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POST-INDUSTRIAL TEXTILE RECOVERY FOR LA SANITATION AND ENVIRONMENT

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Table of Contents

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Table of Contents

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Section 1:
Background & Methodology

1. Glossary

Agrotextiles are technical fabrics used for agriculture, horticulture, gardening, and construction. They protect crops against weather, help conserve water, resist solar radiation, and guard against microorganisms. They are high-strength textiles and do not wear out easily. They can be made from a number of textile types including viscose, cotton, wool, as well as plastic, and plastic composites. Mulch mats and crop nets are examples of agrotextiles.

Apparel manufacturing refers to the process of creating garments and clothing items from raw materials such as fabrics, fibers, and other components.

Business-as-usual (BAU) refers to the current practices, systems, and processes related to textile production, consumption, and disposal, which operate without significant efforts to promote sustainability, circularity, or waste reduction.

Carbon dioxide equivalent (CO_2e) is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

Cut-and-sew garment manufacturing is the process of cutting fabric pieces to specific shapes and patterns, then sewing them together to create the final garment. There are a number of cut-and-sew shops in the LA Fashion District that can offer both full and limited garment manufacturing services.

Deadstock refers to excess or leftover fabric from textile production or manufacturing that is unused and typically sold off at discounted prices to reduce waste.

Economic (workforce) development refers to a human centric approach to economic development, through the training and employment of residents, as a means to support the local economy.

Environmental justice (EJ) ensures the equitable treatment and inclusion of all individuals in governmental decisions impacting both human health and the environment, irrespective of socioeconomic status, race, ethnicity, national origin, tribal affiliation, or disability. Minorities and low-income individuals most often make up EJ communities.

Extended producer responsibility (EPR) is an environmentally centric policy approach and framework that seeks to hold producers accountable for the full life cycle of the products they produce, including product end-of-life. EPR bills seek to leverage incentives and penalties to shift producer behavior towards more responsible production.

Global warming potential (GWP) is a term used to describe the relative potency, molecule for molecule, of a greenhouse gas, taking into account how long it remains active in the atmosphere. GWPs were developed for comparisons between the global warming impacts of different gases. Specifically, GWP is a measure of how much energy the emissions of one ton of a gas will absorb over a given period of time, relative to the emissions of one ton of carbon dioxide (CO_2). The current GWP is calculated over a 100 year time horizon.

Greenhouse gas (GHG) is a gas that traps heat in the atmosphere. It includes gases like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Geotextiles are a type of agrotextile and are primarily used to protect soil and prevent weeds from growing. Farmers use geotextiles to separate crops and reinforce boundaries. They can be made from natural and synthetic materials, and can be manufactured as woven, non-woven, and knitted textiles. Geotextiles are increasingly using greater amounts of recycled content in their production process.

Hangers / Headers are small pieces of fabric typically attached to a card or swatch book that displays information about the fabric. It usually includes details such as the fabric type, composition, color, pattern, and any other relevant specifications. Fabric headers are commonly used in the textile industry for showcasing fabric samples to potential buyers, designers, or clients, allowing them to evaluate the fabric's characteristics and make informed decisions about its suitability for their projects.

HIGG Index is a comprehensive global framework for measuring environmental and sustainability performance in the textile industry supply chain. It was developed by Cascale, a global non-profit alliance of 300 leading consumer brands, retailers, manufacturers, sourcing agents, service providers, trade associations, NGOs, and academic institutions, in collaboration with its multi-stakeholder membership.

Hub has two meanings throughout this report. It refers to a "Textile Circularity Hub"or "HUB" document, provided by the client and created in partnership with California Product Stewardship Council. This hub organizes the information of current and potential pilot partners by the role they fulfill within the circular ecosystem (ie. generators, sorters, recyclers, etc.). Additionally, the term also refers to a physical space, proposed by LASAN for the purpose of housing their textile sorting operations.

International Organization for Standardization 2400 (ISO 2400) establishes international manufacturing facility standards and best practices.

Jobbers are individuals who recover fabric and deadstock from textile manufacturers and resell the materials to retailers and designers. Jobbers are part of the informal sector and work with generators, sorters, and other businesses.

Just transition is a term that encompasses the understanding that minority communities are most vulnerable to the effects of climate change, and all efforts to address sustainable solutions must be addressed equitably and justly. Furthermore, in seeking to "green" the economy, those most vulnerable should be at the forefront of green job opportunities.

Life cycle analysis (LCA) is a systematic analysis of the environmental impact of a product, material, process, or other measurable activity over the course of the entire product, process, or activity's life cycle.

Material recovery facility (MRF) is a plant that receives recyclable materials from residential and/or commercial sources. Workers and machines separate and sort these materials to sell as commodities, like cardboard, glass, and aluminum.

Open-loop is a circular system where textiles are either reused, upcycled, or recycled. The textiles can remain in the apparel industry to be used in their current state, or be redirected to an alternate industry. In an open-loop system, it is assumed the life of the original textile is extended without much processing beyond the possibility of shredding for an alternative use case.

Closed-loop is a textile-to-textile recycling circular system. In closed-loop systems, textiles are either mechanically or chemically recycled into new textiles. Original fiber type, along with recycling technology, will dictate if the new fiber must be blended with virgin fibers or if it can maintain a tensile strength comparable to virgin fibers.

Post-consumer textile waste is any discarded or unused textile fabric or clothing from a consumer. This type of textile waste typically consists of finished garments and is the last life cycle stage of textile waste. It is discarded by the consumer through donation, upcycling, or throwing away.

Post-industrial textile waste encompasses scraps, cutoffs, and deadstock fabric used in the manufacturing process of a garment. This type of textile waste can, in theory, be easier to recycle than post-consumer waste as there are no features like buttons or zippers that need to be removed prior to recycling.

Volatile organic compounds (VOCs) are gases emitted from solids or liquids. They contain a variety of chemicals and may have adverse health risks if inhaled on a regular basis. Concentrations of VOCs are consistently higher in indoor environments, where the gases don't have an opportunity to dissipate. Examples of VOCs include benzene, ethylene, glycol, and formaldehyde, all chemicals that may be present during textile production.

2. Executive Summary

This report explores opportunities for textile circularity within the city of Los Angeles. It was created for the Pollution Prevention Team within the Industrial Waste Management Division of LA Sanitation and Environment (LASAN). LASAN's primary responsibility is to collect, clean and recycle solid and liquid waste generated by residential, commercial, and industrial users in the city of LA and surrounding communities.

