Clean Capital

UNIVERSITY OF CALIFORNIA

Santa Barbara

Clean Capital

Identifying the Impact Potential of Early-Stage Circular Investment Opportunities

Alex Gaynor, Amber McEldowney, Aya Rosenfeld, Dani Sclafani, Joaquin Meckler

Faculty Advisor: Kelsey Jack, Ph.D.

Ph.D. Student Advisor: Vincent Thivierge

A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management

March 2022

As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Alex Gaynor

Amber McEldowney

Aya Rosenfeld

Dani Sclafani

Joaquin Meckler-Pacheco

The Bren School of Environmental Science & Management produces professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principle of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Kelsey Jack, Ph.D.

Vincent Thivierge

Acknowledgements

We are deeply grateful to the following individuals for their insightful comments, suggestions, and support.

Faculty Advisor

Kelsey Jack

Ph.D. Advisor

Vincent Thivierge

Client

Regeneration.VC

Katie Hoffman, Partner & Investment Committee

Michael Smith, General Partner

Dan Fishman, General Partner

Destana Herring, Analyst

Eva Wallack, Analyst

External Faculty Advisor

Ranjit Deshmukh

External Advisors

Reyna Bryan, President of RCD Packaging Solutions

Marta Pazos, Ph.D.

Special thanks to

Roland Geyer, Ph.D.

Contents

Introduction & Significance

As the environmental impacts of industrialization grow, entrepreneurs increasingly focus on developing new technologies and products that aim to minimize these impacts. In order for new technologies to scale, entrepreneurs look to investors for financial support to develop their ideas and guidance to ensure that environmental impacts are minimized during each stage of the value chain.

Many entrepreneurs are currently developing "circularity-focused" companies that utilize business models designed to advance the circular economy. The circular economy is defined as a regenerative system in which resource inputs and waste are minimized by closing material and energy loops.[1] This exists in contrast to a "linear economy", in which resources are taken from the Earth, used to make products, and are later sent to landfill. Investors and entrepreneurs have both found that circularity-focused businesses have the potential to generate environmental benefits. As described by the Ellen MacArthur Foundation, the circular economy is based on three main principles, all focused on reducing environmental impacts– design out waste and pollution, keep products and materials in use, and regenerate natural systems.

It is important to note that just because a company employs a circular business model, does not necessarily mean that it will provide net environmental benefits (Corvellec et al., 2021; Pieroni et al., 2019). For example, the Jevons paradox occurs when increasing efficiency leads to more consumption, such as when hybrid cars increase the gas mileage of the vehicle, but drivers respond by driving more frequently and for longer distances since it is cheaper to do so. Due to these nuances, innovations that claim to help society through circular mechanisms must be analyzed. In addition to generating a financial return, investors interested in environmental impact want to ensure that an environmental benefit is produced by the company they are investing in. These investors must be able to support their claims with impact indicators and company-level data, as well as qualitative assessments of how impacts will change as the investment companies scale, and assumptions that must be true for each business to produce an environmental benefit.

This project is conducted by the CleanCapital team from the Bren School at the University of California, Santa Barbara in collaboration with Regeneration Venture Capital (Regeneration.VC), a venture capital firm that invests in early-stage companies that are accelerating the transition to the Circular Economy. Our work with Regeneration.VC included a literature review to create a library of existing assessment tools and identify circularity assessment indicators. After identifying important circularity assessment indicators, CleanCapital created an assessment

---

[1] The Circular Economy (CE) is defined as a "regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long lasting design, maintenance, repair, reuse, remanufacturing, refurbishment and recycling" (Dissanayake & Weerasinghe, 2021).

tool that adds value and efficiency to the initial due diligence and screening process for Regeneration.VC and other similar investors.

Currently, Regeneration.VC's due diligence process includes the use of a questionnaire that asks general information about a company's structure, finances, and commitment to environmental and social issues. To improve their process, we developed more comprehensive qualitative and quantitative questions to test the assumptions of circularity-focused business models that must be true in order for environmental benefits to be realized. Regeneration.VC also faces the challenge of asking questions that are broadly applicable to the diverse sectors of companies seeking funding. These span across beverage, apparel, and consumer packaged goods industries.

Our research revealed several challenges commonly faced by investors when trying to assess the potential environmental impact of investment opportunities. First, early-stage companies often lack the necessary data to understand the potential environmental impact they will produce as they scale. Secondly, investors and early-stage companies often have limited resources, including scientific or technical expertise which makes some existing assessment tools unrealistic or inaccessible. Lastly, investors are faced with investment opportunities from a broad variety of sectors and many existing assessment tools are industry specific.

Currently, there is no standardized and integrated approach to measure circularity across industries (Antikainen & Valkokari, 2016; Pieroni et al., 2019; Ranta et al., 2018). While existing tools and frameworks can be utilized or combined to address specific research questions, no method is able to answer questions about the circular economy holistically (Walzberg et al., 2021). Most importantly, through the CleanCapital group's research, a framework capable of testing the assumptions of circular business models was also not found. Existing environmental impact assessments such as Life Cycle Assessment (LCA) or Cradle to Cradle (C2C) certification are costly, time consuming, and may not be applicable for an emerging, small, or early-stage investment company with few resources and limited data. Our solution is the Circularity Assessment Tool (CAT). The goal of the CAT is to provide an efficient mechanism for investors to evaluate potential environmental impacts produced by early-stage companies that utilize circular business models identified in CleanCapital's research.

An important feature of the CAT is that it consolidates the data collection process and organizes the outputs. We divided our tool into two components, the first is the questionnaire which is sent to potential investment companies. The questionnaire identifies an applicant's business model, industry, and mission; assesses assumptions, focusing on displacement, counterfactual, and circularity; and gathers data about environmental impacts such as water and energy use. The circularity section is broken into three categories based on three broad circularity-focused business models: reuse, reduce, and recycle. Importantly, the CAT questionnaire is designed to streamline the existing due diligence process of investment firms.

Once a potential investment company fills out the CAT questionnaire, the output designed as an excel spreadsheet is sent to the investors for easy data analysis and organization.

The second component of the CAT is the research guide designed to accompany the questionnaire and provide context for each question and answer and how one might apply weighting to the results. It also provides baseline data for sectors of interest and highlights some concerns for the three broad circularity-focused business models.

The Added Value of Clean Capital

By developing a new tool specifically designed for circularity-focused early-stage companies, we aim to provide valuable resources during the critical initial stages of growth, planning, and decision making. Considering the sustainability and circularity ambitions of a company is important during its early stages to ensure that environmental impacts are prioritized and engrained into the values of the company as a whole (Ingemarsdotter, 2021). Even if companies do not yet have the available data to accurately answer the questions in the CAT questionnaire, the questions in the tool inform them which data to collect in the future to measure their impacts. Furthermore, our tool provides a baseline and framework for tracking environmental impact metrics as the company grows.

Combining insights from our literature review, meetings with experts, and discussions with our client, the objective of the CAT is to fulfill the shortcomings of existing tools and frameworks by collecting useful information for investors to evaluate the potential environmental impact of circularity-focused early-stage companies. The CAT aims to add value to investors and early-stage companies by addressing the limitations of existing tools and frameworks claiming to measure circularity. The gaps, or limitations, of existing tools and frameworks identified through CleanCapital's literature review are related to displacement, the counterfactual, the challenge of having limited resources as an early-stage company, and the need to assess the longevity, durability, and per-use impacts of a product or service. These gaps are described in more detail below:

Displacement

Displacement is the potential of a product to replace another similar product in the consumer market. For example, a new environmentally friendly laundry detergent displaces a less environmentally friendly laundry detergent if a consumer who usually buys the latter switches to the new detergent. This would be an example of a 1:1 displacement of the new laundry detergent to the old less environmentally friendly detergent. Industrial ecology literature often assumes that displacement occurs on this 1:1 basis (Atherton, 2007; Ekvall & Finnveden, 2001; Mathews & Tan, 2016). However, research shows that one-to-one displacement occurs only under specific parameters that are "unlikely in a competitive commodity market"

(Zink et al., 2016).

We found very few tools and frameworks that incorporate this concept of displacement. Through our literature review and consultation with advisors, we determined that this was a concept that was imperative for determining a potential investment's net benefit, and especially for considering a company's future net benefit as they scale using the funds from the investment. To fill this gap, we have included quantitative and qualitative questions to solicit information about a company's potential to displace higher-impact goods or services in the marketplace. The CleanCapital team has also included example analyses on how to find the necessary minimum displacement potential ratio for a new product or service to have a net environmental benefit.

Counterfactual

The CleanCapital team found very few tools and frameworks that assess the counterfactual, or the alternative scenario absent of the investment, product, or service. It is easy for a company to claim that their product or service will result in an environmental benefit because they use recycled materials, or reduce waste. However, we did not find any existing tools or frameworks that provide a means for assessing alternative realities of what the marketplace or world would look like if the investment firm did not provide the company with funds. Even if the product is "greener" than their competitors, are they simply adding more consumption to the market? How does the newer "greener" product compare to the environmental impacts of its closest industry competitor or the industry average? Is the "greener" product a substitutional good for an existing product? Will there be a switching cost for consumers, or can consumers easily switch to the "greener" product? Are there alternative investments to which the inventors could allocate funds that would provide a greater net environmental benefit? These are some of the questions our tool seeks to address by asking the early-stage companies to face these questions and provide industry average level data.

Small or Emerging Companies with Limited Resources

A key challenge to the proper assessment of indicators that measure circularity is the need for data pertaining to all aspects of the value chain (Saidani et al., 2019). In the case of small and emerging early stage companies seeking seed investment, the resources (time, money, and data) needed to conduct a full Life Cycle Assessment (LCA) or endure lengthy certification processes do not always exist. Through literature review, interviews with our client, and expert review, the tool has been structured with both quantitative and qualitative questions to be able to assess companies both with and without data for each indicator. The questionnaire will serve as a resource for investors to better understand what data to request to assess potential environmental impact.

Longevity & Durability

The number of times a resource is used, and the amount of time the resource lasts are indicators of circularity (Figge et al., 2018). In our review of tools and frameworks, we did not find a tool that holistically addressed the concept of longevity and durability. The longer a product remains valuable due to increased durability slows the demand for extraction of raw material resources used as primary inputs for the production of that product (Urbinati et al., 2017). Therefore, increasing longevity of a product is a circular mechanism aimed at reducing the need for raw material extraction and use. The value of a product is measured not only based on its durability, but how long the consumer is able to gain utility from the product. Fast fashion is an example of short periods of utility. While a piece of clothing may be durable, it may lack longevity due to being “out of trend”. The CAT includes questions about longevity and durability to better understand how a product or service may reduce the need for raw material extraction and primary production based on how long it can be used, and how many functional uses a product can have.

Per-Use Impacts

Often excluded from circularity assessments are the impacts produced from products when in the ‘use phase’. The ‘use phase’ takes place after the product is produced and purchased by a consumer and before the consumer disposes of the product. Impacts during the use phase include shipping, packaging, washing, charging, or other forms of energy use. Impacts per use cross industry barriers, and are most apparent in ‘reuse’ circular business models, which will be analyzed in more depth later in the report. Impacts per use are captured within the CAT by asking targeting questions about the impacts produced during the use phase of products and services.

Simplifying the Due Diligence Process

Many of the tools we examined were costly, time consuming, or required technical skills or specific expertise which are not necessarily feasible for small investment firms or small companies with limited resources. By creating the CAT in a user-friendly interface, and including straightforward, qualitative and quantitative questions, the tool is free and easy to use for both investors and companies. By including a research guide, both parties will also have access to research behind each question, and why the various indicators were chosen to assess circularity and environmental impact.

Case Studies

In order to test the useability of our questionnaire, we conducted several case studies with real company data.

Literature Review

We conducted a literature review of 84 scientific articles to explore definitions of the circular economy and the landscape of venture capitalism in the circular economy, create a library of existing frameworks and tools used to measure circularity, and compare existing business models for circularity-focused early-stage companies.

Defining the Circular Economy

While we reviewed several definitions of the circular economy (as seen in Table 1), CleanCapital defines it as a regenerative system in which resource inputs and waste are minimized by closing material and energy loops (Dissanayake & Weerasinghe, 2021). These goals can be achieved through a more durable design and increased focus on offering maintenance, repairing, refurbishing, or recycling services in regards to the specific product or service a company offers (Geissdoerfer et al., 2020).

Within the circular economy, CleanCapital's scope includes early-stage companies due to the large disruption potential they can create. Early-stage companies can utilize a proactive circular business model, incorporating circular economy principles into the core logic of the business from the outset. The three key circular business models identified by CleanCapital are reduce, reuse, and recycle. Many variations of these business models exist, and are discussed within the literature review section of this report. These businesses may provide products, services, or technologies that enable the circular economy to become a reality and compete with existing companies following linear business models (take, make, waste).

The circular economy aims to preserve and optimize natural resources (Fernandes et al., 2019) from a micro-level, such as products, customers, consumers to a macro level, including cities, regions, nations, and beyond. The overarching goal of the circular economy is to accomplish sustainable development while also creating environmental quality, economic prosperity and social equity (Saidani et al., 2019).

Table 1. *Definitions of the Circular Economy found in CleanCapital's Research*

Source	Definition
(Urbinati et al., 2017)	"The goal of the CE - is to replace open production systems based on a linear consumption model …. With closed systems that reuse resources and conserve energy"
(Pieroni et al., 2019)	"CE emerged as an umbrella concept in the 2010s, and envisions the achievement of a more resource effective and efficient economic system by intentionally narrowing, slowing and closing materials and energy flows"
(Corvellec et al., 2021)	CE is a "regenerative system in which resource input and waste, emission and energy leakage are minimized by slowing, closing, and narrowing material and energy loops thanks to long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling"
(Fernandes et al., 2019)	Purpose of the circular economy- "to preserve natural resources, optimize the ones available to us and guarantee those essential for the future"

(Dissanayake & Weerasinghe, 2021)	"The CE is a system where resource consumption is reduced, production efficiencies are increased, sustainable inputs are sought and materials are repaired, recycled and reused, rather than being thrown away"
(Saidani et al., 2019)	CE is defined as "an economic system that replaces the end-of-life concept with reducing, alternatively using, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, customers, 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"
(Bocken et al., 2018)	"The 'circular economy', in which stakeholders collaborate to maximize the value of products and materials, and contribute to minimizing the depletion of natural resources and create positive societal and environmental impact, gained widespread popularity among businesses and governments"
(Antikainen & Valkokari, 2016)	"a circular economy is a novel economic model in which the focus is to keep materials in use for as long as possible and also to preserve - or even upgrade- their value through services and smart solutions"
(Gonen, 2021)	"It's an economy in advanced technologies related to material science, product design, recycling, and manufacturing that leads to a zero-waste "closed-loop" system in which resources are not wasted"
(Yong, 2007)	The CE defines its mission as "resolving the problems from the perspective of reducing the material flux and making the material flow balanced between the ecosystem and the socio-economic system. It Involves restructuring the material flow from linear approach (resource to products to wastes) to circular approach (resource to products to wastes to resource); raising the efficiency of resource utilization and reducing the intensity of emissions."
(Geng & Doberstein, 2008)	The CE is the "realization of a closed loop of materials flow in the whole economic system and encourages the organization of economic activities with feedback processes which mimic natural ecosystems."
(Mathews & Tan, 2016)	The CE is "a closed system (resource-product-renewed resource), as opposed to the traditional resource-product-waste linear system."
(Kok et al., 2013)	The CE is a "new paradigm that essentially changes the functions of resources in the economy: waste material of one (industrial) process will be input for another, and products will be repaired, reused, and recycled."
(Esposito et al.,	The CE "represents not just a paradigm shift that waste is reconstructed to resources

2018)	through reuse and recreation; it is also about getting more economic boost by resource efficiency and industrial transformation and involves redesign of the future through the restoration and regeneration of new business models and consumption approaches from cradle to cradle.”

Critiquing the Circular Economy

Through a conclusive review of several related academic fields, we have summarized several hurdles for the circular economy to overcome, while remaining supportive of the possibilities of a faster transition to a circular economy (Corvellec et al., 2021). A discussion about how the circular economy is not fulfilling its promise is critical to those seeking to invest into it. Our project aims to better assess the different ways in which early-stage companies can utilize a circular business model, despite these hurdles.

The concepts of the circular economy are not new; material flows, especially recycling, have been under study in the field of Industrial Ecology for decades. As the circular economy becomes popular, researchers have voiced concern that its core ideas must be carefully employed to ensure that net positive environmental impact is achieved (Corvellec et al., 2021). Among the concerns are circular economy rebound (Zink & Geyer, 2017), hidden environmental and social costs, and how to approach situations in which profit and impact are tradeoffs rather than mutually achievable outcomes (Corvallec, 2021).

