize value destruction in the overall system and to maximize value creation in each link in the system (Bastein et al., 2013)."	Kalmykova, 2018
"An industrial model that decouples revenues from material input (World Economic Forum, 2014b)."	Kalmykova, 2018
"An industrial system that is restorative by intention and design. The idea is that rather than discarding products before the value is fully utilized, we should use and re-use them (Wijkman and Skånberg, 2015)."	Kalmykova, 2018
"An economic system aimed at eliminating waste and promoting the continual use of resources, minimising resource inputs and the creation of waste, pollution and carbon emissions. In apparel, we refer to the six Rs: reducing the materials needed and waste created when making products; recycling the materials used to produce new products; refurbishing deadstock and used products into new products — without re-processing the raw materials; reselling second-hand or used products with no refurbishment; renting products through one-off rental or subscription models; and repairing products, by professional or amateur means during the product's use-phase — without changing ownership."	Amed, 2022
Definitions continued on next page >	

Appendix A: Circular Economy Definitions collected and their sources (cont'd.)

Circular Economy [CE] Definition	Source
"An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers (Kircherr et al., 2017, p. 229)."	Kircherr et al., 2017
"An economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces and consumes."	Prieto-Sandoval, 2018
"The central idea is to close material loops, reduce inputs, and reuse or recycle products and waste to achieve a higher quality of life through increased resource efficiency."	Prieto-Sandoval, 2018
"[CE] which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows."	Prieto-Sandoval, 2018
"[CE], material flows are either made up of biological nutrients designed to re-enter the biosphere, or materials designed to circulate within the economy (reuse and recycling) (GEO5	Prieto-Sandoval, 2018
"The [CE] policy seeks to integrate economic growth with environmental sustainability, with one element relying on new practices and technological developments, similar to the application of environmental modernization technology."	Prieto-Sandoval, 2018
"[CE] is a regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with capacity to be implemented at any scale."	Suárez-Eiroa, 2019

Appendix B: Sustainability Reporting Comparative Analysis

Company	On	Adidas (Built Environment)	Allbirds	Hoka One / Deckers	Teva / Deckers	Véja	Salomon / Amer Sports	Nike	Asics	Columbia Sportswear	Reformation	Puma	Mizuno
Report Year	2020	2020	2020	2020	2020	2019	2019	2020	2020	2020	2020	2020	2021
Sustainable Materials Activities													
General													
Currenlty using recycled synthetics (input)	✓		✓	✓	✓	✓		✓	✓	✓			
Target for recycled synthetics (input)	✓			✓	✓				✓				
Currenlty producing recyclable synethics (output)	✓				✓					✓			
Target for recyclable synthetics (output)				✓			✓					✓	
Currently have bio-based materials (input)	✓		✓	✓					✓	✓		✓	
Target for bio-based materials (input)	✓		✓	✓	✓	✓			✓			✓	
Currently have biodegradable materials (output)										✓		✓	
Target for biodegradable materials (output)	✓											✓	
Specific Material Targets													
100% Sustainable Cotton				✓	✓			✓	✓		✓	✓	
Sustainable Cotton Target												✓	
100% Sustainable Leather				✓	✓				✓		✓		
Sustainable Leather Target										✓		✓	
Material Metrics Levels of Detail													
Breakdown of material use in products				✓	✓	✓			✓				
Breakdown of material use targets				✓	✓				✓				
Material Certificates and Standards													
ZQ Merino and Responsible Wool Standard (RWS)					✓								
ECO PASSPORT by OEKO-TEX Water Repellent			✓										
Forest Stewardship Council (FSC)			✓	✓	✓							✓	
FSC-certified Tencel										✓			
FSC-certified Natural Rubber			✓										
Leather Working Group (LWG)	✓		✓	✓	✓	✓			✓	✓	✓	✓	
Better Cotton Initiative (BCI)									✓	✓	✓	✓	
GOTS (Global Organic Textile Standard) certified									✓		✓	✓	
Fair trade certified cotton									✓				
GRS (Global Recycled Standard) certified recycled cotton			✓	✓					✓		✓	✓	
Higg Materials Sustainability Index (MSI)							✓	✓		✓		✓	
Higg Product Module (PM)							✓	✓					
Extended Responsabilies													
Regenerative Agriculture			✓			✓							

Table B1. Excerpt from Comparative Analysis Spreadsheet. The complete spreadsheet can be viewed at the below link:

https://docs.google.com/spreadsheets/d/1qolnknLFGDNailvZxkd8W4MoR__LzGGsR_OFqCMv1Yw/edit#gid=1432058790

Appendix C: Comparative Analysis Tables

Materials	• Global Recycled Standard (GRS)
Social & Labor	• International Labour Organization (ILO)
Life Cycle Assessment (LCA)	• ISO 14040 series standards (Lee & Inaba, 2004) • ISO 14041: Goal and scope definition and inventory methods • ISO 14042: Life cycle impact assessment • ISO 14043: Life cycle interpretation methods • ISO 14044: Requirements and Guidelines for LCA practitioners
ESG Reporting	• Apparel, Accessories & Footwear Sustainability Accounting Standard by The Sustainability Accounting Standards Board (SASB) • Global Reporting Initiative (GRI)

Table C1. Standards used by a subset of the companies in the comparative analysis.