LA is home to the largest garment manufacturing base in the United States. This industry is responsible for a large portion of the industrial waste stream, which is managed by LASAN. Presently, the waste produced by LA's garment manufacturing industry is almost exclusively directed to landfills. In response to several environmental regulations, including the Los Angeles County Zero Waste Plan, the city is attempting to divert such waste away from landfills. This has created an opportunity for the city to develop a circular textile ecosystem, so that discarded items may instead be recycled. In attempts to create a circular economy for the waste generated by textile production in LA, LASAN began work on a Textile Recovery Pilot Program in 2020. At the time of writing, LASAN has successfully completed Phase I of this pilot and is nearing completion of Phase II. With a total of four phases, this Textile Recovery Pilot Program's ultimate goal is to find alternate end-of-life options for the textile waste generated in the city.

Our work with LASAN began during Phase II of their pilot. We were tasked with assisting LASAN as they advance through their remaining stages and create a centralized textile recovery ecosystem in LA. This report explores our work by first providing details on the LA textile landscape and its stakeholders, including the opportunities and challenges associated with the current capacity for textile recovery. We then discussed the research conducted by our team as we developed a final set of tools and guides.

While conducting our research, we found that there are certain challenges to overcome in the development of a circular system, which our tools and guides seek to address. With the compilation of textile recovery case studies, we provide a view of the current landscape, along with snapshots of industry success, industry failure, and potential future partnerships. Our analysis of circular mapping and pathways provides an idea of how organizations such as those examined for our case studies could play a role in LASAN's textile recovery ecosystem, and how they impact certain development considerations. The Greenhouse Gas Emissions Estimator provides LASAN with a means of calculating emissions avoided and created, and to compare circular scenarios to existing systems. Finally, the Industrial Ecosystem Database and Dashboard is a repository of contact information and material flow capabilities of actors and stakeholders in the textile industry.

We intend for these tools and guides to be used by LASAN in the pursuit of creating an operational, circular landscape.

3. Introduction

3.1. Summary

As California continues to lead the nation with ambitious environmental goals and regulations, the urgency to address greenhouse gas emissions (GHG), environmental justice concerns, and negative environmental impacts produced by LA's textile industry is building. LASAN has made a significant effort to introduce upcycling as an alternative to landfill. Despite their progress, the city still generates much more textile waste than upcyclers can handle.

LASAN has developed a pilot project to build a circular textile recovery ecosystem for post-industrial textile waste. With the research and recommendations outlined in this report, our Capstone will support the scaling of LASAN's pilot project through suggestions for industry partners, identification of GHG emissions avoided by creating a successful circular system, and identification of ecosystem actors and their capacities to participate in this proposed system.

3.2. LA Landscape

3.2.1. Current System (Linear and Fragmented)

Los Angeles is the center of garment manufacturing in the United States and a key node for the mid- to low-end of the fashion industry (Kim, 2022). Between 2,500-4,000 companies and contractors operate in LA's Fashion District including spinners, fabric producers, and garment factories (cut-and-sew shops) (Kim, 2022; Garment Worker Center, 2020). The production process generates scraps, cutoffs, deadstock, incomplete garments, and other textile waste that is not typically sold. These textile items are collected from factory floors, put into bins, and enter the city's waste stream.

From 2019-2021, the City of Los Angeles gathered and analyzed waste management data and found that textiles were responsible for 6% of the total commercial waste stream and 2% of the recycling stream by weight (LASAN, 2022). For comparison, the state of California estimates that 2.9% of its commercial waste stream is made up of textiles. Almost one-third of LA's commercial textile waste comes from the fashion industry: about half of which is fabric scrap, a quarter is canceled or incomplete garments, and the remainder is deadstock fabric headers. The fiber content of this stream is diverse and often difficult to identify, as most fabrics are a blend of multiple fiber types and may also have been treated with chemicals.

When city residents place items into blue bins for collection, textiles enter the municipal waste stream. Blue-bin waste is transported to material recovery facilities (MRF), where textiles are sorted out from recyclables and ultimately transported to landfills. Private haulers collect commercial and industrial black-bin waste which is transported directly to landfills.

Disposing of waste through incineration or landfilling produces harmful GHGs and does not offer the possibility of extended use through reuse or recycling.

3.2.2. Stakeholders

There are five key stakeholders involved in the development of a circular textile system in LA: the government, the fashion industry, the recycling/reuse industry, nongovernmental organizations (NGOs), and the local community. The local government (LASAN) lays the groundwork for transporting materials from generators to sorters and recyclers. The government must also provide incentives and/or penalties to motivate the fashion industry to take responsibility for textile waste.

Large fashion brands and retailers must lead the fashion industry in circularity by increasing investment in textile recycling technology and committing to the purchase of recycled fibers. These investments will enable manufacturers to more easily transition to recycled fibers and facilitate the growth of the recycling industry. Currently, LA-based manufacturers and recycling businesses are at a competitive disadvantage, partly due to the high cost of rent and wages.

NGOs have an important role to play in research, advising, and funding the transition to a circular system. They also play a key role in information sharing and creating neutral spaces for collaboration between stakeholders.

The fifth stakeholder is the community and residents of LA. It is important to have their buy-in when planning new waste collection sites. In the past, LA residents have shown their ability to derail city-proposed initiatives, thereby highlighting the necessity for community approval. Additionally, the proposed textile waste collection system must not aggravate existing public health and safety inequities.

A more detailed explanation of each stakeholder type, their goals and challenges are outlined in the table below.

Stakeholder type	Stakeholder	Current involvement in textile recovery system	Core interests relating to circularity	Stakeholder actions needed for textile recovery system	Benefits for stakeholder	Challenges for stakeholder
Government	**California State government**	Setting environmental and climate targets	GHG emissions reduction, economic development, waste diversion	Develop incentives and/or penalties to motivate brand participation, provide support for generators to make the transition	GHG emissions reduction, economic development, waste diversion	Additional monitoring and enforcement
	Los Angeles City government: LA Sanitation	Leading the project for a textile recovery hub	Waste diversion, GHG emissions reduction, economic development	Build relationships with other stakeholders and implement programs for textile collection and processing	Waste diversion, GHG emissions reduction, economic development	Implementation of a new program, additional monitoring and enforcement
Fashion Industry	**Brands and retailers**	Investment in textile recycling technology, post-consumer waste collection	Brand reputation, GHG emissions reduction, waste diversion	Make long-term purchasing agreements for textiles made of recycled fibers, increase investment in technology, invest in LA manufacturing	Improve sustainability and show progress towards sustainability goals, brand reputation	Little incentive to change business-as-usual, raw materials are cheaper, secondary materials are of an unknown quality and quantity.
	Manufacturers (aka Generators, LA-based): textile and apparel manufacturing companies	Minimal, aside from eco-branded companies and CPSC Pilot participants	Reduce waste hauling costs, improving environmental sustainability	Comply with new sorting/waste standards	Reduce waste hauling costs, improving environmental sustainability	Workflow and process changes may affect business viability
	Garment workers and worker groups (LA-based): e.g., Garment Worker Center	None	Fair pay, job security, workers and immigrant rights	Comply with new sorting/waste standards	New job roles for aging workforce (sorting, debranding)	Keeping waste separated could create additional work during the production process