Looking specifically at early-stage companies, it is problematic that the current conversation is focused on win-win business models, in which companies can transition to a circular model while also maximizing revenue. This restricts the focus only to conflict-free solutions and strategies, overlooking anything that addresses the conflicts, trade-offs, and problems of leaving the linear economy (Corvellec et al., 2021). Generally, win-win is extremely rare, therefore stakeholders should be searching for exactly who or what is losing. This is of particular concern at the intersection of Venture Capital and the circular economy because it suggests that capitalists are likely to choose the low-hanging, easy, profitable solutions, while neglecting the difficult parts of the transition.

Investing by optimizing for early opportunities that also have attractive financials means that the lowest hanging fruit with the highest economic return will be selected first. By definition, this means the challenging parts with less attractive financial returns are not as obvious a target. It may be that Venture Capital isn’t appropriate for these harder, more complex problems. Our project aims to enhance the ability of firms within venture capital to pursue and address complex environmental issues.

Another difficulty in assessing companies within the circular economy is that there is no universal definition for the circular economy. The result is that circularity means different things to different people. Among other concerns, this enables companies to claim compliance with the principles of the circular economy on a selective basis, while neglecting to invest in other parts of their business where transition is more expensive or less visible. Additionally, critics suggest that the term 'circular economy' is susceptible to framing the discussion such that endless economic growth and sustainability are compatible, while proof in the real world suggests otherwise (Geyer, 2022).

One particularly important concept is what is known as the rebound effect. The rebound effect occurs when efficiency improvements are offset by a growth in composition or resource usage (Zink & Geyer, 2017). The efficiency improvements seem like an obvious win from the design perspective, but once the product enters the market, new forces are applied. For some products in some industries, there is a chance that the ultimate impact of the innovation ends up being negative. This idea is particularly relevant for assessing early-stage companies in that the value of early-stage technology occurs at scale.

Recoverable rocketry, as seen in various business operations of SpaceX, is an interesting example of circular design wherein designers have closed the materials loop of the rockets themselves to enable reuse. The cost savings of reusing rockets has enabled many more rockets to launch per year, which has in-turn enabled net increases in fuel consumption (Whittaker, 2018). In context, any given company must consider the broad impacts of how their product operates in the marketplace.

Venture Capital Meets the Circular Economy

Since the 1980's, venture capital firms have established themselves as a lifeline to young companies and small businesses, providing capital and strategic guidance in hopes of achieving large growth and monetary returns over a period of time. Categorized as a form of private equity, investments made by venture capital firms are often viewed as high-risk, high return investments with the firms themselves serving as an intermediary of sorts, connecting innovative companies with cash-rich investors (Lerner & Tåg, 2013). As of 2020, roughly $130 billion dollars of investments were made by venture capital firms based in the United States (*Value of U.S. Venture Capital Investment 1995-2020*, n.d.).

The early-stage companies that venture capital firms fund are often characterized by having technically nuanced innovations, unproven product offerings, or a lack of strategic vision (Silviera et al., 2006). Originally, funds provided by venture capital firms largely went into supporting research and development efforts but have since transitioned towards focusing on developing management skills and offering strategic guidance (Zider, 1998). The majority of venture capital firms aim to achieve an ownership period of under 10 years, returning the provided capital to limited partners after collecting proceeds upon exiting.

In the past decade, there has been a rise in impact-focused venture capital firms, also known as impact investors or thematic investors. In this style of investing, venture capital firms focus on investing in companies that aim to provide a societal or environmental benefit from the usage of their product or service while attempting to achieve favorable returns on investment (Viviani & Maurel, 2019). This form of investing has seen growth in various sectors as consumer and societal demands have shifted towards requiring private entities to work toward solving environmental and social issues. However, it is rife with inconsistencies given challenges quantifying and assessing the tangible impact investments can generate (Brest & Born, 2013). While studies have shown that venture capital firms can promote corporate social responsibility, data is sparse on how tangible positive impacts can be made by venture capital (Li et al., 2021).

Venture capital firms, such as our client Regeneration.VC, are increasingly funding circular solutions. The transition to a circular economy has been identified as an important place to invest in new venture financing. As investors increasingly fund circular solutions, they will need tools to determine which innovations fit into circular systems smoothly and result in clear net environmental benefits. The way circularity business models are utilized will determine if in fact a net environmental benefit will be achieved.

Despite critiques of the circular economy, the growth of venture capital presents a significant opportunity to improve the investment process and reduce environmental impacts of new companies. It is first important to understand the limitations of the circular economy, and augment our research project accordingly to provide maximum value to investment firms.

Tool Library and Gap Analysis

Existing circularity and environmental impact assessment frameworks were compared and analyzed to determine which tools and frameworks are most relevant for early-stage investors like Regeneration.VC. Frameworks of interest were chosen based on client recommendation as well as research on widely used circularity frameworks; tools and frameworks that fulfilled at least one aspect of client demands were researched further. Expanding upon the findings of our literature review, we made a library of the following tools and frameworks:[2] InVest, Material Circularity Indicator (MCI), Circular Transition Indicators (CTI), Circulytics, Crane, Circular Economy Toolkit (CET), Circular Economy Indicator Prototype (CEIP), and Cradle to Cradle (C2C). In this library we documented the data inputs required, indicators evaluated, and outputs for each framework and tool.

[2] CleanCapital defines a tool as a program, software, workbook, or calculation used to analyze metrics for a specific purpose, while a framework is a set of tools or metrics used in combination to determine impact for a specific purpose or industry

Using this library, we conducted a gap analysis to identify and document gaps in existing frameworks that did not fulfill our client's needs to comprehensively assess potential investments for circularity and environmental impact.

Tool Library & Review of Existing Tools

We conducted an in-depth review of seven different tools used to assess circularity and environmental categories and indicators, identified the inputs and outputs for each, and any limitations relevant to small-scale investors and early-stage companies. These tools were chosen as a result of our initial literature review, and through conversations with Regeneration.VC.

Table 2: *Table of Existing Circularity Tools*

	Cradle to Cradle Certification (C2C)	Material Circular Indicator (MCI)	Carbon Reduction Assessment for New Enterprises (CRANE)	Integrated Valuation of Ecosystem Services andTradeoffs (InVEST)	Circular Transition Indicators (CTI)	Circular Economy Toolkit (CET)	Circular Economy Indicator Prototype (CEIP)	Circularity Assessment Tool (CAT)
Description	Assesses the safety and circularity of materials and products across five categories of sustainability performance: Material Health, Product Circularity, Clean Air and Climate, Water and Soil Stewardship, Social Fairness	Aims to help companies measure their transition towards a circular economy.	An open access, web-based application that allows users to evaluate the greenhouse gas (GHG) reduction potential of emerging technologies	Suite of models used to map and value the goods and services from nature that sustain and fulfill human life	Measures the circular and linear flows through a company and evaluates its effectiveness in using resources	Assessment tool to identify potential improvement of products' circularity.	Evaluation for product performance in the context of circular economy	Qualitative and quantitative questionnaire to assess net environmental impact/benefit. Questionnaire research guide.
Inputs	Inventory of the materials used to make the product, energy use, water and soil stewardship, and social fairness issues affecting their industry and production region. Certifications and audits required.	Mass of virgin material Mass of nonrecoverable waste Utility Factor (length & intensity of a product's use) Complementary indicators (i.e. emissions, water usage, toxicity)	Geography and time scope Potential market penetration Reference and solution scenarios for your technology	Current Land Cover: GIS raster (required) Future Land Cover: GIS raster (optional) Baseline Land Cover: GIS raster (optional) Threats data: .csv file (required) Sensitivity .csv file (required) for each threat	Product components, weights, % virgin and % recoverable	33 trinary-based questions divided into 7 sub-categories related to lifecycle stages.	15 weighted questions divided into 5 lifecycle stages.	36 qualitative and quantitative questions divided into 4 sections: general, circularity, scaling/displaceme nt, and environmental impacts
Outputs	Bronze, Silver, Gold, or Platinum level certification	Numerical score (0-1) where 1 represents a product with a fully restorative flow	Emissions reduction potential Market penetration Heat map of likely scenarios	Relative extent and degradation of different types of habitat types in a region, and changes across time. Biophysical terms (ex: % of sediment retained) or economic terms (value of carbon sequestration)	Generated Reports for stakeholders	Qualitative: Improvement potential at 3 levels (high, medium, low) for every of the 7 sub -categories.	Quantitative: The CEIP score (%) and a radar diagram showing aggregated score for each lifecycle stage.	Data spreadsheet for investors to compare potential investment opportunities, establish baselines, or monitor performance over time.

	Cradle to Cradle Certification (C2C)	Material Circular Indicator (MCI)	Carbon Reduction Assessment for New Enterprises (CRANE)	Integrated Valuation of Ecosystem Services andTradeoffs (InVEST)	Circular Transition Indicators (CTI)	Circular Economy Toolkit (CET)	Circular Economy Indicator Prototype (CEIP)	Circularity Assessment Tool (CAT)
Relevant limitations	Material focus might not effectively assess services or innovation Requires extensive data and potentially costly certifications/auditing	Material focus might not effectively assess services or innovation Assumes no part of material is lost (i.e. does not consider downcycling)	Only considers CO2 and excludes other indicators like pollution, waste, materials, social, etc.	Requires technical knowledge of ArcGIS Time consuming Does not assess circular indicators	Does not measure environmental or social impacts of a company	Does not assess counterfactual or displacement Does not adequately assess complexity of circular economy	Interpretation through a single score hides the true circular economy complexity. Binary scoring system used for some questions could be quite reductive.	Does not address social or environmental justice implications

Note: The data from the review of CTI, CET, CEIP, MCI comes "How to Assess Product Performance in the Circular Economy? Proposed Requirements for the Design of a Circularity Measurement Framework" by Siadini, et al., 2017, *Recycling,* 2(6), pg. 17 DOI: 10.3390/recycling2010006. The Cradle to Cradle data comes from www.c2ccertified.org. The Crane data comes from https://cranetool.org/. The InVEST data comes from https://naturalcapitalproject.stanford.edu/software/invest.

Of the tools we assessed, we did not find one that fits the needs of small-scale investors in early-stage circularity-focused companies. For example, Cradle to Cradle is the most comprehensive, and covers multiple categories of interest, but requires costly third-party auditing and significant amounts of data that may not be accessible for early-stage startups. Other tools such as MCI and CTI focus solely on material inputs and outputs and may not be applicable to service business models, or innovations that reduce material inputs or otherwise increase circularity. Furthermore, geospatial tools such as InVEST require technical skills that not all investors have, including ArcGIS. We used this analysis as the foundation to develop the CAT, by addressing known limitations, and keeping investors and early-stage companies in mind.

R Business Models

Throughout the literature, we encountered many circularity-focused business models, see Table 3. We first identified definitions for each and consolidated the circularity-focused business models into 3 comprehensive categories: Reduce, Reuse, Recycle. This process distilled the common themes found within the array of circular economy business models, which include: reducing the use of virgin materials through the substitution with secondary production, extending product lifespan, and material recycling (Nußholz, 2017) we found these three categories, reduce, reuse, and recycling, to be appropriate. While other literature categorizes circular business models differently, for the purpose of this project it is helpful to understand the key goal or circular strategy that a company utilizes pertaining to reuse, reduce, or recycle.

After identifying key circular economy business models, CleanCapital explored what assumptions must be satisfied for each business model to produce a net environmental benefit, and the critiques and limitations of each. Questions in the CAT aim to gather information for investors to more effectively assess whether or not potential investments with these circularity-focused business models will produce a net environmental benefit.

Table 3. *Summary of circular business models found in CleanCapital's research, organized into the three main circular business models defined by CleanCapital shown in the R Category column. Definitions of each are available in Appendix 3.*

R- Category	Business Model	Source
Reduce	Maximize material productivity and energy efficiency	(Bocken et al., 2014)
	Substitute with renewables and natural resources	(Bocken et al., 2014)
	Reduce	(Gonen, 2021)
	Renew	(Gonen, 2021)
	Encourage sufficiency	(Bocken et al., 2014)
Reuse	Design for Remanufacturing	(Mayyas et al., 2012)
	Design for Disassembly	(Mayyas et al., 2012)
	Design for Durability	(Mayyas et al., 2012)

	Product-Service Systems (PSSs)	(Tukker & Tischner, 2006)
	Product Service System (PPS)	(Tunn et al., 2021)
	Access-based product-service system (AB_PPS)	(Tunn et al., 2021)
	Deliver function, rather than ownership	(Bocken et al., 2018)
	Reuse	(Gonen, 2021)
	Remake	(Gonen, 2021)
	Recover	(Gonen, 2021)
	Slowing Resource Loops	(Bocken et al., 2016)
	Encourage sufficiency	(Bocken et al., 2014)
Recycle	Design for Recyclability	(Mayyas et al., 2012)
	Create value from waste	(Bocken et al., 2018)
	Closing Resource Loops	(Bocken et al., 2016)
	Design to minimize material usage	(Mayyas et al., 2012)
	Design for Energy Efficiency	(Mayyas et al., 2012)
	Encourage sufficiency	(Bocken et al., 2014)

Reduce

Given that the circular economy is centered around several paradigms, the reduce model has taken on an increased importance as consumption across sectors has continued to increase. The reduce paradigm focuses on "reducing the consumption of nonrenewable and toxic raw materials" (Goyal et al., 2018). Additionally, it can be viewed as shifting from the "take-make-dispose" model to the "take-make-reduce" model. Both of these perspectives focus on an overall decrease in the amount of material, energy, or waste associated with a specific product or service. The following sections will go through the common methods of implementing a 'reduce' business model through innovation. Reduce is often linked to a reuse business model, in some cases enhancing the efficiencies of each other (Reike et al., 2018). We will then provide examples of companies following these business models, and lastly, discuss how the CAT incorporates and assesses a 'reduce' business model.

Example of Reduce through Innovation

Several companies studied in this project offer a 'reduce' business model in the form of reduced emissions or reduced materials and energy required during production. Given that reduction through innovation can occur across several main themes, there has been growth in the amount of funding companies in this model have received. Carbon capture and storage, which aims to reduce the amount of carbon emissions, has seen a rapid proliferation in recent years, even receiving significant government funding (Department of Energy, 2021). We assessed a company that aims to repurpose CO2 emissions captured from commercial HVAC systems into cleaning products and in doing so, reduce the amount of emissions produced. The company has two main channels of operation: a model which sells micro-scale carbon capture units to building owners, and a model that sells soaps, detergents, and other products derived from captured emissions direct to consumers. With the growing focus on carbon scrubbing in HVAC systems, there is abundant room for growth with a large amount of potential buildings needing carbon emissions reduction technology. The company's current technology can achieve a 20% reduction in greenhouse gas emissions and can reduce energy costs by 20% due to increasing hot water efficiency (proprietary data from Company A). Once the carbon is scrubbed, it is repurposed into commercial soap products and sold to consumers. Our tool aims to capture the intricacies of a company like this through including both qualitative and quantitative questions focused on what specific reductions are occurring and to what extent those reductions are contributing towards a circular economy.

Another main avenue in which a company operates within the reduce model is through a reduction of materials or energy in its products. Our company of focus for this case study was a packaging manufacturer that aimed to reduce the amount of polystyrene foam used in packaging. The product offering is a non-toxic, fully home compostable packaging foam that can easily scale to replace conventional polystyrene foam. Given the growing focus on reducing packaging waste, this company is of high interest for its ability to reduce waste (Jang et al., 2020).

One of the major critiques of the reduce business model is an innovation or technology producing more emissions or waste then it aims to reduce. For example, if a carbon capture technology requires significant energy for operation, maintenance, and production, it may not offset the emissions removed. Our questionnaire contains questions designed specifically to learn about what assumptions a company needs to be true to avoid this, and where their technology or business model might have this hidden negative impact.

Incorporating Reduce into the CAT

One large concern associated with the 'reduce' business model is determining the overall reduction relative to the industry average. In doing so, our tool will be able to provide insight into the claims of a specific company and identify any possible data gaps that need to be better addressed. Questions focused on specific areas of reduction, displacement, and impact metrics are asked to best capture a company's disruption potential in this business model.