Materials	• ZQ Merino and Responsible Wool Standard (RWS)
	• Fair trade certified cotton • Global Organic Textile Standard (GOTS) Certification
	• Forest Stewardship Council (FSC) Certified Tencel • Forest Stewardship Council (FSC) Certified Tencel Natural Rubber
	• Higg Materials Sustainability Index (MSI) • Higg Product Module (PM)
Chemical Management	• REACH Standard - Dyes • AFIRM RSL (Restricted Substances List) • ZDCH MRSRL (Manufacturing Restricted Substances List) • Zero Discharge for Hazardous Chemicals (ZDHC) • OEKO-TEX ECO PASSPORT (Textiles chemicals only) • OEKO-TEX Standard 100 (Textiles and textile accessories) • Bluesign Certified
Facilities	• Higg Facility Environmental Module (Higg FEM) • Higg Facility Social & Labor Module (Higg FSLM) • Leadership in Energy and Environmental Design (LEED) • Worldwide Responsible Accredited Production (WRAP) • OEKO-TEX STeP (Manufacturers)
Energy	• Energy Attribute Certificates (EACs) • Power Purchasing Agreements (PPAs)
Packaging	• Forest Stewardship Council (FSC) Certified Cardboard

Table C2. Certifications used by a subset of the companies in the comparative analysis.

Materials	• Leather Working Group (LWG) • Better Cotton Initiative (BCI)
Materials	• Better BuyingTM
Social & Labor	• AAFA/FLA Apparel & Footwear Industry Commitment to Responsible Recruitment • Fair Labor Association (FLA) • Better Work Programme • Global Alliance for Sustainable Supply Chain (ASSC) • Social & Labor Convergence Program (SLCP) • Responsible Labor Initiative • The Leadership Group for Responsible Recruitment • International Center for Research on Women • Issara Institute • Equal Employment Opportunity (EEO)
Packaging	• Sustainable Packaging Coalition (SPC)
Logistics	• Environmental Ship Index (ESI) by World Ports Sustainability Program (WPSP)
Emissions	• Climate Neutral • United Nations Fashion industry Charter
Targets, Reporting & Transparency	• Science Based Targets initiative (SBTi) • Transparency Pledge • Open Apparel Registry (OAR) by Open Supply Hub

Table C3. Commitments through partnerships, pledges and indices used by some of the companies in the comparative analysis.