Table 1: Stakeholder table (Hsiung, 2024)

Stakeholder type	Stakeholder	Current involvement in textile recovery system	Core interests relating to circularity	Stakeholder actions needed for textile recovery system	Benefits for stakeholder	Challenges for stakeholder
Recycling/ Reuse Industry	**Collectors and sorters**: e.g., Homeboy Threads, jobbers	Collecting, sorting and preprocessing textiles for recycling and export to secondhand markets	More regional recyclers and off takers to purchase secondary materials	Scale as system grows	Business growth	Economic viability as the system scales slowly
	Upcyclers: Designers, schools	Small scale textile reuse	Access to deadstock, remnants, trim, etc.	Build awareness of potential for textile reuse	Access to deadstock, remnants, trim, etc.	None
	Recyclers: e.g., Ambercycle	Providing mechanical and chemical recycling services	More brand and off taker purchasing agreements, more funding for technology development, steady supply of waste material with high purity	Accept more fiber types and blends, expand to West coast	Business growth	Environmental regulations and location costs in LA/California
	End Products: Product manufacturers that use the recycled materials as feedstock	Purchasing materials from recyclers	Steady supply of recycled materials	Increased participation and use of recycled materials	Improve business sustainability, brand reputation	Cost of developing production processes that utilize recycled materials
NGOs	**Zero waste and circular groups** like CA Product Stewardship Council, incubators like LACI, universities	As consultants, researchers, funders, incubators. Some financial support.	Supporting the development of a more sustainable economy	Create spaces for stakeholders to share knowledge and collaborate, assist with community engagement	Advance their mission and enable them to garner more support	None
Local Community	**Residents and workers** in the Fashion District	None	Public health and safety	Understand and support the new system	Less waste	Location of textile hub and transport routes (to minimize traffic and pollution)

Table 1 cont'd: Stakeholder table (Hsiung, 2024)

3.2.3. Pressures

The textile recycling market is expanding due to environmental concerns, rising awareness around sustainable fashion, and the need to reduce textile waste. In the last decade, there has been a substantial increase in sustainable fashion trends, with the circular economy helping to increase the demand for recycled textile goods (Schumacher & Forster, 2022). Many companies have implemented take-back programs and upcycling workshops to engage consumers in garment recycling and promote circular fashion.

The apparel industry accounts for nearly 10-15% of the world's carbon dioxide emissions, and textile production and manufacturing are the main contributors to these emissions *(Environmental Sustainability in the Fashion Industry,* n.d.). With the rise of fast-fashion, textiles have become the fastest-growing component of California's landfills, comprising 3% of total landfill waste and representing the fifth-largest material contribution overall (Newman, 2023). Every year, approximately 1.2 million tons of textile waste are disposed of in California, including clothing, footwear, linens, towels, and other fabrics (***Laundry and Textile Management***, n.d.). In fact, "textiles have been identified as a top material, and the fastest growing category, in residential and commercial waste streams in California" (Newman, 2023).

The city of Los Angeles is also facing legislative pressures to reduce textile waste, with recently proposed regulations prioritizing this type of waste. One such bill introduced by California Senator Josh Newman is SB 707, which aims to create a statewide collection and recycling program for textiles. Under this bill, textile manufacturers would have to implement and fund an extended producer responsibility program (EPR) to enhance recycling and encourage reuse. SB 707 is sponsored by the California Product Stewardship Council (CPSC), a network conglomerate of local governments, as well as non-governmental organizations, businesses, and individuals who support policies and projects focused on producers sharing responsibility for managing problem products at their end of life (*CPSC,* n.d.).

Pending legislation, such as SB 707, offers a glimmer of hope in the struggle to divert textile waste from landfills, potentially catalyzing businesses in the textile and apparel industry to embrace recycled materials in their products. However, despite this potential, the volume of textile waste generated in Los Angeles surpasses the industry's processing capacity, underscoring the critical need for improved infrastructure and efficient supply chain models to address this pressing issue effectively.

3.2.4. Opportunities

California is frequently recognized as a leader in the United States for its progressive environmental and climate action policies. Los Angeles has the opportunity to position itself as a frontrunner in textile waste recovery by effectively implementing a circular system. A citywide goal to reduce GHG emissions by 40% by 2030 further drives the need for a circular system (*A Greater LA: Climate Action Framework,* n.d.). The ambitious plan to establish a multi-resource textile recycling hub in the heart of Los Angeles presents significant environmental, economic, and social opportunities.

Transforming the textile industry into a circular system can create an economy that gives value to items which are currently disposed of as waste. The current linear system leaves unexplored economic opportunities and creates numerous negative externalities in terms of social and environmental impacts. These externalities include, but are not limited to, pollution (microplastics, chemical runoff, ecotoxicity, etc.), violations of basic human rights, and overconsumption, leading to vast amounts of textiles in landfills (Theivagt, 2021). A circular model can divert textiles from landfills, extend product-use, and create new workforce opportunities.

Textile recycling creates several environmental benefits, such as reducing land and water pollution, minimizing dependence on virgin fibers, lowering the usage of chemical dyes, and conserving energy and water (Global Research and Insights, 2023). Textile recycling also has the potential for economic and social benefits, through the creation of jobs in the textile industry. Furthermore, by diverting textile waste from landfills, businesses can save on the costs associated with discarding textiles. This diversion also helps reduce disposal costs for local governments, businesses, and residents (New York State Department of Environmental Conservation, n.d.).

Lastly, advancements in textile recycling technologies can change the market by improving and enabling more efficient, effective processes for recycling textile waste. These advancements can reduce energy consumption and processing time while maximizing material recovery rates (Pioneering Marketdigits Consulting and Advisory Private Limited, 2024). Optimizing resource utilization, minimizing waste generation, and reducing reliance on raw materials can also create cost-saving opportunities.

3.3. Client Information

3.3.1. Background

LASAN is a government agency and public municipality responsible for collecting, treating, and recycling solid waste and wastewater generated by residents, businesses, and industries in Los Angeles and surrounding communities (LA Sanitation and Environment, n.d.-a). LASAN protects public health and the environment while enhancing the quality of life in LA neighborhoods through its four program areas: Solid Resources, Clean Water, Watershed Protection, and Environmental Quality.