Reuse

The ‘reuse’ business model fits within the major principles of the circular economy, by continuing to circulate products and materials (Ellen MacArthur Foundation, 2017). By reusing products, the products remain viable in the economy, potentially reducing the demand for primary production of the same product and the amount of waste generated from that product system (Ellen MacArthur Foundation, 2017). A reuse business model can accomplish environmental benefits through three main goals. First, a reuse business model aims to reduce the need for primary production of a product which will in turn help accomplish the second goal of the reuse business model, which is to decrease the demand for virgin materials and the amount of energy needed to transform raw materials into consumer products (Urbinati et al., 2017). Third, reuse business models also aim to reduce the amount of waste produced from a product system by keeping products viable in the circular economy and out of landfill through rental, resale, refill, refurbishment, and repair strategies. Additionally, extending the lifetime of products by designing for durability allows for products to remain viable in the economy for longer, further reducing the demand for primary production of the same products (Bocken et al., 2018; Tunn et al., 2021; Urbinati et al., 2017). Interestingly, in a reuse business model the value of a product is no longer determined by its price, but by the number of functional uses the product can have in its lifetime, therefore increased durability leads to increased value (Urbinati et al., 2017). This is an important note for investors to keep in mind when assessing companies utilizing reuse business models.

In this framework, reuse is defined as the reuse of products through rental and resale services, which can include mechanisms for reuse such as refurbishment and repair, but excludes recycling. Circular strategies such as repair, remanufacture, refurbishment, and design for durability are at times defined as a separate circular business strategy, however, the CleanCapital project has found it most effective to consolidate these strategies into one larger “Reuse” category. The following sections will detail two popular reuse business models – resale and rental – provide examples of companies following these business models, and discuss how net environmental impacts can be produced and measured.

Example of Reuse through Resale:

Reselling used goods and products through secondhand marketplaces has emerged as a widely accepted function of the circular economy. Resell business models fit within the ‘Reuse’ category of the framework developed, as resale is a mechanism for products to be reused. It is thought that reselling old goods produces an environmental benefit by displacing primary production and by keeping viable products circulating in the economy. Within the apparel industry, many companies have emerged utilizing a resale business model, including thredUp, the RealReal, Mercari, and Poshmark. Each of these companies utilizes a secondhand online marketplace to resell clothing, closing the resource loop of old clothing and generating an environmental benefit. For example, when a pair of jeans no longer provides utility to their original owner, instead of donating or disposing of the jeans, the original owner can sell their jeans through a second hand marketplace. A second consumer can then buy the used pair of jeans and gain utility from them.

Through the use of the second hand marketplace, environmental benefits are produced on both ends of the life cycle of the used jeans. First, the environmental impacts from the primary production of jeans are avoided (environmental impacts from the primary production of jeans are produced from cotton farming, processing the cotton, cutting, dying, etc.) (Amutha, 2017). Second, a reduction of waste production due to the diversion of the jeans from landfill is realized for as long as the jeans are able to remain in the economy. Here, impact depends on displacement: if resale jeans displace new jeans at a 1:1 ratio, more environmental benefits can be attributed to the reuse business model. However, if lower prices for resale jeans leads to more purchases or the ability to earn from selling leads to faster turn over, then the number of jeans owned may increase, lowering the benefits of the model. The environmental impacts of consuming a used pair of jeans includes the energy needed to run the computer or smartphone used to purchase the jeans on a website and the impacts from transportation.

In the jeans example, environmental impacts from second hand shopping are assumed to be less than the total environmental impacts from primary production, therefore the consumption of used jeans produces an environmental benefit. However, environmental impacts of reselling can vary based on the product that is being resold and who is doing the reselling. Companies that refurbish, repair, or remanufacture used goods must also account for the environmental impacts generated during this process. It is likely that the higher the intensity of the refurbishment, repair, or remanufacturing process, the greater the environmental impacts generated (Kerdlap et al., 2021). An environmental benefit will only be realized if the total environmental impacts from the resale process, including refurbishment services, are less than the environmental impacts from primary production.

This jeans example showcases why durability is an important aspect of reuse businesses. The more durable the pair of jeans are, the longer life span they will have and the more they will be reused within the economy. In this case, the potential for environmental benefit of reselling is highest when durability is greatest (Gonen, 2021).

Unfortunately, there is an opportunity for the rebound effect (discussed earlier) to minimize the net environmental benefit produced from reselling old clothing. This would occur if more total jeans are consumed either because the buyer can purchase more new jeans with the money saved from buying second-hand, or the seller can buy more new jeans with the funds from selling their old ones. Neither case has observable data, which is why the rebound effect goes unnoticed.

To summarize, in order to determine the potential environmental benefits from utilizing a resale business model, the environmental impacts of both primary production, the 'use' phase, and the resale of the product must be known, as well as the displacement ratio (in our case the displacement ratio will be held constant at 1:1). Additionally, understanding the durability of a product, or the number of times a product can be used before losing its utility, is important to understand the magnitude of environmental benefits possible through the resale of that product. These factors were taken into account when forming the "Reuse" section of CleanCapital's framework.

Example of Reuse through Rental Services

Another business model within the reuse segment of the circular economy is the rental or sharing business model. The rental business model can be defined as a "service that satisf[ies] user needs without users having to own physical products", in which businesses seek to maximize consumer use of products (Bocken et al., 2018). It is often assumed that sharing goods through a rental model will produce environmental benefits and reduce the amount of goods needing to be produced (Geyer, 2022; Tunn et al., 2021). A rental business model is unique, as it extends the responsibility of the company supplying the goods being rented throughout the product's entire life creating large potential for environmental benefits (Bocken et al., 2018). The rental company is responsible for the quality, upkeep, and responsible disposal of the product it rents out to consumers. These companies aim to produce environmental benefits by reducing the demand for primary production and reducing waste.

Several companies within the apparel industry following a rental business model have recently been developed, including Rent the Runway, Nuuly, and FashionPass. These companies follow a subscription model in which their consumers receive new clothes on a regular basis and return them after they are worn. The company maintains ownership over the clothes throughout the rental process and is in charge of cleaning, storing, and repairing the clothing between uses and disposing of the clothing at the end of its life (Bocken et al., 2018). According to Rent the Runway's website, the primary production of clothing is the largest contributor of the fashion industry's negative environmental impact (*Renttherunway.Com*, n.d.). The rental model aims to reduce the amount of primary production by reducing the number of units needed to meet the same demand (Tunn et al., 2021). However, additional environmental impacts are produced throughout the rental business model from cleaning, repairing, shipping, and packaging.

Several factors must be made clear in order to compare the environmental impacts of the linear consumption of clothing and the rental of clothing. First, subscribing to a clothing rental service offers clothing at a lower price than clothing from a linear retail store. The decrease in price may encourage a consumer who does not often buy new clothing for themself to subscribe to the rental service. This may in turn increase that consumer's overall consumption of clothing and environmental impact. This is an example of the rebound effect: lower prices leading to an increase in consumption (Geyer, 2022). On the other hand, for consumers who are already avid shoppers, a rental clothing service may have a greater potential to reduce environmental impacts. The behavior of the subscribers to a rental service is an important variable when evaluating the net impact of the rental service. However, it is unclear how consumers will respond to the availability of a rental service. Instead of replacing the linear consumption of clothing, the rental service could be seen as a complement to traditional shopping habits and could lead to a greater overall consumption of clothing. Rent the Runway claims that 89% of their consumers buy fewer clothes since subscribing, however, measuring the rate at which rental services displace linear consumption is difficult. Although it is problematic, a 1:1 displacement ratio is often assumed to simplify measuring the environmental benefits produced from renting. In the clothing rental example, a 1:1 ratio means that for every item of clothing rented, another item was prevented from being purchased linearly.

While rental clothing business models aim to reduce environmental impacts, there are additional environmental impacts that are produced through the reuse business model. The "use phase" of a rented piece of clothing is broader than the use phase of the same piece of clothing that is purchased linearly. In a linear circumstance, the use phase of a t-shirt includes shipping to the consumer and washing. In one cycle of a reuse business model, the t-shirt is packaged, shipped to the consumer, worn by the consumer, shipped back to the warehouse, and cleaned. The total environmental impact produced from the use phase of the rented t-shirt can be found by multiplying the environmental impacts from use by the number of times the t-shirt is rented. While washing is included in both the use phases of the linear purchased and rented clothing, the type of washing and frequency of washing may vary. For example, every time a piece of clothing is returned to Rent the Runway the item is dry cleaned. Conventional dry cleaning requires energy and uses petroleum solvents which release volatile organic compounds (EPA, 2005). While at home washing produces its own environmental impacts from energy and water use, dry cleaning often produces more environmental impacts from greater energy consumption and air pollution (Blackler et al., 1995). Additionally, the frequency of washing is predicted to be greater when clothing is rented, as rental companies wash the rented clothing items between each user while owners of clothing typically wash their clothes every other time they are worn (Muthu, 2015).

Secondly, rental companies must account for the environmental impacts produced from packaging and shipping rented items to and from consumers. While in some life cycle assessments, transportation can be seen as a minimal contributor to overall environmental impacts (Geyer, 2022), transportation can be a greater contributor in the rental model due to its increased utilization. For example, if a shirt is rented 25 times by 25 different consumers, then the shirt has been shipped to 25 different consumer locations and shipped back to the warehouse or storage facility 25 times. A piece of clothing bought linearly is only transported from the warehouse to the consumer one time. Therefore, the purchase of 25 t-shirts leads to only 25 shipments to various consumer locations. In this example the environmental impacts from transportation from the rental business can be estimated to be 2x that of the linear business.

In order to find the potential net environmental impact, a rental company would need to find specific data regarding the environmental impacts through each stage of the products life cycle when consumed linearly and through a rental model. First and most essentially, the rental company should find the environmental impacts produced from the primary production of their product. Next, the company would need to know the environmental impacts produced during the use phase of the product when consumed linearly and when consumed through the rental model. The rental company should also attempt to figure out their displacement ratio through consumer surveys and market disruption analysis. It can then be determined how many times a product can be rented before the accumulated environmental impacts from rental use equal the (originally avoided) primary production environmental impacts.

This is an important step in deciding if a rental model is appropriate for a product in order to produce environmental benefits. If the environmental impacts of primary production are large, using a rental model which displaces the need for primary production will be beneficial, especially if the impacts produced during the use phase are small in comparison. However, if impacts produced during primary production are small in relation to the impacts produced during use, the accumulated impacts from the use phase may create a net negative environmental impact.

Similar to resale business models, it is essential to know the environmental impacts produced from the primary production of the product and during the use/rental phase of the product's life cycle and the longevity of the product's lifespan to continue to be rented.

Incorporating Reuse into the CAT

Reuse as a strategy to achieve circularity and produce environmental benefits has potential, however, there are several factors to consider to ensure that a net environmental benefit is produced. While reuse business models can be successful, their ability to displace primary production and the purchase of new goods by consumers is essential to determining the full potential of reuse models. While displacement is assumed to be at a 1:1 ratio throughout the framework developed, the CleanCapital team takes into consideration the additional environmental impacts that are produced through reuse business models which are reflected through the questions asked in the "Reuse" section of the questionnaire. Questions surrounding durability, cleaning intensity, shipping methods, and displacement are asked to attempt to capture the desired metrics of primary production environmental impacts, use-phase impacts, and durability.

Recycle

Within the discussion of the circular economy, it is generally preferable to reduce, then reuse, and if neither option is available, pursue recycling (Kirchherr et al., 2017). As it pertains to the circular economy, recycling can be defined as "the most common circular economy process through which used materials are treated so as to make them suitable for reuse" (Urbinati et al., 2017). For the purposes of this project, we have refined the scope as anything pertaining to dismantling products into component parts that will be turned into new products so as to differentiate from refurbishment, which we consider an act of reuse. This includes any physical recycling of products in the traditional sense of home recycling of packaging as well as modern advanced recycling techniques to recover resources from landfills or electronic scrap yards, as well as design concepts that enable recycling of component materials at the end-of-life.

One way that a circular business model might employ recycling is to turn something that society currently sees as waste into value (Bocken et al., 2018). This must be compared carefully to the counterfactual that the waste is destined to be waste in the future. For example, corn stalks could be considered waste, or they could be a valuable on-farm mulch, a fiber feedstock for advanced man-made cellulosics, or a feedstock for combined biochar + biofuel. In this particular example, it is also possible to consider the counterfactual to be the current status quo of burning such excess biomass as is seen in India and elsewhere. This example presents several business opportunities that would fit into the recycle category.

Another notable segment within the 'recycle' model is companies that make use of recyclate. As argued by Geyer et al. "it matters not only how much material is recycled, but also what it is recycled into and therefore can displace (Zink et al., 2016). This circular business model may gather recyclate either pre-consumer, or post-consumer. Post-consumer waste is often not of a uniform grade, contaminated, and unreliable to source. Pre-consumer waste on the other hand is easier to re-incorporate back into production processes before it leaves the production side of a business. Pre-consumer recycling is criticized as an obvious re-incorporation of materials and therefore should not be used by companies to claim they are using recycled materials. Post-consumer recycling, on the other hand, is a challenging and important part of any transition to a circular economy.

In Roland Geyer's 2021 Business of Less, three important hurdles are described to systemic recycling improvements: collection constrained supply chains, reprocessing constraints, and market demand constraints. These are important considerations for innovations in the recycling space (Geyer, 2022).

The first, collection constrained supply chains, describes how pre-consumer waste generally already is recycled, and how post-consumer waste suffers from re-collection challenges. Specifically, for post-consumer waste to re-enter the supply chain it must be “at the right time, in the right quantities, at the right cost, and with the right quality.” (Geyer, 2022). When addressing circular business models that concern post-consumer waste each of these concerns are worth considering.

The second constraint involves reprocessing. Some materials are difficult to reprocess because of their physician or chemical properties, such as carbon-inforced plastic, some lose quality, such as paper fibers, and some are too intermixed, such as some metal alloys. Then there are plastics, which could be recycled, but the cost of doing so is not currently competitive with virgin plastic.

The third constraint involves demand for the products of recycling systems. If the quality of recyclate is inferior to that of virgin sourcing, there is simply less demand. Beyond this, customers may have an inherent preference for “newness.” Demand must be proven for products of a recycling system.

When considering the counterfactual to recycling, the value is derived from displacement. It is important that recyclate is indeed displacing virgin material, otherwise, the effort is not achieving its potential benefits. Importantly, collection and reprocessing of post-consumer waste has its own impacts, including transportation and recycling emissions; and “there is no fundamental law of physics that demands that recycling must reduce primary material production” (Geyer, 2022).

Incorporating Recycling into the CAT

The CAT aims to address not only “how much” but “what” when it comes to recycling. Follow up questions to determine which materials are being recycled, and whether recycling is pre-consumer or post-consumer, give investors a better idea of how recycling is being utilized by the potential investment company. Implications for different types of recycling are outlined in the research guide for investors to more easily evaluate. Questions addressing the use of packaging and whether or not it is recyclable or compostable are asked, and finally whether or not the product itself is recyclable at the end of its life.

Questionnaire Creation

We developed the CAT to meet the needs of venture capital firms targeting early-stage companies, as an alternative to existing tools. The CAT aims to gather quantitative and qualitative data from potential investment companies and holistically assess environmental impact. The CAT is both informed by our exploration of R business models and certain questions are associated with each. We began by pulling impact indicators (metrics) and categories from our literature review and tool library. A combination of qualitative and quantitative questions are used in order to provide meaningful indicators even for companies that do not yet have all of the requested data.

Filling Gaps in Existing Frameworks with our Questionnaire

We determined that companies working within the circular economy often rely on a certain set of assumptions for their business to improve environmental performance. We designed our questions specifically to force companies to clearly identify any assumptions that their business needs to hold for their business to succeed in reducing environmental impact.

Displacement

We reviewed literature and existing metrics that exist to measure displacement. We consulted with Roland Geyer who is a leading expert on this topic to develop quantitative and qualitative questions to gather information that may help investors better understand a company's potential to displace more environmentally harmful goods or services.

Counterfactual

We reviewed literature, sought expert feedback, and compiled and refined indicators that aim to address how investing in a company may compare to the counterfactual(s). We chose to both evaluate the counterfactual for industry impact, in which companies are evaluated against industry standards, as well as consider the counterfactual for company growth without investment.

Small or Emerging Companies with Limited Resources

Using proprietary data provided by our client's portfolio companies as a reference guide, we developed questions more relevant and realistic than existing frameworks to the level of data availability for small and emerging companies in the portfolio company industries. Through literature review, interviews with our client, and expert review, the tool has been structured with both quantitative and qualitative questions to be able to assess companies both with and without data for each indicator.

Longevity, Durability & Per Use Impacts

We reviewed literature to compile indicators pertaining to longevity, durability, and per use impacts. We incorporated these impacts into our tool simply as "per use" impacts.