Appendix D: Technology Readiness Level Scale

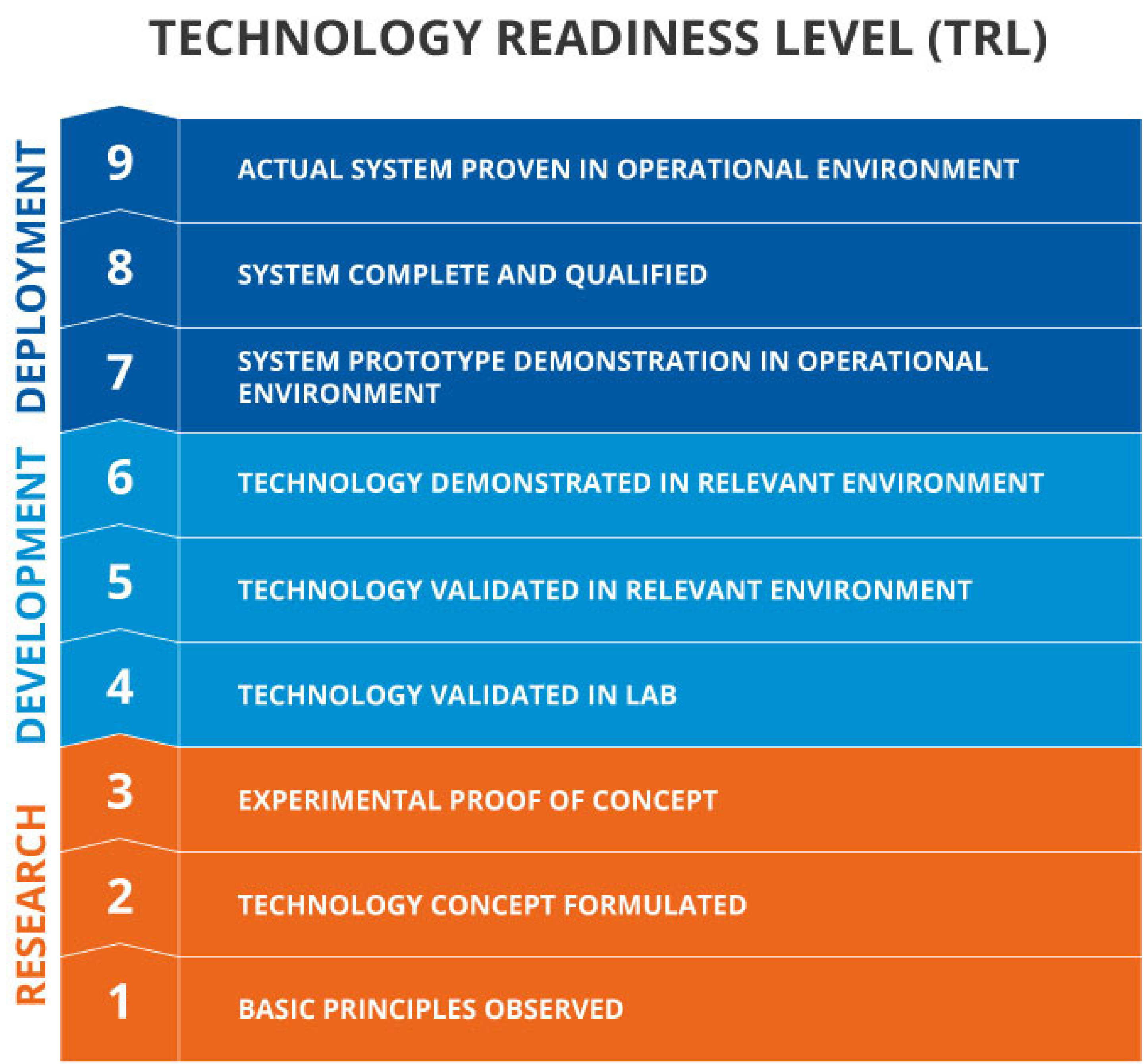

Fig. D1 Technology Readiness Level scale referenced for Circularity Indicators. Source: European Union (TWI, n.d.)

Appendix E: Full On Employee Survey Results

Field	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Circularity requires eliminating or reducing solid waste	7.26% 13	8.89% 8	1.82% 1	0.00% 0	0.00% 0
Circularity requires creating a durable, high quality, product	6.70% 12	4.44% 4	5.45% 3	6.45% 2	5.56% 1
Circularity requires reducing environmental emissions and pollutants	8.94% 16	3.33% 3	5.45% 3	0.00% 0	0.00% 0
Circularity requires using regenerative/renewable materials	9.50% 17	3.33% 3	1.82% 1	0.00% 0	5.56% 1
Circularity requires using recyclable materials	8.38% 15	6.67% 6	1.82% 1	0.00% 0	0.00% 0
Circularity requires keeping materials from On products in circulation	6.70% 12	5.56% 5	5.45% 3	3.23% 1	5.56% 1
Using materials from a Nike shoe to remanufacture an On shoes is considered circular	6.15% 11	7.78% 7	3.64% 2	3.23% 1	5.56% 1
Circularity requires second hand uses for products	5.59% 10	4.44% 4	1.82% 1	16.13% 5	11.11% 2
Circularity requires refurbishing or repairing products so they can be reused	5.03% 9	7.78% 7	3.64% 2	6.45% 2	11.11% 2
Circularity requires a product to have multiple value streams (i.e., initial purchase, recycling, reuse)	6.70% 12	6.67% 6	5.45% 3	0.00% 0	5.56% 1
Circularity requires use of renewable resources when energy dependence is necessary	6.70% 12	5.56% 5	5.45% 3	3.23% 1	0.00% 0
Offseting (hand-printing) programs can be used to achieve circularity	0.00% 0	4.44% 4	23.64% 13	9.68% 3	11.11% 2
Consumer engagement is critical to circularity	8.94% 16	5.56% 5	0.00% 0	3.23% 1	0.00% 0
Product design is the most important element of circularity	0.56% 1	11.11% 10	9.09% 5	12.90% 4	11.11% 2
If all On's products are circular, the company is circular	2.23% 4	4.44% 4	9.09% 5	16.13% 5	22.22% 4
A fully circular economy is an achievable ambition	5.59% 10	6.67% 6	5.45% 3	9.68% 3	0.00% 0

Fig. E1 Statements that On employees were asked to “strongly agree; somewhat agree; neither agree nor disagree; somewhat disagree; or strongly disagree” with to gauge company perception of circularity and circular practices.

Appendix F: MCDA calculation process and strategy tables with impact information for each Circularity Indicator

MCDA Calculations:

In order to measure the viability and effectiveness of each of the circular strategies, we conducted a survey of employees at On to evaluate each strategy on a number of environmental and business factors (See Section 8). After the surveys were completed we compiled the information and allocated numerical values to each response. If the response indicated a “Positive Impact on the Indicator” it was given a value of 1, “Neutral Impact” was given a value of 0, and “Negative Impact” a value of -1.