LASAN introduced the LA Industry Program, a pioneering initiative focused on pollution prevention and fostering collaborative partnerships with industries, with the ultimate goal of combating escalating waste in the city. With a commitment to environmental sustainability, the LA Industry Program champions sustainable manufacturing principles such as green chemistry and biomimicry, striving toward a zero-waste circular economy. Through outreach symposia and extensive engagement efforts across diverse sectors, including food manufacturing, microbreweries, and construction, the LA Industry Program has successfully advocated for responsible waste management practices while supporting business growth and regulatory compliance.

Expanding on this initiative, LASAN's LA Industry team formed a strategic partnership with the CPSC on a four-phase textile recovery pilot project in 2022. The pilot addresses the mounting challenges of textile waste in Los Angeles by creating a centralized hub where material byproducts from businesses can be repurposed rather than directed to landfills. The "hub" aims to create a centralized system for managing and repurposing textile waste in Los Angeles. This centralized system will function as a local closed-loop marketplace promoting a circular economy by providing stable and consistent material streams for reuse or recycling.

Phase I of the pilot project, which ran from 2020-2022, focused on mapping and interviewing local textile diversion companies, analyzing textile waste data, generating a list of commercial textile generators, identifying sources and fiber content of commercial textile waste, and establishing processes to manage unwanted textiles (LA Sanitation and Environment, n.d.-a). The pilot provided examples of waste that was successfully upcycled, recycled, and composted. Key takeaways include the need for a centralized textile-hub location in LA, improved education and outreach, and the need to overcome challenges related to material collection, transportation, and contamination.

3.3.2. Current Project Status

Building on the success and learnings from Phase I, we were tasked with assisting in LASAN's development and execution of Phase II of the textile recovery pilot, which began in May 2023 and is set to wrap in June 2024. The goals of this phase were largely to demonstrate proof of concept for a circular textile recovery system in LA through testing different sorting technologies, securing a sorting site, optimizing collection from generators, and forming an expert working group. This group will play a critical role in helping refine the textile hub's operational model, identify opportunities for innovation and collaboration, and promote adopting best practices for textile recycling and upcycling.

After the conclusion of our project, LASAN will move into Phase III of its pilot program, which will leverage additional funding and partnerships to secure a location for its centralized hub and develop its operational plan. This program has the potential to establish LA as a leader in textile waste recovery, and to serve as a model for other cities worldwide.

3.4. Circular Textile Ecosystem

To understand a circular economy, one must first examine how the global economy functions. While much of the industrialized world is focused on growth, endless production, and increased gross domestic product, our planet's supply of natural resources is being extracted and utilized at an unsustainable rate.

The life cycle of a natural textile fiber often starts on a farm, in the harvesting of commodities such as cotton. Conversely, synthetic fibers are derived from oil, which must be extracted from land or the sea. The raw materials are then formed into yarns and knitted or woven into fabric by textile mills. Once in fabric form, they are distributed to industrial manufacturers and cut-and-sew factories for commercial production. Final goods are sold to consumers in a wide variety of industries, from fashion to automotive to agriculture, and discarded as waste after consumption. At each step in the life cycle, chemicals, water, and energy are used, and harmful GHG emissions are released into the environment.

The current system for designing, producing, distributing, and using textiles functions as a linear economy, one in which large quantities of nonrenewable resources are extracted to create textiles that often have a life of a year or less, after which they are discarded to landfill (EAT, 2015). This system puts immense pressures on our natural resources by polluting and degrading the environment. It creates significant negative economic and social impacts at local, regional, and global scales, and can adversely affect community health and well-being. Estimates show that the textile industry relies on 98 million tons of nonrenewable resources annually to produce synthetic fibers, fertilizers to grow cotton, and chemicals to produce, dye, and finish fibers. (EAT, 2015)

In a circular economy, materials are fed into a system which reduces or eliminates waste and pollution by design. If consumer goods were intentionally designed with end use in mind, products, components, and materials could be kept at their highest value and utility for as long as possible. Purposely turning valuable material into something rendered useless after a year, a month, or a single use doesn't make good economic or environmental sense. Altering this thinking requires radical change in design, business models, energy efficiency, and consumer values. It requires systemic change. If all technical and biological materials were to flow back into the economy and natural materials were returned to the earth, many local, national, and global problems could be solved (EAT, 2015).

3.5. Textile Recovery Project Challenges

Despite the opportunities within LA's textile industry, LASAN must overcome many challenges before a robust circular economy can be established.

One significant challenge is the need for essential data to construct LA's circular textile market. Critical information, such as flow rates and fiber types, have yet to be measured and analyzed, impeding the development of comprehensive strategies. Despite our team's efforts to procure this data from local stakeholders, many do not possess or track such crucial metrics, adding to the difficulty of building a comprehensive understanding of the textile ecosystem.

Moreover, these efforts of stakeholder outreach have unearthed apprehensions regarding the financial implications and increased workload associated with collecting, transporting, and sorting textile waste. Addressing these concerns is paramount to garnering support and participation from key ecosystem actors, which is essential to the project's success.

The logistical challenges inherent in textile-to-textile recycling also pose a formidable barrier. Currently, chemical textile recycling—a key component of circularity—is not practiced in Los Angeles, necessitating the transport of textiles outside the city for processing before reintroduction into the local textile industry. Further, since much of the textile production occurs outside of Los Angeles and sometimes outside of the United States, pursuing local textile-to-textile recycling may not be the most pragmatic approach. Instead, exploring alternative applications such as agricultural products or housing insulation, which require mechanical recycling or upcycling of fibers in their current state, may present a more feasible avenue. To better understand the successes and failures of existing solutions, we analyzed a number of case studies, which will be further dissected later in this report.

Another key challenge has been the need for well-defined system boundaries, which has complicated our efforts to conduct comprehensive GHG analyses. Without clear delineations, collecting and quantifying emissions data has proven challenging, hindering efforts to assess and mitigate the environmental impact of LASAN's textile recovery pilot project.

A fundamental shift in perceptions surrounding waste is also imperative to creating lasting systemic change within the textile industry in Los Angeles. Demonstrating the economic, environmental, and social benefits of utilizing recycled materials is essential to cultivating demand and fostering widespread adoption of circular practices within the textile industry.

In navigating these multifaceted challenges, collaboration, innovation, and strategic partnerships will be instrumental in realizing the vision of a sustainable and resilient circular textile economy in Los Angeles.

3.6. Project Scope

We defined the project scope through a comprehensive research process consisting of client consultations, literature reviews, case studies, in-person site visits, and stakeholder interviews. A clear directive to address post-industrial textile waste drives the project's focus. While LASAN will also be considering pre- and post-consumer textile waste, with eventual program expansion, these textile waste streams are outside of this project's scope.