Flowchart Creation

As a preliminary step in our framework development, we created a flowchart using MindMup to visualize flow logic for impact categories, questions, and answer options.

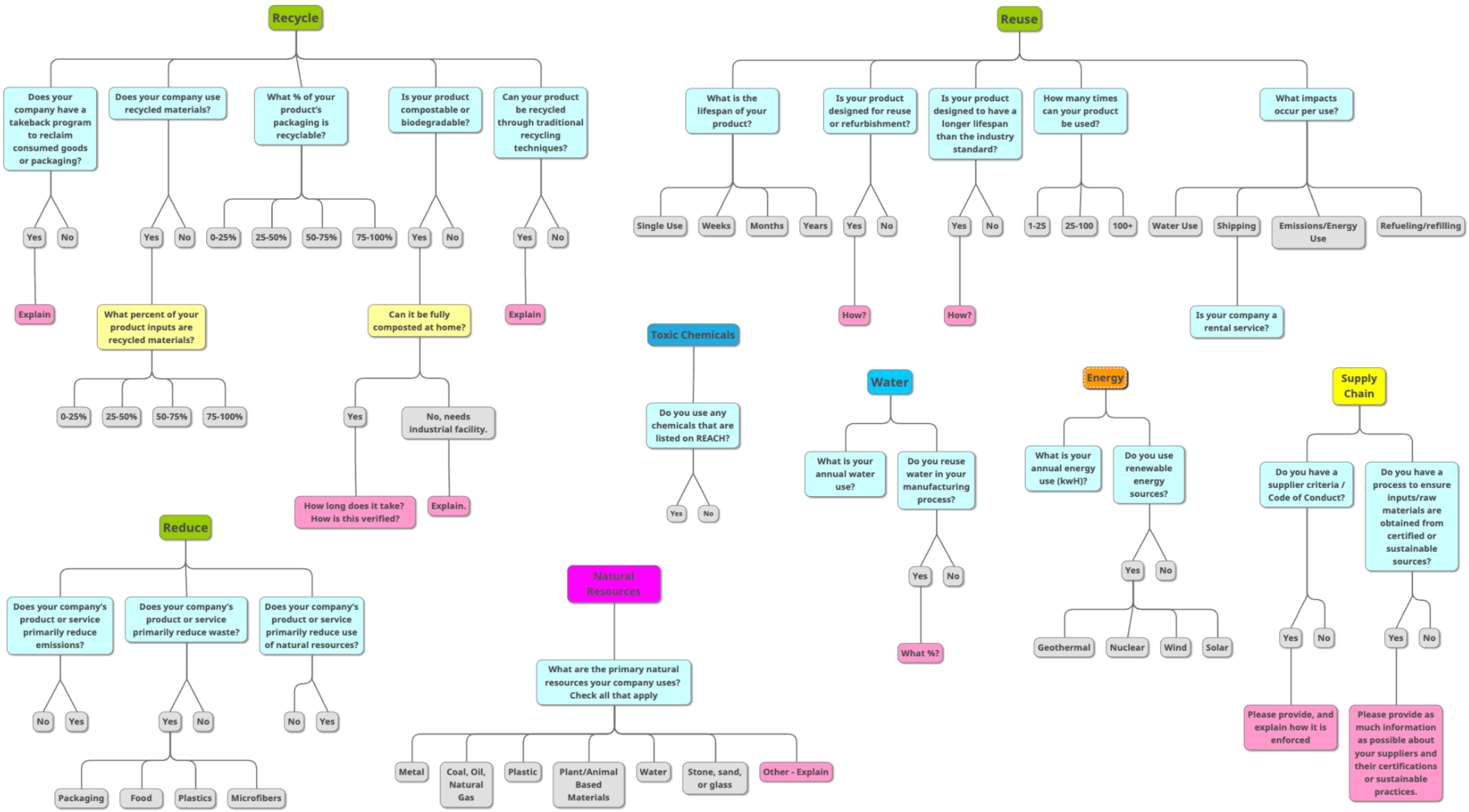

Figure 1: Preliminary questionnaire flowchart developed as part of the iterative questionnaire drafting process.

Software and User Experience

We examined four different software solutions including Qualtrics, OKR, Microsoft Forms, and Google Forms for our questionnaire and created sample forms in each software with our draft questions. We considered factors such as ease of use for users, ease of data analysis and reporting options for questionnaire distributors, open source access, ability for investors to customize, and ease of use for the creators of the questionnaire. We also determined that the software solution would need to have the following functionalities:

- Branching logic flow
- Response weighting
- Investor customization
- Reporting and data export

Ultimately we decided to build the questionnaire in Qualtrics due to its robust customization potential, question logic and weighting capabilities, and user interface. The questions will also be provided as an Appendix in this report for companies to use in a program of their choice.

Questionnaire Guide

In addition to questionnaire development, we have integrated our findings and research into a reference guide for investors. For each indicator, the main takeaways from our literature review including industry baselines, relevant unit comparisons, and assumptions will be readily available in a user-friendly reference guide. The questionnaire guide (Appendix 1) details the specific questions used to assess the desired impacts detailed in previous sections. This guide can be used as a stand-alone document, intended to give investment firms crucial background information about each question, as well as to allow changes in question weighting based on the priorities of each specific investor. For each question, the significance within the circular economy is detailed, followed by any supporting literature, expert feedback, or other relevant research.

Questionnaire Testing and Quality Control

Testing

Using proprietary data provided by Regeneration.VC's portfolio companies, we tested multiple iterations of our questionnaire to find gaps in impact indicators, questions, and assumptions that would need to be true to accurately assess impacts. We ran through the process of how the tool would be utilized by inputting available data into the tool, documenting missing data, and submitting a data request to the investors for additional data from their portfolio companies that was not provided initially.

Expert Review and Consultation

We provided a draft version of our questionnaire to circularity experts and various faculty members at Bren with a professional background in the circular economy and industrial ecology for review. We then met with those reviewers to receive feedback and revise our questionnaire based on expert recommendations.

Our ongoing consultation with our group's faculty advisor, Kelsey Jack, and PhD advisor, Vincent Thivierge, has resulted in numerous improvements and pivots to our process. Early in the project we determined that any given company must be compared against a counterfactual. For example, is an apparel company being compared against a conventional process or against the industry leader in sustainability, and are they assuming the purchase is displacing the purchase of something else? We found it important to clearly elicit the assumptions each company was utilizing to claim their impact. At this stage we also began considering if venture capital is the most effective way for the specific innovation to make impact, or counterfactually, if government grants might be an alternative method.

Additionally, our primary advisors helped us consider exactly how our questionnaire would fit into the investment workflow so that it is actually usable. We focused on ensuring our deliverables mapped onto the desired outcomes put forth by our client. These considerations extend into the final user interface of our product. We were encouraged to focus on useability.

Through two meetings with Ranjit Deshmukh, we reconsidered how plausible it is to compare companies across different verticals. This insight encouraged us to focus specifically on the industries that our client is focused on to make our efforts more valuable. We were encouraged to consider a company relative to the status quo within their industry. Additionally, through these meetings we determined that it is appropriate to put the onus on respondents to support their claims with relative data, rather than attempting to build the environmental footprint of an entire industry's status quo within the tool. There may be room for further research in building industry baselines so as to push respondents to consider the harder questions of sustainability in their industry.

Through one meeting with packaging and supply chain expert Reyna Brown, we learned that chemical supply chains are inherently opaque because of the nature of trade secrets and the hazards of the chemical industry. We learned of innovations such as the Clean Chain initiative in which large companies are pushing for supply chain transparency. We learned from someone working on improving the supply chain in the real world that most companies really don't understand or control the depths of their supply chain. This provides us with an expectation that in certain supply chains important data may not be possible to acquire.

We reviewed our project and draft questionnaire with industry ecology expert, Professor Roland Geyer. In addition to his breadth of literature on the industrial ecology and the circular economy, Professor Geyer provided valuable insights during our review meeting and process. Dr. Geyer encouraged us to consider any given activity of a company as a net negative for the environment until it is proven that this activity provides displacement of something more harmful, as the environmental cost of even a green alternative is still important. In Dr. Geyer's vocabulary, this is termed 'net green'. Additionally, he explained that differentiating between post-consumer and pre-consumer recycling is critical to net impact. In reality, pre-consumer recycling is not particularly difficult and does not deserve the same amount of credit. In metal industries, "run-around" scrap is that which is trucked from the middle or end of the line back to the start and melted back in. Rebranding this process as 'pre-consumer' recycling damages the efforts of more impactful recycling efforts. To address these ideas, we were encouraged to include questions pertaining to technology that might enable a transition to a circular economy, and questions that evaluate whether recycling is pre-consumer or post consumer.

Investor Review and Consultation

We provided a draft version of our questionnaire to Regeneration.VC for review and feedback. Regeneration.VC provided suggestions about how to restructure and categorize the questions, noted questions that were not clear or led to ambiguity, and provided alternative rephrasing of specific questions to reduce ambiguity or repetition. They also noted which of the questions fell under the categories of waste, CO_2 equivalent, Water, Toxics, and Resource Footprint. This feedback was instrumental to the iterative improvement of our questionnaire, and illustrates how investors can utilize the questions to meet their own needs by re-categorizing or providing scores or weights to priority indicators or sections.

Company Review and Consultation

Regeneration.VC is in the process of utilizing our framework with their portfolio companies and will provide us with feedback from the company perspective in terms of user experience, effectiveness, and overall thoughts and we will meet with Regeneration.VC to review feedback and incorporate it into our final framework design.

Case Studies

Through our testing process, we utilized proprietary data from four different industries: materials manufacturing, apparel, rental as a service, and carbon capture and reuse. For each case study, we ran the available company data through our questionnaire, identified valuable data that was missing, and examined how each company's business model fits into the circular economy. We then offered examples of how further analysis could be conducted with the information acquired.

Case Study: Reduce

The first case study we analyzed using the CAT questionnaire was the aforementioned carbon capture company that repurposes CO2 emissions captured from commercial HVAC systems into cleaning products. A secondary benefit of the technology is reduced energy requirements. The assumptions made are focused on the emission associated with the production, maintenance, and operation of the technology. It is necessary for these emissions to be lower than the amount of emissions the technology will reduce from the atmosphere or soap making process to have a net positive impact.

Table 4. *Results from the CAT from Company A Case Study.*

S3.2 Q1: What does your company aim to reduce? Waste Emissions/pollutants Natural Resources/Virgin Materials Energy consumption Other	Emissions/pollutants, energy use
Q1b: If your company aims to reduce emissions/pollutants, which emission(s) and how does your company's primary product or service reduce emissions? ● Air Emissions: ○ CO_2 ○ Methane ○ Aerosols ○ NOx ○ SOx ○ Halogenated Gases ○ VOCs ○ Other ● Water Pollutants ○ Nitrogen Compounds ○ Phosphorous Compounds ○ Other	Carbon Dioxide Technology works in tandem with commercial and industrial heating systems through diverting a portion of the flue gas into a chemical reaction chamber, which is charged with anhydrous hydroxides. The hydroxide is agitated to ensure unreacted particles are exposed to the CO_2, producing carbonates as an output as well as heat from the exothermic reaction. The heat from the reaction as well as the flue gas is captured by a heat exchanger, which then transfers the heat to a water storage tank that returns hot water to the building's municipal water supply.
Q1b.1: How much emissions does your product or service reduce? What baseline comparison is used in your assumptions?	The average CO_2 emissions from the furnace was observed as 28.96 kgCO_2/day (baseline) and the average mass of CO_2 diverted into the system was 16.81 kgCO_2/day, resulting in a net reduction in emissions of 12.15 kgCO_2/day.
Q1d: If your company aims to reduce energy use, please explain how:	Yes

	The captured heat following the reaction is used to heat municipal water usage, with the potential to reduce overall energy usage by 20%.
Q1d.1. How much energy usage does your product or service reduce? What baseline comparison is used in your assumptions?	Integration of a system in a residential space heating system can significantly reduce the GWP (by 12% to 24%) compared to the reference scenario.

Note: Answers in Table 4 from proprietary data provided by Company A.

With the information provided by the survey respondent, several important considerations are quantified. First, this type of technology is very nascent and any claims made are likely relying on self-reported data. The questionnaire helps the investor determine the relevant baseline to compare with company claims. Using data provided by the company, an emissions reduction of 12.15 kgCO2/day was recorded relative to an HVAC system without this technology implemented. Second, it is important to determine if there is a possibility that the energy required to operate the carbon scrubber could be more intensive then a traditional HVAC system. Following a review of the proprietary data of Company A, it was found that integrating this system on a natural gas residential space heating system can reduce the GWP by 12% -24% relative to without the system. This provides further insight into Company A's ability to result in a net-positive emissions reduction. Overall, this information is helpful in validating a company's claims in an efficient and transparent manner.

Case Study: Reuse

The first case study produced by the CAT focused on an outdoor gear rental company, which will be referred to as "Company B" in this case study. Company B provides outdoor gear such as tents, sleeping bags, sleeping mats, ski gear, clothing, and much more. The target customers for Company B are those who are not avid outdoor enthusiasts, but rather those who may go camping or skiing a few times in their life, or those who are outdoor enthusiasts but do not have the ability to own their own gear or are traveling without the ability to bring their gear along with them. Company B provides consumers with an alternative to owning and purchasing outdoor gear with the ability to rent for various periods of time. The mechanism by which Company B operates is that customers can order rental gear on their website and have the gear delivered to them. Once the consumer is done using the gear, the gear is shipped back to where Company B holds the gear where it is cleaned and stored. Due to the data available from Company B, the rental model will be tested based off of the rental of a 4-person tent. As discussed earlier, there are two key assumptions that must be tested to determine if a rental company produces a net environmental benefit. The first assumption is that the rental of a product decreases the primary production of that same product, by displacing the linear purchasing of that product on a 1 to 1 ratio, meaning that one rented tent displaces the purchase of one tent purchase. The second assumption is that the rental of a tent will produce less environmental impacts than the purchase of a tent.

In order to test these assumptions the following data must be collected. First off, the environmental impacts from primary production of the product that is produced or rented must be known. Secondly, the environmental impacts produced during the use phase of the rental process from shipping, washing, energy, and packaging materials. The collection of primary production and use impacts can then be used to compare the environmental impacts of the tent rental to the tent purchase. Third, the durability of the rented product must be known, or the number of times the product can be rented before it loses its utility. Once the number of times a tent can be rented in its lifetime is known, along with the environmental impacts from primary production and the use phase, the minimum displacement ratio can be found. The minimum displacement ratio is the number of purchased tents that must be displaced by the rental of one tent throughout its lifetime in order for an environmental benefit to be produced. A low displacement ratio is more desirable than a high ratio, as it is more realistic to assume that a tent rented out will displace a lower number of purchased tents throughout its entire lifetime. Also, if the true displacement rate of tent rentals is higher than the minimum displacement ratio, then an even greater environmental benefit will be accomplished. This will be explored in more detail in the analysis of Company B below.

In order to gather the relevant data to account for these two factors, the following questions in the reuse section of the CAT are necessary to ask.

Table 5. *Results from the CAT from Company B Case Study*

S4.1 Q2: Do you know the environmental impacts of the primary production of your product or service? (in kg CO2eq or other GHG equivalent) Yes No Q2a: If yes, please include here	Yes, ~ 53 kg CO2eq per tent
S3.3 Q7: What are the environmental impacts which occur per the use of your product or service? Answer Choice: Selection of multiple Water Use (i.e. washing) Shipping (i.e. rental) Energy Use (e.g. charging) Emissions (e.g. hairspray) Refueling/refilling (e.g. refill gas tank) Other	Water use Shipping

Q7a: Explain (quantify if possible)	Information on washing impacts not available
S3.3 Q9: What mechanisms are used to ship your product? Answer Choices: Truck Marine Shipment Air Train Other: Fill in response Q9a: Do you know the estimated GHG emissions in kg COeq produced per order? Answer Choices: Yes No Q9a1: If yes, quantify here Q9b. What is the average number of shipping miles per order for the last year of sales? Answer Choice: Fill in response. Q9c: Is your company taking steps to offset emissions? Answer Choices: Yes No Q9c1: If yes, what steps is your company taking to offset shipping emissions? Answer Choice: Fill in response	Truck Yes 3.58 kg CO_2eq 2,800 miles No
S3.3 Q2: How many uses does your product get within a single lifespan? Answer Choice: 1-25 25-100	25-100

100-1000 1000+ <u>Q2b:</u> Fill in the specific value here.	40

Note: Answers in Table 5 from proprietary data provided by Company B.