Given the values of each response, we then tallied the cumulative score for each impact category. For example if an indicator for a specific strategy received 2 responses that indicated it has a “Positive Impact,” 1 that indicated it has a “Negative Impact,” and 1 that indicated it has a “Neutral Impact,” then the indicator received a score of 1 point (math: 2 + 0 + -1). The score received was then divided by the theoretical best score, so for 4 responses the best score would be 4 points. In this example the effect of the indicator would be scored at 25% impact (1 total divided by 4 possible).

Once the impact was quantified as a percentage, the percent was documented as a decimal (25% = 0.25) and multiplied by the weights determined in the initial survey (See Results from Research on On’s Circular Activity, and On’s Company-wide Survey and Expert Interview). For example, let’s apply the previous example that yielded an impact of 25% to the Resource Use category. The initial survey of On employees yielded weights for each impact category, so Resource Use was determined to have a weight of 16.4% for the total MCDA (as compared to other impact categories, all together the weights add to 100%). Again the impact was translated to a decimal and multiplied by the impact, so 0.164 (weight) times 0.25 (impact) would yield a score of 0.041. This number was added to the results yielded from the other environmental impact categories, so the result was total impact over 1 (x/1). Summated together, the scores indicated the overall effectiveness of each strategy. For example, Fig. F1, an MCDA for Material’s Strategy 3 results in a total effectiveness of 81.2%. This number represents the respondents total perceived effectiveness of each strategy.

Material Strategy 3: Prioritize less intensive pretreatment, dyeing, and finishing processes for material production

Resource Use	Emissions	Material Waste	Input Materials	Utility/Durability	Business Case	TRL
Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator
Positive Impact on Indicator	Positive Impact on Indicator	Neutral / No Impact	Positive Impact on Indicator	Neutral / No Impact	Positive Impact on Indicator	Positive Impact on Indicator
Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator	Positive Impact on Indicator
Positive Impact on Indicator	Positive Impact on Indicator	Neutral / No Impact	Positive Impact on Indicator	Neutral / No Impact	Negative Impact on Indicator	Neutral / No Impact
1	1	1	1	1	1	1
1	1	0	1	0	1	1
1	1	1	1	1	1	1
1	1	0	1	0	-1	0
0.164166667	0.2375	0.167916667	0.2225	0.207916667	2	3
0.164166667	0.2375	0.083958333	0.2225	0.103958333		
Total:	0.81208333					

Fig. F1 MCDA process example for Material Strategy 3: Prioritize less intensive pretreatment, dyeing, and finishing processes for material production

Appendices

Table F1. Material Strategies' impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Material Strategy 1: Invest in and scale-up innovative sustainable materials and practices for synthetic materials	Water Use: Polyester: 26% reduction General: 19% reduction Energy Usage: 21% reduction in (fossil fuel) energy usage [M1]	Polyester: 24% reduction in GHG emissions General: 15% reduction in GHG emissions [M1]	Potential for waste reduction in using materials created specifically to be recycled, reused, composted, or biodegraded	Plausible to achieve a 100% change to renewable, recyclable or regenerative materials by 2030, based on On's current trajectory toward material goals [M2]	Concerns about quality in current R&D form of most preferred materials [M3]	Cost of changing material portfolio for existing products Large upfront cost to invest in R&D of materials in low TRL phase to bring to market [M3]	TRL of preferred materials is low - many are still in the R&D phase Availability and quality of sustainable alternative materials in current state may not meet demands or performance needs for athletic footwear/apparel [M3]
Material Strategy 2: Utilize materials from pre-consumer and post-consumer textile waste	Less water and energy usage from initial material creation, but must account for potential increased resource use from recycling process, especially chemical recycling	This currently depends on the type of recycling used to recoup the material	25% of garments in the industry are currently unsold and less than 1% are being recycled into new clothing each year [M4]	25% of garments in the industry are currently unsold and less than 1% are being recycled into new clothing each year	Concerns for lowered quality of mechanically recycled materials	Fashion industry is valued at $2.4 trillion, loses $500 billion of value every year due to lack of recycling and clothes thrown away before ever being sold If scaled, textile recycling industry could become a $10-20b market [M4]	Advanced recycling is currently a costly, complex, and fragmented system. Significant infrastructure and scaling of solutions will be necessary to make textile-to-textile recycling viable
Material Strategy 3: Prioritize less intensive pretreatment, dyeing, and finishing processes for material production	Water usage: 95% reduction using dry processing, Polyester specific: 99% reduction in water use/kg Energy usage: 87% reduction using dry processing Polyester dope dyeing: 65% reduction/kg " [M5; M6]	76-89% reduction in Tier 2 emissions [M5; M7]	32% reduction in waste (for polyester dope dyeing) [M5]	N/A	More durable due to less abrasive dye treatments	Cost, requires investment in switch with suppliers as well	Many options such as dope dyeing are already growing in popularity within the industry currently
Material Strategy 4: Invest in and require energy efficiency and renewable energy supply for materials partners	Water Use: 60% renewable energy = 17% reduction in freshwater consumption 60% efficiency increase = 29% reduction in freshwater impact Energy Use: 15% savings [M8; M9]	69%, 60% renewable energy = 39% reduction in climate change 60% efficiency increase = 21% reduction in GWP impact [M8; M10]	N/A	N/A	N/A	The 56 Mills participating in Clean by Design program (NRDC) saved $22.3 million annually in operational costs between 2015-2019 [M11]	Programs such as Clean by Design are readily available for companies to work with, though dependent on availability, cost, and feasibility in specific countries