Our research occurred during Phase II of LASAN's four-phase pilot project, which focuses on testing sorting methods and developing a proof of concept for a circular textile recovery system within the city. Understanding the stakeholders, the work already completed by LASAN, and the next steps, has allowed our team to assess where and how our support could best be utilized.

3.6.1. Establishment of Deliverables

A focus on the current textile ecosystem identified and engaged key players essential for successfully implementing a circular textile recovery system. These include waste generators, fabric mills, cut-and-sew manufacturers, sorters, recyclers, potential end users, policymakers, and community organizations. This work led to a series of highlighted **case studies** that explore the current industry landscape along with applicable successes, failures, and challenges.

Building upon case studies, **circular mapping and pathway analysis** highlight the potential benefits and drawbacks of various circular scenarios (open- and closed-loop), grounded in policy, economic development, and supply chain levers, and as examined through the lenses of GHG emission impacts, economic development, and environmental justice. This deliverable consists of a circular scenario mapping and pathway analysis, which should support decision-making for implementing best-case circular scenarios, as considered through the above lenses. This deliverable also spotlights potential players found to be particularly relevant to achieving best circular practices, whether they are open to partnership or particularly interesting as an example of circular possibilities.

The next two deliverables are tools that can be used to support marketplace facilitation and optimization of the circular textile ecosystem. The first tool-based deliverable is an **industrial ecosystem database and dashboard** to standardize industry data, enable accurate material flow calculations, and track materials through the system. In addition, this database hosts a comprehensive list of notes or transcripts from stakeholder outreach interviews. The second tool-based deliverable is a **GHG emissions estimator.** This wire-frame offers an analysis between two different scenarios to understand potential GHG impacts or savings, and identify the preferred version. This tool can be used to compare best-case scenarios for textile recovery to business-as-usual (BAU) operations or two circular scenarios or pathways.

Our final deliverable is this **report**, which takes an in-depth look at our research process, findings, and deliverables. Additionally, we offer next-step recommendations and insights to support the best path forward as LASAN transitions into Phase III.

4. Methodology

4.1. Methodology Overview / Summary

At the outset of our research, our team first became familiar with examples of textile recycling landscapes at the local, national, and global levels before applying this knowledge to the Los Angeles post-industrial textile ecosystem. Meetings and email correspondence with our contacts at LASAN influenced this research and the methodology we developed for collecting information. Ultimately, our client's objectives for progressing with their textile recovery pilot program, their desire to explore GHG impacts resulting from said program, and the information they provided our team at the start of our Capstone, led us to the final deliverables chosen for the culmination of our project.

4.1.1. Project Approach and Process

To familiarize ourselves with the necessary steps to achieve textile waste circularity, we identified several key themes with which to conduct a literature review, including GHG emissions, industrial ecology, waste haulers, end processors, alternate uses, and policy. These themes provided examples of successful textile reuse and recycling, including relevant technological, environmental, and structural considerations, and highlighted challenges faced within these systems. The information collected from the literature review allowed us to understand what progress has already been made in textile recovery and reuse, and where to position ourselves to make meaningful recommendations to LASAN.

Following the literature review, we defined the primary stages that textile waste would progress through within the boundaries of LASAN's pilot: generators, sorters, recyclers, and alternate end users. Using these stages of progression, we then mapped out several open- and closed-loop scenarios to track potential paths of post-industrial textile waste through LASAN's proposed textile recovery system. In conducting this exercise, we contacted local and non-local companies identified as potential partners for LASAN. Alongside the information collected from our outreach efforts, we considered the impact of our mapped scenarios on matters of GHG emissions, economic (workforce) development, and environmental justice. This research provided insight into the potential of LASAN's pilot program and helped us understand the data gaps in their current body of information. We quickly realized these gaps need to be addressed before LASAN can achieve several of its goals, most prominently its goal of measuring GHG emissions. This led us to develop our final deliverables: highlighted case studies, scenario mapping and pathway analysis, a GHG emissions estimator, and an industrial ecosystem database and dashboard.

5. Literature Review

5.1. Summary

The literature review serves as the basis for this report and provides valuable insights into the challenges and opportunities of developing a circular textile economy in Los Angeles. The topics included in the review are greenhouse gas emissions, industrial ecology, haulers, end processors, alternate uses, and relevant policies. Key findings of our research revealed data that supports an increase in global textile consumption and waste, growth in global greenhouse gas emissions, the importance of communication and trust between actors in industrial ecosystems, the critical roles of haulers and end processors in the textile recovery process, and the potential impact of extended producer responsibility (EPR) bills on the implementation of a textile recycling ecosystem. In the context of textile recovery, EPR policies aim to shift the financial and operational burden of managing textile waste from local governments and taxpayers to the companies that produce and sell textile products.

The benefits of this literature review are numerous. It provided a solid foundation for understanding the industry landscape, which enabled us to provide informed recommendations, targeted strategy proposals, and a well-researched plan for establishing a successful textile recovery pilot project. By incorporating the insights gained from this research, we are positioned to effectively guide LASAN towards creating a sustainable, circular textile economy in Los Angeles, reducing the environmental impact of textile waste, and fostering economic and social benefits for the city and its residents.

5.2. Greenhouse Gas Emissions

The textile industry is experiencing unparalleled growth, driven by escalating consumer demand for affordable and fashionable clothing. This surge in consumption has dire environmental consequences. In 2015, the industry's emissions totaled a staggering 1.2 billion metric tons of carbon dioxide equivalent (CO_2e), surpassing those of all international flights and maritime shipping combined (UN Climate Change News, 2018). If current trends persist, projections indicate a tripling of clothing sales to 160 million metric tons by 2050 (Laville, 2017). This increase in textile volume would further compound the industry's negative impacts, where it would be estimated to use more than 26% of the carbon budget associated with a two-degree Celsius pathway.

Understanding the distribution of GHG emissions across the textile value chain is essential for devising effective mitigation strategies. However, this task is complicated by factors such as material type, product design, category, sources, and manufacturing location. Nonetheless, certain stages including raw material extraction, dyeing, finishing, yarn preparation, and fiber production, emerge as significant contributors, collectively accounting for over 50% of the sector's life cycle emissions (Sari et al., 2021). Additionally, this use phase presents challenges in assessing energy consumption and GHG emissions due to variations in consumer behavior regarding clothing care and utilization.

From a modern sustainability perspective, reliance on overseas production poses significant environmental challenges, particularly regarding transportation impacts. It is far more efficient to process the feedstock locally and utilize the waste as close to the production and processing sites as possible.