From the provided information from Company B, the environmental impacts from primary production and from the use phase can be compared. Thereafter, the displacement ratio can then be found.

The formulas in Box 1 use the data provided in Table 4 to find the emissions in kg CO2eq of renting one tent throughout its lifetime, which Company B assumes to be 40 times, and the emissions from the linear purchase of 40 virgin tents. The emissions from renting the tent 40 times includes emissions from primary production only once, and emissions from shipping times 80, due to the 40 rentals and the tent being shipped to and from the consumer. It can be noted here that emissions for washing the tent are not included in the use phase emissions of the rentals as Company B is unable to gather this information. This is worth mentioning as this is a typical scenario for startups. Seed-level companies do not typically have complete information and when reviewing the results of the analysis it is important to remember that the emissions from the use phase are actually higher than reported due to the exclusion of washing emissions. The primary production equation includes emissions from primary production and emissions from shipping multiplied by the number of virgin tents purchased. In this case study the rental of one tent 40 times is compared to the purchase of 40 virgin tents. The equations in Box 1 are specific to Company B, however, they can easily be adapted to fit other companies utilizing a rental business model.

Box 1. *Formulas designed for use in case study of Company B*

Rental Equation: (emissions from primary production) + (# rentals) * (emissions from shipping) * (2) Linear Equation: (emissions from primary production + emissions from shipping) * (number of virgin tents purchased)

Figure 2 displays the accumulated emissions from renting one tent a total of 40 times. The total accumulated kg CO2eq emissions is around 200 kg CO2eq. Figure 3 shows the accumulated kg CO2eq emissions of the purchase of one through 40 virgin tents. Figure 3 also shows a red dotted line at around 200 kg CO2eq, which is the amount of CO2eq emissions from the rental of one tent 40 times. On the graph, the red dotted line looks to be around the amount of kg CO2eq emitted from the purchase of four virgin tents. The purchase of four virgin tents results in the production of about 215 kg CO2eq. From this analysis the minimum displacement ratio can be found to be around four to forty rentals of one tent. This means that the rental of one tent 40 times must at a minimum displace the purchase of four virgin tents. For investors, knowing the minimum number of virgin tent purchases that must be displaced by the tent rental is important for understanding the ability of Company B to produce environmental benefits. It is more realistic to assume that the rental of one tent forty times would displace the purchase of four tents than 20 tents.

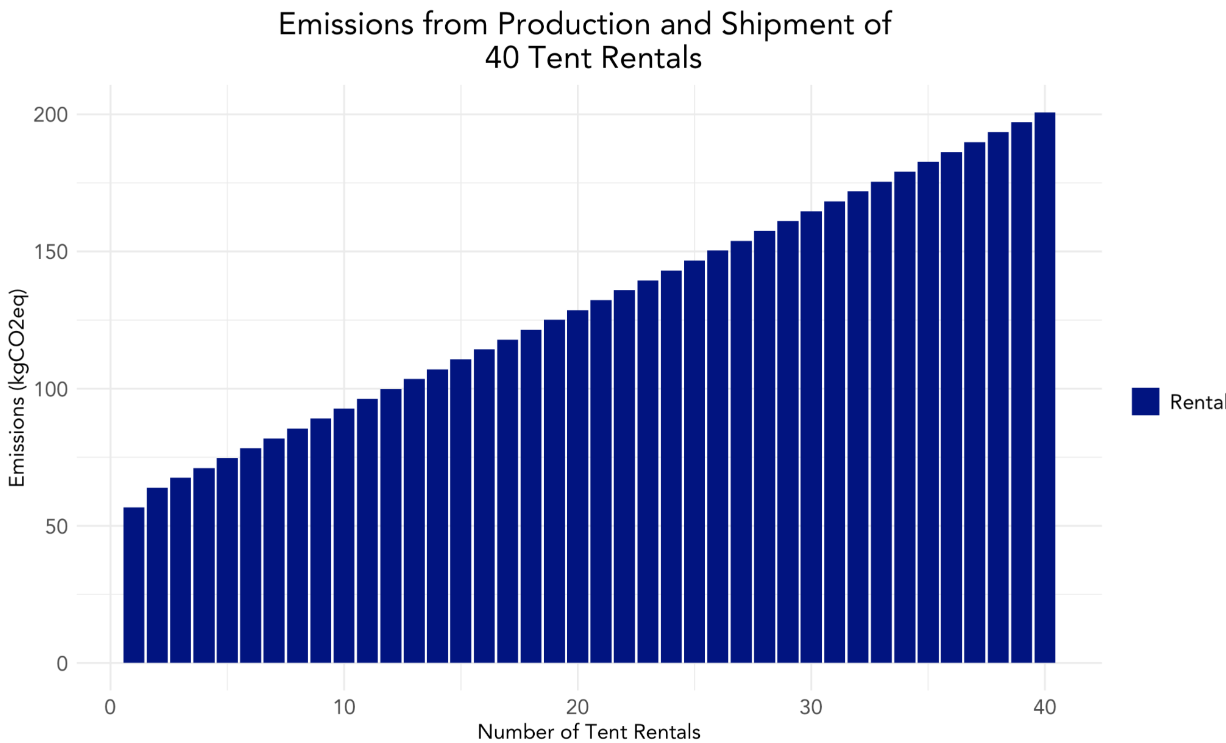

Figure 2. *Accumulated kg CO2eq from the rental of one tent 40 times.*

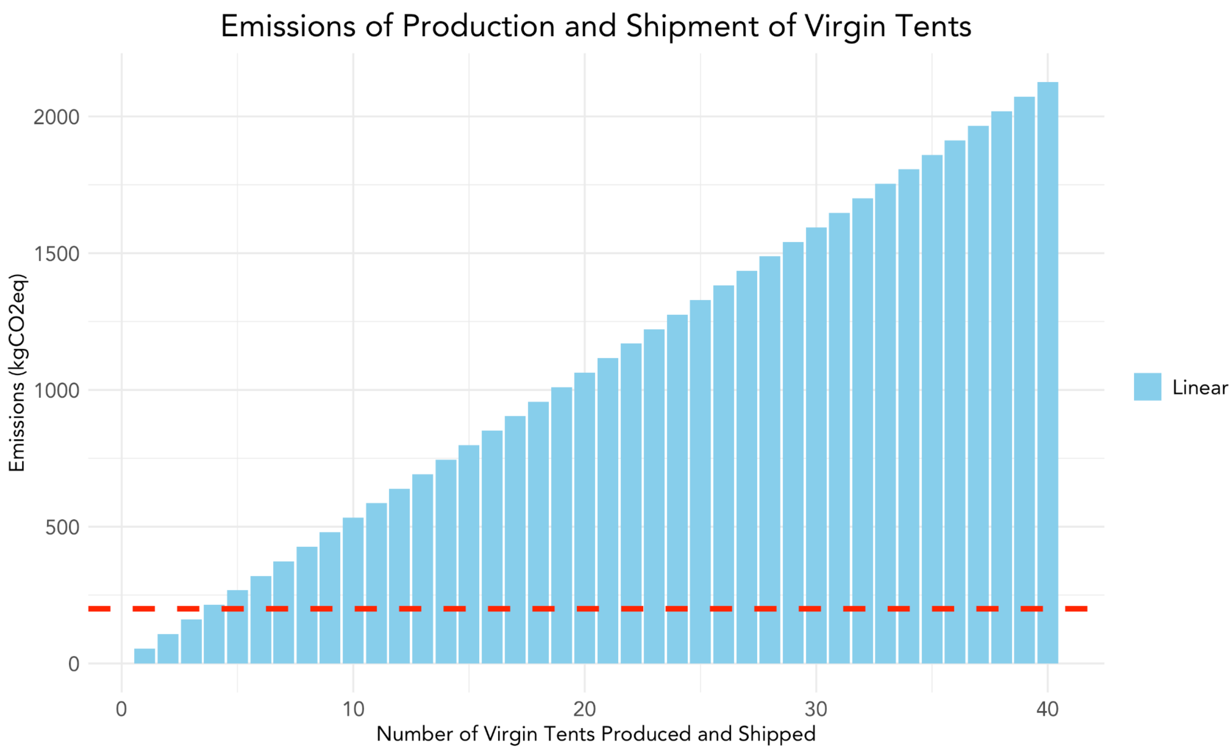

Figure 3. *Accumulated CO2eq emissions from the purchase of one to 40 virgin tents with an additional line showing CO2eq emissions from the rental of one tent 40 times.*

The minimum displacement ratio for the tent is determined on the accumulated CO2eq emissions during the use phase from the process of renting out the tent. If Company B uses a washing technique that results in a high production of CO2 emissions, then the red line would be higher in Figure 3, raising the minimum displacement ratio. Another influential factor on the minimum displacement ratio is the intensity of CO2eq emitted from primary production. If CO2eq emissions from primary production were to decrease, then the minimum displacement ratio would increase. Alternatively, if CO2eq emissions from primary production were to increase then the minimum displacement ratio would decrease. This provides further insight into Company B's ability to produce an environmental benefit, as oftentimes outdoor gear is rented out as a bundle of goods. The bundle of goods could contain sleeping bags, sleeping pads and more which would increase the overall emissions from the primary production of these goods, while the emissions during the use phase would also increase, but not as drastically as those from primary production. This shows investors that the more times the tent is rented out, or a bundle of gear is rented out, there is a low minimum displacement ratio and therefore it is more reasonable to assume that an environmental benefit is being produced.

Case Study: Recycle

For a third case study we assessed a single operation from a company with a wide range of materials innovations in the apparel industry. The 1:1 displacement assumption in this case means that for each item of clothing that uses organic cotton, it is displacing an item of conventional cotton, and that each time recycled cotton is used it will displace the organic cotton the company currently uses. We can think of recycled cotton as displacing an item of conventional cotton that a user might otherwise purchase. The circular business model deployed here makes use of recycling, so understanding demand for recycled products is an important part of understanding how they will displace products that use virgin materials.

In order to gather data that can discern the improvement over status quo, the following questions in the recycle section of the CAT are necessary.

Table 6: *Questions & Results from the CAT from Company C Case Study*

S2 Q4: Will your product or service displace existing products or services that have a greater environmental impact?	Yes. Our organic cotton and hybrid organic cotton + recycled cotton items displace higher impact articles when consumers shop with us.
S3 Q1: Does your company use recycled materials as a product input? Q1a. If yes, what percent of your product inputs are recycled materials? Q1b. What type of recycled material is used? Q1c. Does your product use pre-consumer or post-consumer recycled material?	Some of our cotton items are 100% organic, some are 55%:45% organic:recycled, some are 50:50, and some are 70:30. We are exploring 100% recycled. The recycled material is cotton. Pre-consumer or post-consumer is not specified. Several sources of each exist in the supply chain mapping to Turkey, Portugal, Tanzania, Switzerland, Uganda, and Brazil, which makes data collection complicated.
S3 Q2: Is your product packaged? Q2a: What is the primary material used in packaging? Q2b: What percentage of your product's packaging is recyclable?	Yes. It is packaged in compostable TIPA 302 resealable bags which are made from proprietary blends of fully compostable polymers that are both bio-based and fossil-based. This packaging is 0% recyclable.
S6 Q: What is your water use per unit?	The global benchmark for conventional cotton is 2,841 l/kg, organic cotton requires between 66 and 159 l/kg, and recycled cotton requires between 22 and 29 l/kg. So a 50:50 organic:recycled blend would use

	between 44 to 94 l/kg

Note: The answers supplied in Table 6 come from proprietary data and the responses provided by company C.

With this information, the investor can see how the company assumes their potential for water reductions. The investor can compare the water usage during production and use to current industry standards to better understand what environmental benefits may come from the company choosing alternative sourcing. The investor can also consider how water usage may be further reduced as the company explores 100% recycled cotton as they scale. Figure 4 is an example of a data visualization that could be produced from the data collected from the CAT. It is clear that using alternatives to conventional cotton will result in significant water savings. A visualization such as Figure 4 can be used to easily communicate these types of findings with limited partners and other stakeholders.

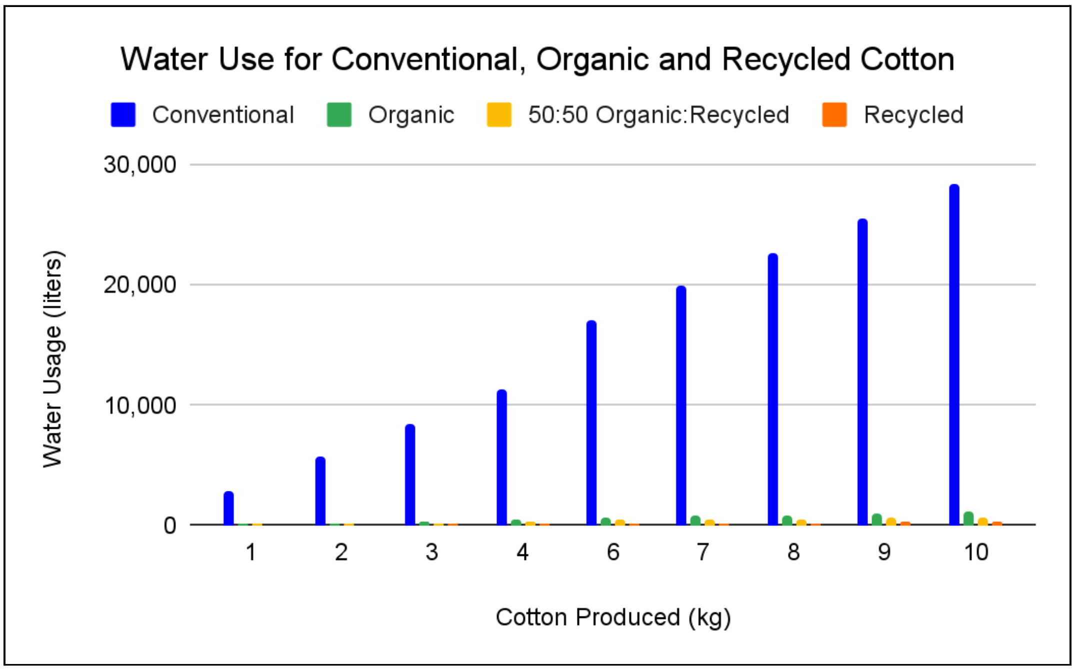

Figure 4: Liters of water required to produce 1kg to 10kg of conventional, organic, recycled, and 50:50 organic:recycled cotton.

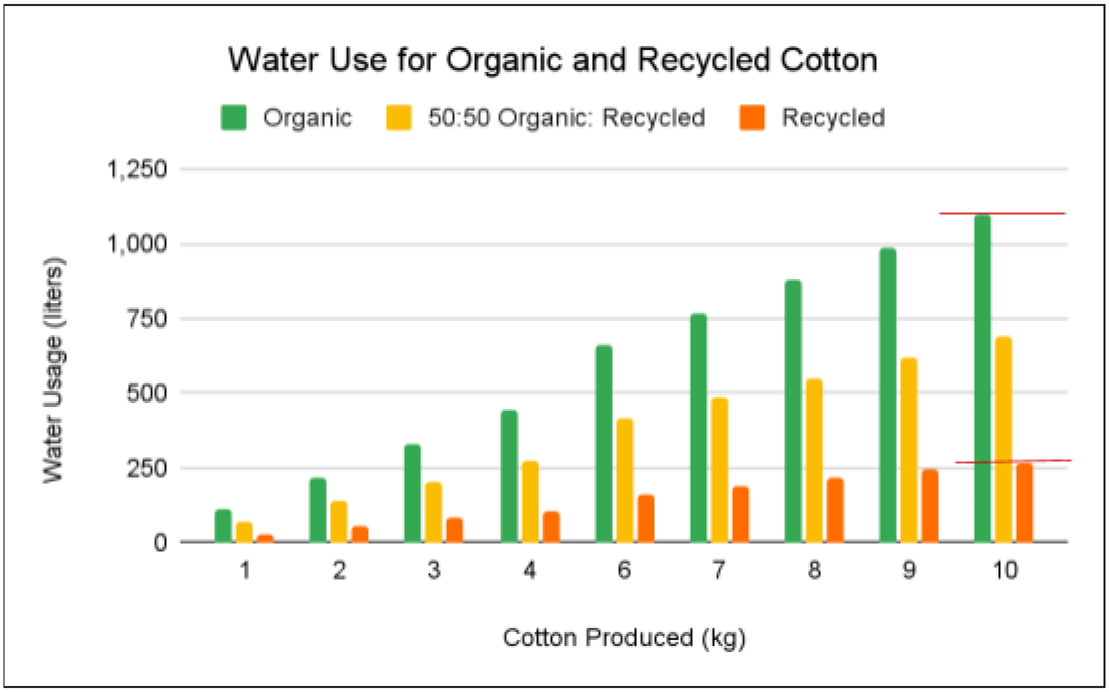

Figure 5: Liters of water required to produce 1kg to 10kg of organic, recycled, and 50:50 organic:recycled cotton. The red lines illustrate the water use that can be reduced if Company C switches 10kg of their cotton to 100% recycled cotton.