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Table F2. Design Strategies' impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Design Strategy 1: Provide training for design and product development teams on circular design principles	Regenerative materials, renewable energy increase,more efficient processes, nutrient recirculation [D1]	Safe return of nutrients to the earth, decreased pollution and emissions [D1]	Longevity, reuseability, repairability, recycling [D1]	Regenerative and recycled materials [D1]	Longevity and design for disassembly/reuseability/ repairability [D1]	Cost and time for training- but could have payoffs in long run due to increased knowledge of circularity and avoided cost of retrofitting in the future	Many options such as EMF or Nike Circular Design guide for learning, and many examples of their design principles in practice Though some in a relatively experimental phase [D1; D2]
Design Strategy 2: Design for disassembly	Nike Considered Boot: Reduced 35% in energy consumption [D3]	Nike Considered Boot: reduced 89% of solvents used. Adhesives can contribute to 15% of the assembly process emissions, due to organic solvents, hazardous chemicals, and polymers form fossil fuels origins [D3]	Nike Considered Boot: Reduced 61% of manufacturing waste [D3]		Disassembly allows for parts to be more easily switched out, potentially extending life of core parts of shoe	Disassembly is a great option for footwear, as it allows for multiple materials and pieces to still be used. This puts less constraint on the aesthetic and performance options for footwear and apparel	Nike commercially launched ISPA link in June 2022. However, most disassembly projects remain in the R&D Phase [D4]
Design Strategy 3: Prioritize mono-material products	N/A	N/A	Potentially reduces waste as a material could be used in multiple parts of a product, and also reduces the EoL difficulties associated with mixed material products	Focuses on utilizing recyclable compost-able, or regenerative materials	N/A	Could be limit options for design and performance of products due to the constraint to one material	Options on the market, like On's Cyclon. But other products are mainly small releases or experimental projects like Future.craft from Adidas x Allbirds [D5]
Design Strategy 4: Implement modular design	Potential for less resource use related to each shoe due to ability to replace parts and extend life of other parts	Potential for less emissions related to each shoe due to ability to replace parts and extend life of other parts	Potential for less waste because more parts can be utilized longer when parts that wear faster can be replaced	N/A	Potential to extend life of products with ability to replace parts that war out faster than others (e.g., soles)	Would require investment in directing consumers to best places to repair or replace parts of shoe, as well as verify viable repair partners globally	More research and development needed to get modular athletic options to scale for production
Design Strategy 5: Implement better process design, modeling, and simulation tools in the design and development process	Less resource use associated with prototyping + potential for savings in process from initial efficiencies in design and patterning	Potential to reduce emissions associated with prototyping and wasted materials	Cutting techniques can help reduce material waste by 2% [D6]	N/A	N/A	Potential to save money on prototyping process. However, zero waste principles of patterning may be difficult in an industrial setting. Could be time consuming to adjust patterns	Multiple patterning programs and some 3D modeling options available on the market, such as Modo and Shoemaster

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Table F3. Mfg Strategies' Impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Mfg Strategy 1: Use Power Purchasing Agreements and International Renewable Energy Certificates	PPA can reduce non-renewable usage by up to 100% Can be onsite or offsite but must be in local power market to benefit. Not always available Time-based, long-term contract [often in 10-20 years] PPA's use RECs to guarantee renewable energy is being supplied RECs and I-RECs allow for indirect use of renewable energy, to claim reduced Scope 2 emissions When renewables and non-renewable energy enters the grid, there is no way to guarantee the energy one consumes is renewable. I-RECs are certificates that earmark, per MWh, renewable energy for the purchaser Not limited by geographic boundaries or transmission constraints Shows a company's commitment to investing in a renewable future, when renewables are not locally available [Mf1]	Based on a 30% energy efficiency gain in HVAC, 20% increase in sewing machine equipment, and 100% renewable energy, this opportunity can present a reduction by about 5% reduction in overall footwear manufacturing emissions [Mf2]	N/A	N/A	N/A	Would reduce impact per unit of product for company, and boost companies sustainability related image	Depends on grid availability. PPA is currently not available in Vietnam at scale For existing contractors: Little control For new contractors: Can be factored into contractor and location decisions
Mfg Strategy 2: Leverage government incentives to invest in joint or on-site renewable projects	N/A	Renewables reduce emissions from grid sources	N/A	N/A	N/A	Vietnam is heavily incentivizing renewable investments, but this would mainly be for public facing projects In 2021, solar photovoltaics were being sold on average for $0.32/watt. Price varies based on conversion efficiency Vietnam allows for renewable energy projects to be 100% owned by foreign investors Renewable energy, clean energy, and waste-to-energy projects have a reduced Corporate Income Tax (CIT) 17% tax rate for 10 years; tax-exempt for two years and in the subsequent four years a 50% reduction will be applied for new investment projects located in difficult socioeconomic areas 10% tax rate for 15 years; tax-exempt for four years and in the subsequent nine years a 50% reduction will be applied for new investment projects located in difficult socioeconomic areas Machinery and equipment imported for renewable energy products are import tax free For specific areas, can be land lease and taxation free up to 15 years Onsite or hyper-local projects will have reduced incentives, but would allow for better capacity matching, and avoid larger grid challenges such as mandatory generation shutoffs [Mf3; Mf4]	Ready, purely a financial decision