Efforts to mitigate these environmental impacts have led to the adoption of circular economy principles and the promotion of innovative recycling technologies and business models. However, the efficacy and implications of these approaches still need to be determined, with potential progress blockers such as rebound effects (a situation in which activities aimed at environmental benefits are not realized because of negative external factors) and behavioral challenges hindering widespread implementation (Ottelin et al., 2020).

Over time, environmental life cycle assessment (LCA) studies have provided insights into the comparative environmental performance of different textile recycling techniques. For instance, an LCA study aimed to assess the environmental benefits of various textile recycling techniques regarding energy usage and global warming potential (GWP) was conducted in Sweden (Zamani et al., 2014). This study compared three recycling techniques for model waste: material reuse, cellulose/polyester separation, and chemical recycling of polyester against conventional incineration. Results revealed significant variations in environmental performance. Material reuse emerged as the most environmentally beneficial option, yielding substantial reductions in GHG emissions and primary energy consumption per metric ton of textile waste. Cellulose/polyester separation also demonstrated considerable savings in GHG emissions and energy consumption compared to incineration.

Similarly, an LCA study in the European Union assessed the global warming potential of different ownership and end-of-life scenarios for a pair of jeans (Levänen et al., 2021). Findings indicated that extending the use (reduce) and re-selling (reuse) scenarios offered the lowest environmental impacts, aligning with circular economy principles of prolonging product lifespan. However, industrial processing into new raw materials (recycle) and rental services (share) presented varying degrees of emissions intensity, with the latter potentially increasing overall emissions due to increased mobility associated with rental services.

While there is still much to learn about the real impact of circular initiatives in the textile industry, it is evident that transitioning to a circular textiles system is imperative for mitigating the industry's significant environmental footprint and achieving meaningful reductions in GHG emissions and resource consumption.

5.3. Industrial Ecology

Industrial ecology studies industrial systems and their processes, relationships, energy use, and material flows in and out of a system. It is inspired by ecological systems, and the understanding that no waste exists in a natural system; one organism's by-product is another organism's food. Similarly, industrial ecology looks to move and convert materials currently in a waste stream to secondary materials, reducing waste and the need to extract more raw materials.

We researched industrial ecology to understand how industrial ecosystems develop and function, in order to provide context for ideal development routes that LASAN's textile recovery project could pursue. Three main themes were discovered: the relationship between region size and potential participants, the need for trust and communication between participants, and the economic challenges associated with developing a textile-centric industrial ecosystem.

In the first theme, industrial ecosystems at the local or industrial park scale are ideal for maximizing environmental benefits and reducing transportation costs. However, it can be difficult to find companies that have compatible materials and processes within a small area. Research suggests developing industrial ecosystems at the regional scale, so there are more matches and redundancies within the system, despite the trade-offs in cost and environmental impact (Sterr & Ott, 2004). If a closed-loop system is dependent on one participant, there is risk that the whole system will collapse if they leave or change their processes (Sterr & Ott, 2004).

The second emerging theme was the need for close communication between actors within a system. At a high level, transparency, shared cultural norms, social networking, and trust are necessary among companies (Herczeg et al., 2018). At the implementation level, the supplier and buyer must align the quality of secondary materials with production requirements (Prosman & Wæhrens, 2019). Secondary materials often have a lower and less consistent quality than raw materials and may need further processing before they can be used as feedstock. In textile recycling, managing the quality of waste materials is complicated by the variety of mixed fibers, threads, prints, metals, plastics, dyes and chemical treatments (Elander & Ljungkvist, 2016). Aligning supplier and buyer needs can be very technical, and the research data shows that exchanging information through multiple departments (sales and operations) and channels (reports, emails, calls, and site visits) becomes critical to the system's success. In-person meetings and phone calls were found to be the most useful (Prosman & Wæhrens, 2019). After initial alignment, introducing software for waste management is recommended for intercompany coordination (Sterr & Ott, 2004).

The third theme was the profitability challenge of developing a textile-centric industrial ecosystem. The cost of recycling textiles and transporting waste are high, and the demand for recycled fibers and end products are low (Elander & Ljungkvist, 2016). In interviews, textile sorters and recyclers identified "lack of economic viability" as a critical challenge for fiber-to-fiber recycling (Elander & Ljungkvist, 2016). Sorters and recyclers also need a reliable flow of materials to be economically sustainable. Brands can help to alleviate these economic challenges by committing to using recycled materials and labeling the fiber composition of products (Adler, 2020).

5.4. Haulers

Haulers play a crucial role in the textile recovery process. They are responsible for collecting textile waste from various sources, such as local businesses, institutions, and residential properties, and transporting it to sorting and processing facilities. Though they are an indispensable part of the ecosystem, haulers face challenges such as lack of standardized collection practices and logistical complexities which have the potential of leading to increased transportation costs and GHG emissions.

Despite these challenges, haulers still have a vital role to play in the development of a circular economy, as textile waste is diverted from landfills in support of the growing recycling and reuse markets. To maximize their impact and willingness to participate, policy support, infrastructure development, and collaborative partnerships are essential.

The opportunities for meaningful infrastructure developments are many. Co-location of waste generators, haulers, and processing facilities can reduce transportation distances and GHG emissions while improving efficiency. Clear guidelines for waste collection, sorting, and processing can standardize practices and improve material quality. Incentives for developing recovery infrastructure can create a more robust ecosystem for haulers to operate within.

On the other hand, collaboration between stakeholders can lead to streamlined protocols, knowledge sharing, and innovation, enhancing haulers' ability to contribute to a circular textile economy. By addressing challenges and leveraging partnerships, haulers can help reduce GHG emissions, conserve resources, and create new opportunities for growth in the textile sector.

California's Responsible Textile Recovery Act of 2023 (SB 707) aims to tackle the growing problem of textile waste in the state by requiring producers to establish stewardship programs for collecting and recycling "covered products" (Safaya, 2023). These products include any apparel or textile article that is no longer suitable for reuse in its current condition. This new legislation could increase LASAN's negotiating power with local haulers as they would likely be required to comply with specific guidelines and regulations regarding the handling and transporting of textile waste. As LASAN continues developing and refining its textile recovery pilot project, the

Responsible Textile Recovery Act would provide a solid foundation for LASAN to build upon and expedite its efforts to create a circular textile recovery system.