If Company C planned to use 10kg of cotton for an investment product, and was considering switching to 100% recycled cotton, the investor could easily assess the water use the company would reduce by making this change. This type of analysis can also be conducted for energy use, transportation methods, or durability improvements amongst other environmental indicators.

Discussion

Further Research

Further research that would add value to the CAT includes establishing baseline metrics for relevant industries, so companies and investors can more quickly determine how their responses to the questionnaire compared to the relevant status quo. For now, the CAT places the responsibility on the potential investment company to provide this research, but having a database developed by a neutral third party may help reduce potential bias in the process. While data availability constraints prevented us from integrating baseline data in the tool, investors can use company inputs to create their own baseline databases as companies use the CAT.

This tool could be expanded to cover supply chain considerations. There are real chemical and physical limits to transitioning to a circular economy, which are generally ignored because they are hidden in the supply chain. As one cannot destroy or create energy, new materials and energy need to be injected into any circular material loop to overcome dissipative losses that occur (Cullen, 2017). Notably, labor can be a solution, such as sorting trash or performing chemical or electronics recycling to fit materials back into the circular economy. Each of the above factors may be subtle but add up to consequence through entire supply chains. The CAT does not include a section pertaining to supply chain considerations and labor issues, due to time constraints during tool development, but we hope that investors will consider such issues during the due diligence process.

Additionally, time constraints prevented the inclusion of an environmental justice (EJ) section in the CAT. We originally hoped to explore the EJ implications of a company's operations using questions assessing impacts on local air quality, exposure of workers to toxins, and other differential impacts, but found little justification within the literature that such questions could be included in a circularity tool. The current understanding of the circular economy primarily focuses on the broad environmental benefits resulting from departing from the linear economy, without exploring differing effects on different populations. While future work must be done in ensuring that a circular transition results in benefits for all, we were unable to incorporate EJ effects in the CAT.

One other area of further research regards how new efforts in the circular economy such as this ought to integrate with the established recycling etiquette of the world. For example, as a non-profit, Goodwill has been providing reuse for decades, and second hand thrift stores are as old as industrial society. This is related to the counterfactual of a clothing resale model, in which they consider themselves the displacers of virgin production, when really, they are just displacing an item heading to the local thrift store. Discerning who deserves attribution for the public good in these discussions with empiric study is a challenge.

Tool Application

In our research on the circular economy and the role of venture capital in growing circularity-focused businesses, we identified challenges faced by investors in understanding the true environmental impacts of their investments as a company scales. We initially set out to create a tool that would provide a circularity "score" for potential investments so investors could easily rank them from "best" to "worst". However, we quickly discovered that a comprehensive look at circularity requires a nuanced understanding of environmental impacts, displacement potential, and the counterfactual, which are difficult to compare across sectors and impact categories. Furthermore, different investment firms may prioritize impact categories differently based on their specific business strategy and focus. To address these obstacles, we synthesized the top circular indicators from our research into a comprehensive questionnaire and research guide for investors to more effectively and efficiently understand the potential environmental impacts of a product or service as the company scales with the investment funds.

Our questionnaire aims to address the challenges faced by investors and startups who do not necessarily have all the data or resources to complete a full-scale LCA or environmental certification, but need a consistent set of indicators to establish baselines for these early-stage companies, and monitor and report progress over time. One important takeaway is that no data is data itself. Meaning, investors can better understand a potential investment's commitment to creating an environmental benefit by the research the company has done to address these important questions. For companies that do not yet have this level of reporting, this questionnaire provides important environmental concepts they can explore at early stages when stakes are lower, and investors can use this research to consult with the client on how to address key impact categories to achieve net environmental benefits.

Potential uses and applications beyond what we've explored in this report include providing consistent metrics and data that can be used in annual impact reports, or an efficient way for investors to analyze their entire portfolio. For example, investors could easily compile data for how many of their portfolio companies focus on a "reduce" business model, or which environmental certifications their companies have earned. The CAT can also be used for the monitoring and evaluation of portfolio companies post-investment; investors can use the CAT annually, to glean standardized information on the environmental benefits resulting from their investment.Investors can also weigh or score specific categories or questions based on their firm's specific goals and objectives. Specific risk or red flag indicators can be easily identified amongst a number of potential investments such as the use of toxic chemicals, or high energy or water usage.

By making our questionnaire and research guide available in Qualtrics and in this report, we aim to make the CAT accessible for all investors and start-up companies. By providing this open-source tool to help understand, track, and monitor key environmental indicators, especially those that are not considered by other tools, such as displacement potential, the rebound effect, and the counterfactual, we hope to help investment funds create a net environmental benefit, rather than succumbing to the effects of greenwashing. The link to download the CAT questionnaire Qualtrics file is located on the CleanCapital project page on the Bren project website[3], and the questionnaire questions and research guide are available in the Appendix section of this report.

---

3 https://bren.ucsb.edu/projects/circularity-framework-development-regenerationvc-portfolio

Appendices

Appendix 1: Circularity Tool Descriptions

Cradle to Cradle

Summary: Cradle to Cradle Certified assesses the "safety, circularity and responsibility of materials and products" across five sustainability categories: Material Health, Product Circularity, Clean Air and Climate, Water and Soil Stewardship, and Social Fairness (Cradle to Cradle Products Innovation Institute, 2021). The four certification tiers offered by Cradle to Cradle (bronze, silver, gold, and platinum) allow smaller, emerging companies the ability to start their sustainability reporting, and build upon it as they grow and are able to improve operational efficiencies and reporting. Cradle to Cradle has an additional certification, the Material Health Certificate Standard which focuses specifically on material and chemical improvements, and could provide a valuable stepping stone for early-stage companies on their path to the more comprehensive Cradle to Cradle certification (Cradle to Cradle Products Innovation Institute, 2021). The Material Health Certificate Standard also offers four tiers to encourage continuous improvement.

Gaps in circularity assessment for early-stage companies: Some concerns with Cradle to Cradle are that there are fairly stringent requirements in some areas (such as materials), and investments in third-party auditing would need to be made to achieve certification at any level. Cradle-to-Cradle certification can be extremely costly to attain, both for the laboratory tests needed to prove material and chemical improvements, as well as the cost of transitioning to C2C approved materials(Ismayilova & Silvius, 2021). Furthermore, while it is comprehensive, some specific standards, especially at the lower tiers, are not particularly stringent (i.e. bronze climate requirements only address emissions reporting availability, whereas the platinum tier requires 100% emissions offsets).

Furthermore, Cradle to Cradle certification focuses on the production and materials of a product, but further research and standards must be considered to address the counterfactuals and total environmental impact of using a Cradle to Cradle certified product compared to business as usual, the absence of the product, or investment in other solutions, which is not addressed in the methodology itself. The focus on material requirements for product certification may not be suitable for evaluating a service or technology innovation.

Material Circularity Indicator

The Ellen MacArthur Foundation's Material Circularity Indicator (MCI) assesses a product or company's contribution to the circular economy. The MCI primarily focuses on materials — specifically the quantities of virgin material, recyclable material, and nonrecoverable waste materials that are consumed and produced in the manufacturing of a product (Ellen MacArthur Foundation, 2022). While these factors are vital in any circularity score, the actual environmental impact is much more than simply the materials flow. MCI allows for "Supplementary Indicators" to be added to the primary circularity indicator, which allows companies to include various measures of risk (the urgency of implementing circular practices, i.e. material scarcity or toxicity) and impact (the benefits of circular models, i.e. energy or GHG impacts). The lack of standardization among these complementary indicators, however, means that consumers and investors are not able to make a comparison between different MCI scores without delving deeper into the methodology behind MCI. When used in conjunction with tools and standards such as LCA, environmental product declarations (EPDs), and ISO standards for reporting water footprint (ISO 14046:2014), MCI is an invaluable indicator; a standard for use of these complementary tools is necessary in order for MCI to be a useful metric for comparison and assessment.

Gaps in circularity assessment for early-stage companies: The scope of the MCI is narrower than what circular economy stands for, it does not favor more granular levels of recovery beyond recycling and reuse, such as remanufacturing or refurbishment, and it does not consider important changes to material along the circular process such as what occurs with downcycling (Saidani et al., 2017).

InVEST

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is "a suite of models used to map and value the goods and services from nature that sustain and fulfill human life" (Zaks, 2019). This tool can be used to inform how human benefits will be affected by changes in the ecosystem. The information provided by InVEST is useful for informing decisions regarding land and water management policies, and could prove most useful if a potential investment opportunity is centered around conservation or will significantly impact land and water resources. InVEST will also be relevant when comparing the effects a product system has on the environment, however an LCA may also provide similar information.

Gaps in circularity assessment for early-stage companies: Completing an InVEST assessment requires access to mapping software such as ArcGIS or QGIS, and basic proficiency in GIS software. Discussions with our client indicated that not all investors have this level of knowledge or technical expertise for specific softwares like ArcGIS which creates a barrier to entry for tools like InVEST. Furthermore the time requirements for using InVEST are moderate to high, depending on data availability, which could additionally deter investors from using InVEST (Bagstad et al., 2013).

Crane

Crane, equipped with AI, compares greenhouse gas emissions of new technology compared to current industry standards (cranetool.org, 2022). Crane is also able to predict the percentage of the market a new technology may take over and displace.

The tool uses the predicted displacement of an older, more emission intensive technology, to predict the carbon emissions mitigated from the new technology.

The current state of development for Crane is moving in real time as the team integrates more data sets and more users. The more granular these data get, the more potential their AI has to provide useful insights. The new update of Crane will allow more customization of inputs to allow for better comparison of new technologies to the industry standards.

Outputs from Crane may be useful for comparing potential investment company impacts to industry standards in regards to CO_2 emissions.

Gaps in circularity assessment for startups: Crane does not include social factors when analyzing these technologies, or non-carbon related outputs such as waste, pollution, and materials.

Appendix 2: Questionnaire Guide

This questionnaire guide details the specific questions used to assess the desired impacts detailed in previous sections. This guide can be used as a stand-alone document, intended to give investment firms crucial background information about each question, as well as to allow changes in question weighting based on the priorities of each specific investor. For each question, the significance within the circular economy is detailed, followed by any supporting literature, expert feedback, or other relevant research.

Questionnaire Implementation Guide:

Goal:

The overall goal of the CAT is to provide a means of data collection from potential investment opportunities to inform an investment firm's decision making process. This tool does not provide insight into what the "right" investment could be, but instead, collects information to uncover potential discrepancies between a company's claims and its delivered products and services in a holistic and data-driven approach. This tool has been developed to be able to overcome gaps in data availability through an extensive and flexible weighting system.

Onboarding:

Prior to implementation, an investment firm should review the CAT in its entirety to determine the specific weighting preference they would like to establish as well as remove any questions they do not feel provide a value-add to the tool. This can be completed independently in the Qualtrics platform.

Implementation:

Upon completion of a preliminary review of the tool, an investment firm can disseminate a link to a potential investment opportunity or existing portfolio company. The receiving party will then be able to securely complete the questionnaire, either on a mobile phone or computer. All responses will be recorded in an excel spreadsheet upon completion.

Analysis:

Finally, an investment firm will be able to assess a company's response through several means. First, they can look at the quantitative responses submitted and determine the differences between industry specific averages and the company's responses. Secondly, they can use the qualitative responses as a means to assess potential areas for a greater focus or engagement. Lastly, any unanswered questions can be followed up on to ensure no significant data gaps exist.

Section 1: Company Structure & Introduction

This introductory section allows companies to describe themselves broadly, and provide

Q1: Describe your company.

Q1 gains insight on the company structure and products/services provided by asking companies to describe themselves. Additionally, the details prioritized by each company in their answer can help investors gain insight into the direction their investment will go.

Q2: Does your company utilize a circular business model? If yes, please indicate which business model best describes your company. Yes No Q2a. If yes, select: Reduce Reuse Recycle Other

Q2 presses companies to evaluate their business in relation to the broader circular economy. By choosing the circular business model that best suits their company, companies will then be directed to answer a series of questions for their specific business model, as well as two broader sections exploring scaling/displacement and general environmental impact.

Q3: What industry is your company in? Consumer packaged goods Packaging Food and beverage Electronic

Transport
Apparel
Construction & Manufacturing
Technology
Other

Q3 provides a basis for comparison in many of the sections to come. In subsequent questions, companies will be asked to compare their own impact to industry standards; this question ensures that investors are aware of what industry that comparison is being made within.

Q4: Does your company or product have any environmental certifications or third-party verifications?

Yes

No

Q4a. If yes, please indicate which certifications or verifications and provide documentation here (upload).

While this tool aims to fill the gaps inherent in many environmental certificate programs, additional verifications can give investors helpful information; Q4 provides a space for companies to supplement their answer to CAT with documentation of additional certifications or verifications.

Section 2: Scaling and Displacement

Q1. What are the biggest negative impacts of running your operation?

Q1a. How does that compare to your competitors?

Q1b. Where do you see the biggest opportunities to improve your operational footprint?

While subsequent questions collect metrics for company impacts, this question allows companies to self-report impacts. The answers to these questions reveal the impacts the company is currently aware of, as well as the areas in which the company would be most likely to pursue improvements.

Q2: How will company growth change the impact produced from the core product or service?

As companies scale, impacts increase. This question examines whether or not the company has a plan to decouple impact from growth.

> Q3: What environmental benefit would an investment facilitate that would not otherwise occur absent of the investment?

This question explores the different potential changes companies will be able to implement with an investment. While companies may not know the specifics of how a theoretical investment could affect their company operations, the answer to this question gives insight into the areas that companies are hoping to improve, pending receival of seed funding.

> Q4: Will your product or service displace existing products or services that have a greater environmental impact?
>
> Yes
> No
>
> Q4a: If yes, please explain.
>
> Q4b: Have you conducted any research to determine *how* your product or service will displace higher impact products?
>
> Yes
> No
>
> Q4c: If yes, please explain.

Displacement, where the purchase of a "greener" product replaces a purchase of a product with a higher environmental impact, is crucial in determining company impact beyond traditional metrics (e.g. GHG output, energy use, etc.). Q4 explores whether companies have taken steps to ensure that their product will displace "worse" products, as well as any research confirming the effectiveness of such steps.

> Q5: Does your company attempt to value potential environmental benefits?
>
> Yes
>
> No
>
> Q5a: If yes, please explain how.

Q5 allows companies who have previously attempted to estimate environmental impact to state so, and gives them a space to explain the methodology used to reach an estimate;

investors are able to place any benefit quantifications in context of the methods used to obtain those values. For companies that have not yet estimated their monetized environmental benefits, they are able to discuss the factors hindering them from making those estimates. Investors are thus able to identify areas in which support would be needed.

<u>Q6</u>: Are there any relevant policy decisions or incoming regulations that affect your solution or the competitive landscape?

Yes
No

Q6a: If yes, explain.

Due to constantly changing regulations on labeling, disclosure, and sustainability claims, companies that are aware of possible upcoming policy changes, and preemptively compliant with such changes, are a lower-risk investment than companies whose operations may be hindered by the passage of a new regulation. This question gauges companies' awareness of the changing policy landscape surrounding their product and service, and evaluates the steps they have taken to adapt to new policies.

Section 3: Circularity Section

Subsection 1: Recycle

This section aims to assess the amount of material being recovered from waste streams. This section explores product inputs, packaging inputs, and end-of-life options. Point values for weighted questions are indicated to the right of each question; questions without indicated point values are unweighted.

<u>Q1:</u> Does your company use recycled materials as a product input?

Answer Choices:
Yes
No

Q1a. If yes, what percent of your product inputs are recycled materials?

Answer Choices:
0-25%
25-50%
50-75%
75-100%
N/A

Q1b. What type of recycled material is used?

Answer Choices:
- Recycled aluminum
- Recycled steel
- Recycled cardboard or paper
- Recycled glass
- Recycled plastic
- Recycled textiles
- Other

Q1c. Does your product use pre-consumer or post-consumer recycled material?

Answer Choices:
- Pre-consumer
- Post-consumer

Q1 assesses the percentage of non-virgin material included in product inputs. Higher percentages of recycled content are preferred to lower percentages and pre-consumer recycled content is preferred over post-consumer content. Companies are also asked to specify the type of recycled material used for data gathering purposes.