Table F3. Mfg Strategies' Impact on Circularity Indicators (cont'd.)	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Mfg Strategy 3: **Low-cost substitutions: Address lighting and on-site fuel uses**	Reduction in fuel use	Switching heating processes' fuel to any of the gases in Table 6 would result in a decrease in emissions per mmBTU Landfill Gas, Other Biogases, and Coke Oven Gas, provide the largest reductions Switching from Fluorescent to LED lighting is a 41-50% GHG emissions reduction [Mf5; Mf6]	N/A	N/A	N/A	Less controllable emissions in manufacturing	Fuel substitutes are limited by the boiler burner compatibility and cost of fuel
Mfg Strategy 4: **High-cost substitutions: Invest in new, efficient equipment**	Electric boilers eliminate direct fossil fuel usage	HVAC and Machine Upgrades: Can decrease emissions by 9%, assuming a 30% efficiency improvement in HVAC, and 20% efficiency improvement in equipment like sewing machines Switch to Electric Boilers with Heat recovery: 16% of emissions reductions can be associated with switching from coal boilers to electric boilers Recovery from heating exhaust can increase boiler efficiency by 1-7% (typically 5%) [Mf2; Mf8]	N/A	N/A	N/A	Large upfront costs or leasing, but costs could be justified by looking at the saving from efficiency over time as well as potential productivity improvements Switch to Electric Boilers: For a full-load steam system (86%-94% utilization), the fuel cost accounts for 96% of the total life-cycle cost while investment, operating and maintenance costs usually account for 3% and 1%, respectively [Mf8]	Already available, but requires large investments
Mfg Strategy 5: **Utilize waste through Waste-to-Energy**	Indirectly offsets fossil fuel inputs, by generating energy from waste Vietnam has >75MW capacity from WTE plants [Mf9]	Emissions from waste-to-energy facilities: almost zero emissions Municipal Solid Waste is responsible for 15% of Methane emissions in U.S. alone [Mf10]	Subjective - If being used to convert unusable material into energy this is a benefit. If being used to convert usable material into energy, this is a con	N/A	N/A	Mainly would be a sustainability selling point for unusable waste Has a high utilization rate of about 85%, compared to 15-45% of that of solar and wind [Mf11]	Dependent on availability of service. WTE plants are often more expensive to operate and the produced energy is more expensive, so may not be available option Often located near urban areas, where other renewables are constrained to specific geographic locations