By partnering with haulers who are well-versed in these new regulations and best practices, LASAN could significantly enhance the efficiency, reliability, and sustainability of its textile recovery operations. To do this, LASAN can focus on building strong relationships with haulers and establishing clear communication channels to ensure that both parties are aligned in their goals and understanding of the textile recovery process. This might involve working with haulers to identify the types and volume of textile waste being generated in different areas of the city, as well as discussing the specific challenges and opportunities haulers face when collecting and transporting these materials. It could also involve a collaboration to develop and test new collection methods which aim to increase the efficiency and effectiveness of textile recovery efforts.

By engaging in open and transparent dialogue with haulers, LASAN can gain valuable insights into the realities of textile waste collection and identify potential areas for improvement or collaboration. The Responsible Textile Recovery Act further presents a significant opportunity for LASAN to strengthen its partnerships with local haulers thereby enhancing the effectiveness of its textile recovery pilot project. By leveraging the expertise and resources of haulers who are well-equipped to operate within the new policy framework, LASAN can continue to lead the way in developing innovative solutions for textile waste reduction and recycling in Los Angeles.

5.5. End Processors

End processors were an essential part of our research, as they are necessary to achieve a fully circular textile ecosystem. Textile waste is gathered from manufacturers (post-industrial) or consumers (post-consumer). If diverted from landfill, this waste can be sorted by category, condition, or material composition, to be processed for its next use (Khandelwal et al., 2023). The role of an end processor in this system is to prepare textile waste for its new use. End processors include textile sorters, shredders, and recyclers.

Textile sorting involves separating collected textile waste by material composition. This process can be done manually, or by using emerging technology and AI to identify the material composition of the textiles. While new sorting technology has exciting potential for optimization and scaling, capabilities are still limited, especially when sorting textiles of mixed material composition. Examples of companies that participate in textile sorting (by hand or with technology) and recycling are Fabscrap, Recover, Helpsy, and Everywhere. These companies are all US-based, but mainly reside on the east coast, with the exception of Everywhere, which is based in California. Fabscrap has locations in New York City and Philadelphia, and has served as an impressive example of industry success throughout our research. We drew research from each of these businesses to better understand who was already engaged in textile sorting and recycling, and what opportunities could arise for LASAN's pilot program.

After sorting, shredding is typically the next step in processing. Shredders can reduce textiles for further processing through recycling, or compress textiles into a versatile fluffy mixture known as shoddy, with applications ranging from rug padding to furniture stuffing and housing insulation. Shredders may exist as standalone operations, or function within textile recycling facilities.

The two primary types of textile recycling are mechanical and chemical. Mechanical recycling has the capacity to turn textile waste into new raw materials without altering the polymer chemical structure of the fibers. However, mechanical recycling has limitations, as often the fiber length is shortened in the recycling process reducing tensile strength. To counter such, mechanically recycled fibers are often mixed with virgin fibers. Mechanical recycling is also not well equipped to deal with mixed fibers (e.g., cotton polyester blends, etc.). Chemical recycling is better equipped to process mixed fibers, as it alters polymeric waste by changing the chemical composition and turning it into monomers, which can be used as raw materials to remanufacture new polymers (Baloyi et al., 2024). Chemical recycling addresses the challenges posed by mechanical recycling by focusing on recycling materials like polyester and multi-fiber blends that are difficult to process, while also generating output comparable to virgin materials (Khandelwal et al., 2023). Despite its potential, this approach is still in its early stages, with restricted processing capabilities and a current lack of economic feasibility.

Under the umbrella of textile recycling, materials can pass through an open-loop or closed-loop system, each with its own set of benefits, drawbacks, and trade-offs. Open-loop recycling focuses on utilizing textile-waste in its current or downcycled form. However, downcycling textiles can turn them into lower-use value items—which depending on the use-case—can more quickly lead to landfill (Khandelwal et al., 2023). Open-loop recycling includes product-life extension uses such as upcycling fabric scraps into new garments or creating new products from deadstock fabric. This use-type also includes sending the intact textile-waste to alternate industries with textile needs. Open-loop downcycling options include shredding the fabric to be used

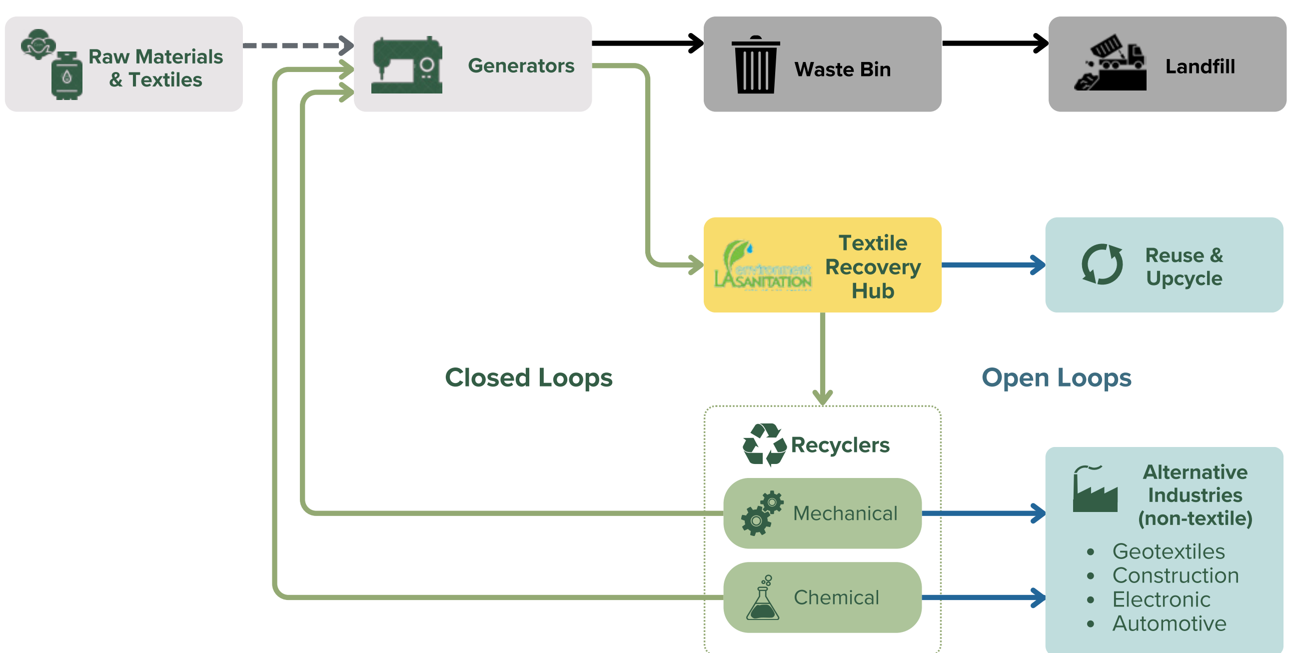

Figure 1: Diagram of circular system mapping (Hsiung, 2024).

as insulation or padding for multiple industries. Closed-loop recycling turns textiles back into yarn, as a base-use for the creation of new textiles. As discussed above, this is achieved through mechanical or chemical processing.