Products with higher recycled content would have a lower net environmental impact than the same product constructed with virgin materials. It is also vital to differentiate between post-consumer and pre-consumer recycled content, and favor the use of post-consumer content. Pre-consumer recycled content is defined by the U.S. Green Building Council as "material diverted from the waste stream during the manufacturing process" – in contrast to post-consumer recycled material, which is defined as "waste material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product, which can no longer be used for its intended purpose" (*Going All In*, 2022).

Q2: Is your product packaged?

Answer Choices: Yes, No

Q2a. What is the primary material used in packaging?

Answer Choices:
- Thin film plastic
- Cardboard
- Plastic lined cardboard
- Other

Q2b: What % of your product's packaging is recyclable?

Answer Choices:
- 0-25%
- 25-50%

50-75%
75-100%

Q2c: Does your company reuse its product packaging?

Answer Choices:
Yes
No

Q2 collects information on product packaging. Q2a categorizes companies by commonly used packaging varieties (users can also add additional packaging types to expand the selection), while Q2b categorizes companies by percentage of recyclable packaging. Q2c assesses whether companies are reusing within their own product cycle; for example, using reusable containers for product inputs, reusing packaging to consumers, etc.

Q3: Is your product compostable or biodegradable?

Answer Choices:
Yes
No

Q3a: If yes, can it be composted in a home composting system with no additional inputs?
Yes
No

Q3b: If no, explain what additional inputs are necessary.

Q3 assesses any claims about the biodegradability and compostability of a product. Q3a asks for the assumptions used in the characterization as compostable/biodegradable, and asks the company to provide additional information on the predicted break-down process of the product.

Due to a lack of standardization surrounding claims of biodegradability and/or compostability, it is necessary to collect information on the assumptions behind any claims made. The US Federal Trade Commission (FTC) Guide for the Use of Environmental Marketing Claims defines a compostable product as one in which "all the materials in the product or package will break down into, or otherwise become a part of, usable compost (e.g., soil conditioning material, mulch) in a safe and timely manner in an appropriate composting program or facility, or in a home compost pile or device", while biodegradable products require that the "entire product or package will completely break down and return to nature, i.e., decompose into elements found in nature within a reasonably short period of time after customary disposal" (Federal Trade Commission, 2012).

Claims of compostability are evaluated by compliance with existing standards. The American Society for Testing and Materials (ASTM) Standards 6400 is widely used as a standard for determining compostability. ASTM 6400 – the primary standard used by the Biodegradable Products Institute (BPI), a widely-known US 3rd-party certifier – is a four-part biodegradation test that assesses biodegradation, eco-toxicity, and plant growth (ASTM, n.d.; BPI, n.d.; Greene, 2007). While the high temperatures used in ASTM 6400 closely mimic the conditions used in industrial composting facilities, and do not reveal compostability within an at-home composting system, compostable plastics that meet ASTM 6400 requirements were found to degrade at rates similar to cellulose materials in a municipal green yard-waste compost environment (Greene, 2007).

Companies that have evaluated their products using recognized standards and certifications (e.g. ASTM 6400, BPI, etc) are favored over those without verifiable claims of compostability. California AB 1201, which tightened regulations surrounding product degradability claims, indicates that the usage of such claims may be more heavily regulated in the future (Millar et al., 2021) – companies that have preemptively complied with AB 1201 will not need to complete additional steps to achieve compliance if stronger labeling regulations are enacted at the federal level.

Q4: Can your product be recycled?

Answer Choices:

Yes

No

Q4a: If yes, how exactly can it be recycled and what infrastructure is required?

Answer Choice: Fill in response

Q4 determines whether or not a company is producing a recyclable product, and evaluates the infrastructure needed to successfully recycle the product. While a priority of the circular economy is designing products to minimize waste from the outset, the creation of some amount of ‘end-of-pipe’ waste is inevitable.

This tool specifically gathers information on the assumptions necessary for a product to be recycled. The lack of regulation surrounding use of the chasing arrows symbol (♺) allows any product to display the icon, regardless of whether or not the product is actually recyclable in a municipal recycling program (Tabuchi & Choi-Schagrin, 2021). California SB 343, a 2021 bill estimated to come into effect in 2024, restricts use of the chasing arrows symbol to products or packaging that are considered recyclable based on the statewide criteria detailed in the bill; however, California is the first and only state to enact this type of regulation (Millar et al., 2021). Companies with verifiable claims that their products or packaging is able to be recycled in municipal programs (i.e. products that would already be in compliance with a bill such as SB 343) should be preferred over those without such verification.

Companies that have a takeback program to facilitate in-house recycling are able to give details of their program in Q5.

Q5: Does your company have a takeback program to reclaim consumed goods or packaging?

Answer Choices:

Yes

No

Q5a: If yes, explain

Q5 assesses whether a company has created alternative avenues for post-consumer goods, generally in cases where products or packaging cannot be recycled through a conventional recycling program (i.e. an easily accessible municipal recycling program), such as a takeback, buyback, or recycling program. Companies with a takeback program are asked to describe details of the program.

Companies that have established a takeback program for post-consumer materials are ranked higher than those without a program. Takeback, buyback, and recycling programs are a subset of Extended Producer Responsibility (EPR), a policy approach that shifts the responsibility for the management of post-consumer goods to the producer, rather than to consumers or local waste agencies (Biron, 2020; Rogoff, 2014). EPR programs have been found to lead to higher rates of recycling and collection rates (OECD, 2014) and have achieved widespread success – Best Buy has recycled 2 billion lbs of e-waste since 2009 (Smith, 2019), while Patagonia repaired 100,000 pieces of clothing in 2018 alone (Bianchi, 2019).

In addition, in light of the adoption of EPR policy worldwide (OECD, 2014), companies with already established take-back or recycling programs are regarded by this tool as more attractive investments due to their preemptive compliance with EPR regulations. EPR programs also encourage companies to design their products for easier recycling, repair, or refurbishment (Clean Production Action, 2007), indicating that companies with take-back programs are more likely to be actively designing products for a more circular end-of-life.

Subsection 2: Reduce

This section evaluates the potential for a company's product or service to contribute to reductions in waste, emissions, and other natural resources.

Q1: What does your company aim to reduce?

Waste
Emissions/pollutants
Natural Resources/Virgin Materials
Energy consumption
Other

Q1a: If your company aims to reduce waste, select which type of waste

Plastic Packaging
Cardboard Packaging
Food (Meat)

Food (Produce)
Plastics
Microfibers
Other: Fill in response

Q1a.1: If your company aims to reduce waste, how much waste does your product or service reduce? What baseline comparison is used in your assumptions?

Q1b: If your company aims to reduce emissions/pollutants, which emission(s) and how does your company's primary product or service reduce emissions?

- Air Emissions:
  - CO2
  - Methane
  - Aerosols
  - NOx
  - SOx
  - Halogenated Gases
  - VOCs
  - Other
- Water Pollutants:
  - Nitrogen Compounds
  - Phosphorous Compounds
  - Other

Q1b.1: How much emissions does your product or service reduce? What baseline comparison is used in your assumptions?

Q1c: If your company aims to reduce consumption of natural resources, please explain how:

Q1c.1. How much consumption of natural resources does your product or service reduce? What baseline comparison is used in your assumptions?

Q1d: If your company aims to reduce energy use, please explain how:

Q1d.1. How much energy usage does your product or service reduce? What baseline comparison is used in your assumptions?

Q1 collects information on what reductions a company claims to make. Companies select categories in which they claim to cause reductions and are prompted to answer additional questions for each category.

Q1b collects information about any avenues by which a company's product or service reduces emissions or pollution. Information about the types of emissions/pollutants, as well as details about how the company achieves emissions reductions, is collected in Q1b.1. The emissions and pollutants given as answer choices are divided into Greenhouse Gases, Air Pollutants, and

Water Pollutants. Greenhouse gas emissions are ranked by Global Warming Potential, as detailed in the figure below. The primary greenhouse gasses of concern are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride, and sulfur hexafluoride. These gasses are compared to one another due to their shared ability to absorb infrared radiation. Table 3 includes some key characteristics of the greenhouse gasses listed.

Table 3. Characteristics of Greenhouse Gases (US EPA, 2016)

Species	Chemical Formula	Lifetime (years)	Global Warming Potential (100 years)
Carbon Dioxide	CO_2	variable	1
Methane	CH_4	12	25
Nitrous Oxide	N_2O	114	298
Hydrofluorocarbons	HFCs	270	14,800
Perfluorocarbons	PFCs	2,600-50,000	12,200
Nitrogen Trifluoride	NF_3	740	17,200
Sulfur Hexafluoride	SF_6	3,200	22,800

Subsection 3: Reuse

This section explores the assumptions behind a reusable product or reuse service. This section assesses product lifespans and displacement of single-use products, as well as environmental effects during the use phase of a reuse service model.

Q1: What is the lifespan of your product?

Answer Choices:
- Single Use
- Weeks
- Months
- Years

Q1a: How does your product lifespan compare to the status quo? Please state any assumptions made.

Answer Choice: Fill in response

Q1 collects information on the estimated lifespan of a product. Investors can compare product lifespan to the average product lifespan across the industry, and examine the assumptions made to obtain that value.

Q2: How many uses does your product get within a single lifespan?

Answer Choice:
- 1-25
- 25-100
- 100-1000
- 1000+

Q2b: Please fill in the specific value here.

Q2 collects information on the estimated number of uses during a product's lifespan. Investors can use this information in further analysis that requires per-use data.

Q3: Is your product designed for reuse (displacing single use products)?

Answer Choices:
- Yes
- No

Q3 and Q4 categorize companies into two prominent business models within the 'reuse' category: rental companies and product life extension companies. Additional questions in this section explore the assumptions behind each business model.

Q4: Is your business a rental service?

Answer Choices:
- Yes
- No

Q4a: How many times does each customer typically use your product before returning?

Answer Choice: Fill in response

Q3 and Q4 categorize companies into two prominent business models within the 'reuse' category: rental companies and product life extension companies. Additional questions in this section explore the assumptions behind each business model.

Q4a asks companies to give pertinent information about customer behavior when using their rental service. Collecting information on customer usage of a rented product can help investors understand the environmental harm avoided by using a rented product instead of purchasing a new product.

<u>Q5</u>: Is your product designed for refurbishment?

Answer Choices:
Yes
No

<u>Q5a:</u> If yes, please explain your refurbishment process. Is the product returned to the same customer or refurbished and resold to a new consumer?

Answer Choice: Fill in response

Q5 asks companies to explain any product refurbishment that occurs. Companies that provide in-house refurbishment services are able to explain the process of refurbishment, as well as details about the post-refurbishment phase.

<u>Q6:</u> Is your product designed to have a longer lifespan than the industry standard?

Answer Choices:
Yes
No

<u>Q6a:</u> If yes, what is the typical lifespan (or # of uses) of the product following the industry standard?

Answer Choice: Fill in response

<u>Q6b:</u> If yes, what is the lifespan (or # of uses) of your product?

Answer Choice: Fill in response

Q6 allows investors to learn how a product's lifespan compares to the industry standard. This provides investors with a more easily understandable idea of the possible environmental benefits of a reusable product.

<u>Q7:</u> What are the environmental impacts which occur per the use of your product or service?

Answer Choice: Selection of multiple
Water Use (i.e. washing)
Shipping (i.e. rental)
Energy Use (e.g. charging)
Emissions (e.g. hairspray)

Refueling/refilling (e.g. refill gas tank)
Other

Q7a: Explain (quantify if possible)

Q7 collects information on any environmental impacts that occur during the use phase of a reusable product. Using information collected about resources consumed during product reuse allows investors to determine whether the reuse of a product will be able to displace the resources consumed during primary production.

Q9: What mechanisms are used to ship your product?

Answer Choices:
- Truck
- Marine Shipment
- Air
- Train
- Other: Fill in response

Q9a. Do you know the estimated GHG emissions in kg COeq produced per order?

Answer Choices:
- Yes
- No
- Q9a1: If yes, quantify here

Q9b. What is the average number of shipping miles per order for the last year of sales?

Answer Choice: Fill in response.

Q9c. Is your company taking steps to offset emissions?

Answer Choices:
- Yes
- No

Q9c1: If yes, what steps is your company taking to offset shipping emissions?

Answer Choice: Fill in response

Q9 explores the emissions resulting from the delivery phase, as well as any offsetting programs used by the company. While a variety of emissions are released in all shipping mechanisms (e.g. NOx, SO2, particulates, etc), this tool focuses on CO2 emissions due to varied effects of additional pollutants. Marine shipment was found to result in the lowest CO2 emissions, followed by train, truck, and air transport (EEA, 2021; OECD, 1997).

Q10: Does your product produce any emissions during use?

Answer Choices:
- Yes
- No
- If yes, explain (quantify if possible)

Q10 collects information on any emissions produced during the use phase of a reusable product. Using information collected about resources consumed during product reuse allows investors to determine whether the reuse of a product will be able to displace the resources consumed during primary production.

Q12: How much energy is required to use one unit of your product one time?

Answer Choice: Fill in Response

Q12 collects information on any energy used during the use phase of a reusable product. Using information collected about resources consumed during product reuse allows investors to determine whether the reuse of a product will be able to displace the resources consumed during primary production.

Q12: Does your product require refurbishment between each use?

Answer Choices:
- Yes
- No

Q12a: If yes, what inputs are required to refurbish your product?

Answer Choice: Fill in response (N/A is acceptable)

Q12 collects information on any refurbishment or repair that is necessary during the use phase of a reusable product. Using information collected about resources consumed during product reuse allows investors to determine whether the reuse of a product will be able to displace the resources consumed during primary production.

Section 4: Environmental Section

This section collects basic environmental information for monitoring and data analysis purposes. LCA data, primary production impacts, water use, and energy use are covered in this section, along with information on those metrics for close industry competitors. This data can be used in conjunction with others for further analysis; for example, as shown in the case studies included in previous report sections, primary production values are vital in determining the net benefits of a rental model.

This section also includes a question evaluating compliance with REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulations. While this regulation only restricts companies within the European Union, compliance with REACH protocols is highly valued due to the possibility of similar regulations being enacted elsewhere.

Subsection 1: Impact

Q1. Has your company completed an LCA on your product or service?

Yes

No

Q1a. If yes, please upload

Q2. Do you know the environmental impacts of the primary production of your product or service? (in kg CO2eq or other GHG equivalent)

Yes
No
Q2a: If yes, please include here

Q3: Do you know the comparable GHG intensity of your closest industry competitor or industry average?

Q3a. If yes, please include here

Q4: Do you know the comparable water intensity of your closest industry competitor or industry average?

Q4a. If yes, please include here

Q5: Do you know the comparable energy intensity of your closest industry competitor or industry average?

Q5a. If yes, please include here

Subsection 2: Water

Q1. What is your annual water use?

Answer Choice: Fill in response (_____ liters per unit (or annual total if per unit measure does not apply)

Q2. Do you reuse water in your manufacturing process?

Answer Choices:
Yes
No

Q2a. If yes, how much water do you reuse?

Answer Choices:
0-25%
25-50%
50-75%
75-100%

Subsection 3: Toxic Chemicals

Q1. Do you use any chemicals that are listed on REACH?

Answer Choices:
Yes
No

Q1a. If yes, which ones?

Answer Choice: Fill in response

Subsection 4: Energy

Q1. What is your annual energy use (kwH)?

Answer Choice: Fill in response (_____ KwH per unit (or annual energy use if per unit measure does not apply).

Q2. Do you use renewable energy sources?