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Table F4. Logistics Strategies' Impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Logistics Strategy 1: Further invest in On's advanced analytics and IT infrastructure to track and enact system-wide changes more efficiently throughout On's supply chain	Increased use of electricity and natural resources to build and operate IT infrastructure is could possible. However, greater system efficiency and updates could lead to resource decrease in other stages. For example, there could be 25-35% less returns from a better sizing tool. This could decrease shipping needs and supply accurate numbers for how much manufactures need to produce leading to less material waste [L1; L2]	Emissions and pollutants from mining resources needed for computer components could increase with system expansion. However, emissions and pollutants could decrease in other systems like logistics that benefit from better IT infrastructure. Around 4.7 million metric tons of CO_2 is emitted yearly worldwide from shipping leading to the emission of lots of chemicals like black carbon. If more robust IT infrastructures are created that lead to less products being returned and accurate estimates of the quantity to produce, this could lead to less items being unnecessarily shipped [L3; L4; L5]	Obsolete technology could be thrown out. In addition, over 4 billion pounds of [landfill] waste is generated in one year in the US from reverse logistics. This number should decrease as less items are returned [L3; L4]	N/A	Server lifespans are 3-5 years, and hard drive lifespans are 6 years. Systems need to be updated for top efficiency [L6]	With an IT infrastructure, a company can: - Provide a positive customer experience and improve relationships - Develop and launch solutions to market with speed - Collect data in real time to make quick decisions - Improve employee productivity - Decrease operating costs by automating many office functions 68% of consumers say they are willing to pay more for products and services from a brand known to offer good customer service experiences. 86% of one-time customers that receive good customer service will turn into long-term clients. Increasing customer retention rates by just 5% can increase profits by between 25% and 95% [L7; L8]	Feasible, but the rate of success of a technological transformation goes up when companies already use technological tools/ systems, have an enterprise-wide workforce-planning and talent practices. Extremely feasible since technology exists. However, if developing this program internally, On will need to expand their IT infrastructure
Logistics Strategy 2: Partner with retailers to create parcel pick-up stations instead of only providing home deliveries	Could significantly decrease fuel use and fleet size if not as many delivery trucks are needed because of the creation of parcel pick-up stations. However, this would require materials and land to build the stations. These stations could hold more brands than On, which could decrease the price and environmental impact that On would bear individually	Shipping the average package leads to 181g CO_2-eq when a package is perfectly delivered. However, this can be decreased by up to 100% with the implementation of a parcel pickup station. This CO_2 footprint is very reliant on these key factors: walking or biking to parcel station, and if "trip-chaining" is occurring [L9]	N/A	N/A	N/A	-Saves money on shipping costs, reduces costs from new facilities and creates a distribution service coverage - If the parcel pick-up station is near stores it could create compulsive shopping which could be a positive factor in why a store would want to partner with On to create these stations -Could decrease "last-mile" transportation if the person picking up "trip-chains," bikes, walks, or takes public transit to the parcel pick-up station -60% of home deliveries can fail the first time because of slow identification of handover points, long walking distances, and the customer not being home. All resulting in delivery services needing to make second run during this "last mile" -By utilizing parcel pickups points instead of typical home delivers it's estimated that 2/3 of the CO_2 generated can be saved -Parcel pick-ups work best in densely populated areas, but even in rural and suburban areas can have a 40% saving in CO_2 emissions [L10; L11]	Would require investment in a system that could figure out the relation of one's shipping address to a local store that could deliver and a map of optional pick-up stops. As well as, investment in relationships with sellers [L12]

Table F4. Logistics Strategies' Impact on Circularity Indicators (cont'd.)	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Logistics Strategy 3: Create or join a standard sustainable supply chain assessment framework	Framework will enable a company to track where their resources are going, which will allow for strategic decision making and understanding the social/environmental impact [L13]	Framework will enable a company to track how emissions are being created, which types of emissions are being created, and where emissions/ pollutants are being generated throughout the supply chain [L14]	Framework will enable a company to track material use, which will allow for strategic decision-making and understanding the social/ environmental impact [L13]	N/A	More resilient, reliable, flexible, and responsive supply chains from deeper understanding of the relationships with logistic providers [L13]	Pressure from customers, NGOs, and governments to provide transparency and back-up claims Ability to do an in-depth analysis on social, business, and environmental aspects of company supply chain [L15]	Feasible, but extremely difficult. There's the Assessment of Sustainability Supply Chains Framework which provides companies with resources on how to build their own framework, along with many scholarly articles. The Supply Chain Operations Reference (SCOR) is another existing resource on how to evaluate one's supply chain [L13]
Logistics Strategy 4: Redesign shoe packaging to be lighter, smaller, and use fewer resources to increase the number of shoes per master carton	Alternative packaging has a lot space for innovation. For example, the Omni clip is made up of all recycled materials and uses only 10% of original packaging resources that a typical package uses [L16]	20-50% of volume in shipping containers can be maximized which could lead to less trips with more products shipped per trip. In addition, there could be a 16.8% reduction in CO_2-eq by not using adhesive shipping labels for every 1000 labels [L17; L18] e.g., Viupax and Datalase	Packaging that uses less materials or recycled materials will decrease the amount of material waste being landfilled [L18]	N/A	Dependent on design, small risk of scuffed/stained shoes in transit due to less packaging material [L19]	Customers prefer green packaging, lighter packaging, and less resources used to create and ship packaging [L20]	Extremely feasible, many companies including On are re-thinking packaging and there are package specific LCA programs available e.g., GreenBlue Compass Program [L17; L19; L21]
Logistics Strategy 5: Choose distribution center locations based on On's current evaluating standards, but also consider distribution center's locations by their location's estimated climate resiliency	Resource use could decrease by building climate resilient structures and choosing to build in areas that are not at high risk to natural disasters. This could lead to less damage to On buildings that would require resources to be fixed post-climate event [L22]	Less pollutants and emissions produced by building climate resilient structures and choosing to build in areas that are not high risk to natural disasters, and thus less risk of damage to building and products that would result in repairs or increased production [L22]	Less materials could be needed by building climate resilient structures and choosing to build in areas that are not at high risk to natural disasters. Less products being destroyed from disasters would eliminate the need to re-supply inventory and rebuild these structures [L22]	N/A	Increased longevity and durability of infrastructure in terms of climate resiliency [L22]	The EU has spent an estimated EUR 487 billion from 1980-2020 from climate-related weather events while the US has spent $2.295 trillion on climate-related events in that time period. When extreme weather events occur businesses and people are affected even if it's not direct damage, losses, or fatalities. For example, roadblocks inhibiting travel or drop in demand [L23; L24; L25]	Feasible, but would need to create a framework that ranks warehouse locations and transit routes based on frequency of droughts, wildfire, extreme rainfall, inland flooding, extreme heat, as well as sea-level [L25]

Appendices

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Appendices

Table F5. Use Strategies' Impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
Use Strategy 1: Create care and wash instructions for all products	Reduced energy reliance on washing/drying clothes. Extending product life by 9 months can reduce water use by 20-30% [U1]	Reducing washing and drying by 16% can eliminate 186 mt CO_2-eq. Extending product life by 9 months can reduce carbon emissions by 20-30% [U1; U2]	Reduced washing prevents microfiber pollution. Extending a product life by 9 months can reduce waste generation by 20-30% [U1]	N/A	Proper washing reduces wear and prevents products aging [U3]	Potential to increase consumer satisfaction with the product	Need to establish clear care and wash criteria
Use Strategy 2: Develop a shoe registration program	N/A	Extending product life by 9 months can reduce carbon emissions by 20-30% [U1]	Engages with consumer to promote proper disposal of products at end of life	N/A	Engage with consumers to increase proper maintenance of products	More consumer engagement	Similar apps currently exist, such as the Strava community-based running app, and Nike's product app – though these currently do not track product use info or provide care info for products
Use Strategy 3: Communicate product norms on labels	N/A	Extending product life by 9 months can reduce carbon emissions by 20-30% [U1]	N/A	N/A	Increases lifespan of product through communicable norms of product use	N/A	Requires research into product life cycle
Use Strategy 4: Organize a donation program for products	N/A	Extending product life by 9 months can reduce carbon emissions by 20-30% [U1]	N/A	N/A	Extends product use through recirculation	Promote company CSR	N/A
Use Strategy 5: Identify repair partners and create a repair-ability index	N/A	Extending product life by 9 months can reduce carbon emissions by 20-30% [U1]	N/A	N/A	Increases lifespan of a product by 1.35x [U4]	N/A	Requires design for modification and repair instructions for products

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Table F6. End of Life Strategies' Impact on Circularity Indicators	Resource Use	Emissions and Pollutants	Material Waste	Input of Materials	Durability and Longevity	Business Case	Technology Readiness Level
EoL Strategy 1: Cooperate closely with recycling companies to have an efficient EoL process	Might reduce the resource use if the shoes can be recycled and diverted to material for new shoes	N/A	Reduce waste significantly compared to not cooperating with recycling partners	N/A	N/A	Cooperate with external companies to help with their business growth while ensuring that On's products have an alternative EoL to landfill. Requires recycling companies that exist within all major markets to achieve scaled recycling	Some shoes do not currently have an efficient way to be recycled; the recycling industry is still in its infancy for textiles and footwear
EoL Strategy 2: Invest on improving current EoL process/ techniques	Might lead to less resource use in recycling process Improving the current EoL process might result in more efficient energy use	Optimization could lead to less emissions in reverse logistics	Potential for more material to be recyclable Improving efficiency of current EoL process will lead to less waste	N/A	N/A	Investment needed, might need to work with recycling partners to see if this is feasible	Some materials are not recyclable/worth to recycle, technology advancement is needed in terms of expand the recyclability of materials
EoL Strategy 3: Develop an effective takeback program and ensure end of life shoes will be returned for recycling/donation	Might lead to more resource use because of recycling process	Might lead to more emissions due to increased reverse logistics and recycling treatment, but reduce pollutants from landfill and footwear products significantly	Take back programs could increase the amount of shoes recycled which would result in less shoes ending up in a landfill. This would reduce material waste	N/A	End of life shoes might be able to be repair or reused	Nike is accepting all brands of used athletic sneakers via a drop off box in retail shoes. Nike then sorts them and either donates them or recycles them. Some other brands like Brooks or Allbirds are also working on developing a take back program [E1]	N/A
EoL Strategy 4: Create key metrics to track EoL performance to make sure On is in the right direction, including non-Cyclon™ products	N/A	The purpose of setting metrics is to reduce unnecessary emissions in the EoL process by keeping track of them, and setting up targets for each metric, resulting in emissions/ pollutants decreasing over time	Setting metrics will make sure the EoL process is efficient and reduce waste	N/A	N/A	Nike, PUMA, and other companies already set up certain metrics to track their performance on EoL and waste reduction	Some metrics might be more difficult to track than others but there is no limitation in terms of TRL
EoL Strategy 5: Seek partnerships with competitors to share ideas and resources for EoL management	Potential for less resource use with more efficiently operating facilities (due to larger supply and demand fulfillment capabilities through partnership)	Pooled supplies for recycling facilities could reduce the emissions from reverse logistics and overall recycling process	Potential for less waste with more efficiently operating facilities (due to larger supply and demand fulfillment capabilities through partnership)	N/A	N/A	Adidas x Allbirds, they are not cooperating specifically in EoL, but their collaboration can be an example on what partnering with other brands could look like [E2]	No limit on TRL

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