Answer Choices:
Yes
No

Q2a. If yes, which

Answer Choices:

- Geothermal
- Nuclear
- Wind
- Solar
- Other

Appendix 3: Circular Business Model Definitions

Business Model	Definition/Description	Source	R- Category
Design for Recyclability	"Implies that materials are processed out of one form and remade into a new product… involves the remanufacturing phase as its core part"	(Mayyas et al., 2012)	Recycle
Design for Remanufacturing	"To return parts and sub-assemblies to an acceptable performance level for reassembly, enabling its materials to be re-used in their highest value state, hence preventing waste and reduce the use of virgin resources"	(Mayyas et al., 2012)	Reuse
Design for Disassembly	"To ensure that a product can be disassembled at minimum cost and effort- helps to recover a larger proportion of system components"	(Mayyas et al., 2012)	Reuse
Design for Durability	"Designing products to last longer reduces both resource use and waste generation"	(Mayyas et al., 2012)	Reuse
Design to minimize material usage	"Reducing the amount of material used over the product life cycle is an effective method of reducing its environmental impact"	(Mayyas et al., 2012)	Reduce
Design for Energy Efficiency	Design for energy efficiency or the emission control	(Mayyas et al., 2012)	Reduce
Product-Service Systems (PSSs)	"A mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs"	(Tukker & Tischner, 2006)	Reuse
Product Service System (PPS)	"Satisfy consumer needs through bundles of products, services, and infrastructure, potentially decoupling needs satisfaction from resource consumption"	(Tunn et al., 2021)	Reuse
Access-based product-service	Rental, leasing, or sharing system	(Tunn et al.,	Reuse

system (AB_PPS)		2021)	
Maximize material productivity and energy efficiency	"Do more with fewer resources, generating less waste, emissions, and pollution"	(Bocken et al., 2014)	Reduce
Substitute with renewables and natural resources	"Reduce environmental impacts and increase business resiliency by addressing resource constraints 'limits to growth' associated with non-renewable resources and current production systems"	(Bocken et al., 2014)	Reduce
Deliver function, rather than ownership	"Provide services that satisfy user needs without users having to own physical products"	(Bocken et al., 2018)	Reuse
Encourage sufficiency	"Solutions that actively seek to reduce consumption and production"	(Bocken et al., 2014)	Reuse, Reduce, Recycle
Create value from waste	"The concept of 'waste' is eliminated by turning existing waste streams into useful and valuable input to other production"	(Bocken et al., 2018)	Recycle
Reduce	"Continually cut down on the amount of natural resources used, the waste generated, the environmental damage done, and the amount of greenhouse gasses emitted"	(Gonen, 2021)	Reduce
Reuse	"Build for durability so products and their packaging can recirculate to new users, with little or no refurbishment"	(Gonen, 2021)	Reuse
Remake	"Repair, refurbish, and more substantially remanufacture"	(Gonen, 2021)	Reuse
Recover	"Design products for easy disassembly and repurposing of materials, and develop "reverse logistics" by which manufacturers and retailers take their products back for either refurbishment and resale or recycling"	(Gonen, 2021)	Reuse

Renew	"Use only renewable energy, work with regenerative methods of production, and construct the built environment so that it actually replenishes resources"	(Gonen, 2021)	Reduce
Slowing Resource Loops	"Through the design of long-life goods and product-life extension (i.e. service loops to extend a product's life, for instance through repair, remanufacturing), the utilization period of products is extended and/or intensified, resulting in a slowdown of the flow of resources"	(Bocken et al., 2016)	Reuse
Closing Resource Loops	"Through recycling the loop between post-use and production is closed, resulting in a circular flow of resources"	(Bocken et al., 2016)	Recycle

Bibliography

Amutha, K. (2017). 2—Environmental impacts of denim. In S. S. Muthu (Ed.), *Sustainability in Denim* (pp. 27–48). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-102043-2.00002-2

Antikainen, M., & Valkokari, K. (2016). A Framework for Sustainable Circular Business Model Innovation. *Technology Innovation Management Review*, *6*(7), 5–12.

ASTM. (n.d.). *Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities*. Retrieved February 16, 2022, from https://www.astm.org/d6400-21.html

Atherton, J. (2007). Declaration by the Metals Industry on Recycling Principles. *The International Journal of Life Cycle Assessment*, *12*(1), 59–60. https://doi.org/10.1065/lca2006.11.283

Bagstad, K. J., Semmens, D. J., Waage, S., & Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, *5*, 27–39. https://doi.org/10.1016/j.ecoser.2013.07.004

Bianchi, M. (2019, August 14). *Recycling Is Broken. Now What? - Patagonia*. https://www.patagonia.com/stories/recycling-is-broken-now-what/story-73479.html

Biron, M. (2020). 11 - Plastics Sustainability: Drivers and Obstacles. In M. Biron (Ed.), *A Practical Guide to Plastics Sustainability* (pp. 557–593). William Andrew Publishing. https://doi.org/10.1016/B978-0-12-821539-5.00011-2

Blackler, C., Denbow, R., Levine, W., Nemsick, K., & Polk, R. (1995). *A Comparative Analysis of Perc Dry Cleaning and an Alternative Wet Cleaning Process*.

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N. M. P., Schuit, C. S. C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, *28*, 79–95. https://doi.org/10.1016/j.eist.2018.02.001

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). *A literature and practice review to develop sustainable business model archetypes | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.jclepro.2013.11.039

BPI. (n.d.). *BPI Commercial Compostability Certification Scheme -2.3*. 26.

Brest, P., & Born, K. (2013, September 30). *When Can Impact Investing Create Real Impact*. Stanford Social Innovation Review. https://law.stanford.edu/publications/when-can-impact-investing-create-real-impact/

Clean Production Action. (2007, March 2). *How Producer Responsibility for Product Take-Back Can Promote Eco-Design: Joint Statement by a Group of Industry and NGOs on Producer Responsibility for Waste Electrical and Electronic Equipment*.

https://www.cleanproduction.org/static/ee_images/uploads/resources/EPR_ecodesign_Apr08.pdf

Corvellec, H., Stowell, A., & Johansson, N. (2021). Critiques of the circular economy. *Journal of Industrial Ecology*. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-299935

Cradle to Cradle Products Innovation Institute. (2021). *MATERIAL HEALTH CERTIFICATE STANDARD, VERSION 4.0*. https://cdn.c2ccertified.org/resources/certification/standard/STD_Material_Health_Certificate_Standard_FINAL_031621.pdf

cranetool.org. (2022). *CRANE*. https://cranetool.org/

Department of Energy. (2021). *DOE Awards $20 Million to Help States Deploy Carbon Capture and Storage*. Energy.Gov. https://www.energy.gov/articles/doe-awards-20-million-help-states-deploy-carbon-capture-and-storage

Dissanayake, D. G. K., & Weerasinghe, D. (2021). Towards Circular Economy in Fashion: Review of Strategies, Barriers and Enablers. *Circular Economy and Sustainability*. https://doi.org/10.1007/s43615-021-00090-5

EEA. (2021). *Rail and waterborne—Best for low-carbon motorised transport—European Environment Agency*. https://www.eea.europa.eu/publications/rail-and-waterborne-transport

Ekvall, T., & Finnveden, G. (2001). Allocation in ISO 14041—A critical review. *Journal of Cleaner Production*, *9*(3), 197–208. https://doi.org/10.1016/S0959-6526(00)00052-4

Ellen MacArthur Foundation. (2017). *The Circular Economy In Detail*. https://archive.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail?gclid=Cj0KCQjwub-HBhCyARIsAPctr7yalTS2IySU8ckFUyHlLRezVLZM6s8AonpbbxXQaU-9edgnjtWZRigaAmb6EALw_wcB

Ellen MacArthur Foundation. (2022). *Material Circularity Indicator (MCI)*. https://ellenmacarthurfoundation.org/material-circularity-indicator

EPA. (2005). *Reducing Air Pollution from Dry Cleaning Operations*. 3.

Esposito, M., Tse, T., & Soufani, K. (2018). Introducing a Circular Economy: New Thinking with New Managerial and Policy Implications. *California Management Review*, *60*(3), 5–19. https://doi.org/10.1177/0008125618764691

Federal Trade Commission. (2012). *Guides for the Use of Environmental Marketing Claims*. https://www.ftc.gov/sites/default/files/documents/federal_register_notices/guides-use-environmental-marketing-claims-green-guides/greenguidesfrn.pdf

Figge, F., Thorpe, A. S., Givry, P., Canning, L., & Franklin-Johnson, E. (2018). Longevity and Circularity as Indicators of Eco-Efficient Resource Use in the Circular Economy. *Ecological Economics*, *150*, 297–306. https://doi.org/10.1016/j.ecolecon.2018.04.030

Geissdoerfer, M., Pieroni, M. P. P., Pigosso, D. C. A., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, *277*, 123741. https://doi.org/10.1016/j.jclepro.2020.123741

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving "leapfrog development." *International Journal of Sustainable Development and World Ecology - INT J SUSTAIN DEV WORLD ECOL*, *15*, 231–239. https://doi.org/10.3843/SusDev.15.3:6

Geyer, R. (2022). *The Business of Less: The Role of Companies and Households on a Planet in Peril*.

Going all in: USGBC creates net zero certification | U.S. Green Building Council. (n.d.). Retrieved July 28, 2021, from https://www.usgbc.org/articles/going-all-usgbc-creates-net-zero-certification

Gonen, R. (2021). *The Waste-Free World: How the Circular Economy Will Take Less, Make More, and Save the Planet*. Penguin Random House.

Goyal, S., Esposito, M., & Kapoor, A. (2018). Circular economy business models in developing economies: Lessons from India on reduce, recycle, and reuse paradigms. *Thunderbird International Business Review*, *60*(5), 729–740. https://doi.org/10.1002/tie.21883

Greene, J. (2007). Biodegradation of Compostable Plastics in Green Yard-Waste Compost Environment. *Journal of Polymers and the Environment*, *15*(4), 269–273. https://doi.org/10.1007/s10924-007-0068-1

Ingemarsdotter, E. K. (2021). *Circular Strategies Enabled by the Internet of Things: Opportunities, Implementation Challenges, and Environmental Impact* [Dissertation (TU Delft)]. https://doi.org/10.4233/uuid:9ac826a1-2203-4f23-b074-3d765abd73e3

Ismayilova, A., & Silvius, A. J. G. (2021). Cradle-to-Cradle in Project Management: A Case Study. *International Journal of Circular Economy and Waste Management*, *1*, 1–27. https://doi.org/10.4018/IJCEWM.20210101.oa1

Jang, Y.-C., Lee, G., Kwon, Y., Lim, J., & Jeong, J. (2020). Recycling and management practices of plastic packaging waste towards a circular economy in South Korea. *Resources, Conservation and Recycling*, *158*, 104798. https://doi.org/10.1016/j.resconrec.2020.104798

Kerdlap, P., Gheewala, S., & Ramakrishna, S. (2021). To Rent or Not to Rent: A Question of Circular Prams from a Life Cycle Perspective. *Sustainable Production and Consumption*, *26*, 331–342. https://doi.org/10.1016/j.spc.2020.10.008

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kok, L., Wurpel, G., & Ten Wolde, A. (2013). *Unleashing the Power of the Circular Economy*. https://www.osti.gov/etdeweb/biblio/22174941

Lerner, J., & Tåg, J. (2013). Institutions and venture capital. *Industrial and Corporate Change*, *22*(1), 153–182. https://doi.org/10.1093/icc/dts050

Li, J.-J., Xu, C., Fung, H.-G., & Chan, K. C. (2021). Do venture capital firms promote corporate social responsibility? *International Review of Economics & Finance*, *71*, 718–732. https://doi.org/10.1016/j.iref.2020.10.012

Mathews, J., & Tan, H. (2016). Circular economy: Lessons from China. *Nature*, *531*, 440–442. https://doi.org/10.1038/531440a

Mayyas, A., Qattawi, A., Omar, M., & Shan, D. (2012). *Design for sustainability in automotive industry: A comprehensive review | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.rser.2012.01.012

Millar, S. A., Walker, J.-C., & Rahman, A. N. (2021). California Governor Newsom Signs Laws Affecting Environmental Marketing Claims. *The National Law Review*. https://www.natlawreview.com/article/california-governor-newsom-signs-laws-affecting-environmental-marketing-claims

Muthu, S. S. (2015). 5—Environmental impacts of the use phase of the clothing life cycle. In S. S. Muthu (Ed.), *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing* (pp. 93–102). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100169-1.00005-8

Nußholz, J. L. K. (2017). Circular Business Models: Defining a Concept and Framing an Emerging Research Field. *Sustainability*, *9*(10), 1810. https://doi.org/10.3390/su9101810

OECD. (1997). *THE ENVIRONMENTAL EFFECTS OF FREIGHT*. https://www.oecd.org/environment/envtrade/2386636.pdf

OECD. (2014). *The State of Play on Extended Producer Responsibility (EPR): Opportunities and Challenges*. OECD. https://doi.org/10.1787/9789264189867-en

Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Business model innovation for circular economy and sustainability: A review of approaches. *Journal of Cleaner Production*, *215*, 198–216. https://doi.org/10.1016/j.jclepro.2019.01.036

Ranta, V., Aarikka-Stenroos, L., & Mäkinen, S. J. (2018). Creating value in the circular economy: A structured multiple-case analysis of business models. *Journal of Cleaner Production*, *201*, 988–1000. https://doi.org/10.1016/j.jclepro.2018.08.072

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Renttherunway.com. (n.d.). Rent the Runway. Retrieved March 14, 2022, from https://www.renttherunway.com/sustainable-fashion

Rogoff, M. J. (2014). 3—Collection Approaches. In M. J. Rogoff (Ed.), *Solid Waste Recycling and Processing (Second Edition)* (pp. 19–42). William Andrew Publishing. https://doi.org/10.1016/B978-1-4557-3192-3.00003-8

Saidani, M., Yannou, B., Leroy, Y., & Cluzel, F. (2017). How to Assess Product Performance in the Circular Economy? Proposed Requirements for the Design of a Circularity Measurement Framework. *Recycling*, *2*(1), 6. https://doi.org/10.3390/recycling2010006

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A taxonomy of circular economy indicators. *Journal of Cleaner Production*, *207*, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014

Silviera, R., Wright, R., Helwig, C., & Manovskii, I. (2006). *The Venture Capital Cycle*.

Smith, M. (2019, June 19). After collecting 2 billion pounds of e-waste, Best Buy expands recycling program. *Best Buy Corporate News and Information*. https://corporate.bestbuy.com/after-collecting-2-billion-pounds-of-e-waste-best-buy-expands-recycling-program/

Tabuchi, H., & Choi-Schagrin, W. (2021, September 9). California Aims to Ban Recycling Symbols on Things That Aren't Recyclable. *The New York Times*. https://www.nytimes.com/2021/09/08/climate/recycling-california.html

Tukker, A., & Tischner, U. (2006). Product-services as a research field: Past, present and future. Reflections from a decade of research. *Journal of Cleaner Production*, *14*(17), 1552–1556. https://doi.org/10.1016/j.jclepro.2006.01.022

Tunn, V. S. C., Van den Hende, E. A., Bocken, N. M. P., & Schoormans, J. P. L. (2021, April 19). *Consumer adoption of access-based product-service systems: The influence of duration of use and type of product | EndNote Click*. https://click.endnote.com/viewer?doi=10.1002%2Fbse.2894&token=WzMwNTI2NzAsIjEwLjEwMDIvYnNlLjI4OTQiXQ.HqrhR_4GF-vI-CsCBTBH1_dIrAg

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, *168*, 487–498. https://doi.org/10.1016/j.jclepro.2017.09.047

US EPA, O. (2016, January 12). *Global Greenhouse Gas Emissions Data* [Overviews and Factsheets]. US EPA. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Value of U.S. venture capital investment 1995-2020. (n.d.). Statista. Retrieved January 17, 2022, from https://www.statista.com/statistics/277501/venture-capital-amount-invested-in-the-united-states-since-1995/

Viviani, J.-L., & Maurel, C. (2019). Performance of impact investing: A value creation approach. *Research in International Business and Finance*, *47*, 31–39. https://doi.org/10.1016/j.ribaf.2018.01.001

Walzberg, J., Lonca, G., Hanes, R. J., Eberle, A. L., Carpenter, A., & Heath, G. A. (2021). Do We Need a New Sustainability Assessment Method for the Circular Economy? A Critical Literature Review. *Frontiers in Sustainability*, *1*. https://www.frontiersin.org/article/10.3389/frsus.2020.620047

Whittaker, I. (2018). *Is SpaceX Being Environmentally Responsible?* Smithsonian Magazine. https://www.smithsonianmag.com/science-nature/spacex-environmentally-responsible-180968098/

Yong, R. (2007). The circular economy in China. *Journal of Material Cycles and Waste Management*, *9*, 121–129. https://doi.org/10.1007/s10163-007-0183-z

Zaks, I. (2019, April 1). *InVEST* [Text]. Natural Capital Project. https://naturalcapitalproject.stanford.edu/software/invest

Zider, B. (1998, November 1). How Venture Capital Works. *Harvard Business Review*.

https://hbr.org/1998/11/how-venture-capital-works

Zink, T., & Geyer, R. (2017). Circular Economy Rebound. *Journal of Industrial Ecology*, *21*(3), 593–602. https://doi.org/10.1111/jiec.12545

Zink, T., Geyer, R., & Startz, R. (2016). A Market-Based Framework for Quantifying Displaced Production from Recycling or Reuse. *Journal of Industrial Ecology*, *20*(4), 719–729. https://doi.org/10.1111/jiec.12317