Presently, the number of recyclers in Los Angeles does not support textile recycling at scale. Most large-scale mechanical recyclers are located out-of-state, and many chemical recyclers are located outside the United States, necessitating increased transportation and resulting emissions to properly process textiles for reuse.

5.6. Alternate Uses

After moving through LASAN's proposed textile processing hub, one option for the next stage of a textiles' life cycle is to find new, alternate uses. Our research identified a wide variety of alternate uses for textiles, following processing. These uses include furniture stuffing and padding, agricultural supports, construction materials, housing insulation, moving materials, blankets and clothing, rug pads, and more. The final use for the materials will depend on how they were processed per the methods discussed in the previous section. For example, textile scraps can be mechanically shredded and turned into shoddy, which as previously mentioned has a variety of downcycled uses. Chemically recycled textiles can be turned into a number of different end products based on their chemical structure. For example, chemically recycled polyester can be repurposed for use in the automotive or electronic industry. Further, textile scraps, which are still in their original form, can be upcycled in patchwork clothing, blankets, tents, and more.

Through our research, we identified local alternate users to keep the collected textile waste in Los Angeles, facilitating a lower GHG emissions impact, and to create a fully circular system within the city. A few promising options that utilize existing industries in the city were agriculture, construction, entertainment, and materials for unhoused persons' shelter and clothing.

We anticipate that the exploration of alternate end uses for textile waste will assist LASAN to divert larger amounts of the city's textile waste from landfills, and instead enter the circular textile economy.

5.7. Policy

Newly proposed policy has the potential to radically change the textile waste and recovery landscape in Los Angeles and beyond. We explored policy through our literature review and subsequent research, most notably the role of the proposed California Senate Bill 707 (SB707), an extended producer responsibility (EPR) bill, and how it relates to implementing a textile recycling ecosystem and necessary infrastructure. At the state level, CalRecycle—California's Department of Resources Recycling and Recovery, which manages the state's recycling and waste programs—would be at the helm of recycling efforts (Safaya, 2023). However, a successful textile recycling pilot by LASAN could set the stage as a blueprint for the state.

We also examined the Fashion Sustainability and Social Accountability Act (NY Fashion Act) and the federal level Fashioning Accountability and Building Real Institutional Change (FABRIC) Act. The NY Fashion Act focuses on social and environmental due diligence, supply chain emissions, and ethical labor practices (*The Fashion*

Act, n.d.). The FABRIC Act is centered on reshoring incentives, grants for workforce development, and wage protections, including base pay and violations (*The FABRIC Act,* n.d.). Like SB707, both bills are currently on the legislative agenda. While neither bill directly addresses EPR, their passage could signal a stateside uptake of trending regulation in the apparel industry, which is already underway in Europe.

Zooming out, we examined London as an unofficial case study for understanding government-supported circular systems in the textile industry. Of particular relevance to LASAN is ReLondon. ReLondon is a partnership between the Mayor of London and London boroughs, with funding provided by the UK government (ReLondon, n.d.-a). Its aim is to improve waste and resource management and accelerate the transition to a low-carbon circular city. The program supports small businesses with resources and funding, features "circular matchmaking" programs and job opportunities, and collaborates with various stakeholders to better connect the textile recycling ecosystem (ReLondon, n.d.-b). This program, in many ways, mirrors LASAN's partnership with CPSC and can serve as a model for further programming upon LASAN's pilot expansion.

To analyze past policy pitfalls, the journal article *Improving Recycling of Textiles Based on Lessons from Policies for Other Recyclable Materials: A Minireview* provides valuable insights. The article acknowledged its applicability to post-industrial waste collection, and several financial-based avenues were noted to facilitate successful recycling implementation: fiscal and monetary government support as necessary for policy promotion; incentives for supply chain actors; and environmental tax as a mechanism for empowering industries to take initiatives to implement effective recycling techniques (Hole & Hole, 2020). The article also highlighted business partnership networks, co-location for optimization, and cooperative implementation as necessary elements for effective program uptake.

The Or Foundation's report *Stop Waste Colonialism!* introduced the concept of harmonized EPR for a circular textile economy, supporting a justice-led transition through internalized costs (producer-paid), global accountability (supply chain), and disclosures (production volume transparency) (The Or Foundation, n.d.). As proposed in this report, harmonized EPR suggests a consistent and unified global fee structure and floor for all newly produced garments, modulating from $0.50 to $2.50 per garment. This fee structure is based on the cost of waste management otherwise borne by secondhand markets.

6. Final Lenses

We selected three lenses to analyze and evaluate how a new textile circular economy would impact the city of Los Angeles and its many communities, beyond the standard metric of textile volume diverted from landfills. These lenses include GHG emissions, economic impact, and environmental justice. While additional impact categories could be explored, these three were selected as the most relevant based on conversations with the client alongside our research. Each activity within a circular economy inevitably has environmental, financial, and social costs and benefits.
We evaluated these costs and benefits within a series of open- and closed-loop scenarios and pathways, by looking at criteria such as co-location, transportation,

extended textile life through reuse, recycling technologies, economic and workforce development, and opportunities for reduced air and water pollution. There is no best solution, rather a series of trade-offs to be considered depending on the impact category of focus.

6.1. GHG

LASAN was particularly interested in obtaining a better understanding of potential GHG emissions reductions if textile waste was diverted from landfills. To facilitate the transparency of numbers behind actions, we developed a GHG emissions estimator tool to provide a baseline carbon footprint account for each circular pathway (after the appropriate data has been collected and input). For example, when calculating the GHG emission impact of a volume of textile waste, emissions resulting from transportation at each life cycle stage are included in the overall carbon footprint. These stages might include transport from producer to sorter via hauler, and from sorter to recycler via hauler or consumer. Transportation to a landfill is also included in the calculation if the textile waste is not being recycled.

In order to calculate the CO_2e emissions generated through transportation, we multiply the number of miles traveled from one facility to the next by an emission factor for gasoline or diesel fuel. If the transport is by air, train, or boat, the same multiplication equation applies, however, the emission factor will change to account for the type of fuel used. More miles traveled equates to more fuel consumed and, thus, a more significant contribution to the overall carbon footprint. For this area of focus, co-location of stakeholders is one strategy that could be considered to reduce transportation and the resulting emissions. Another approach is emphasizing textile reuse over recycling, requiring fewer energy inputs.

6.2. Economic / Workforce Development

The Los Angeles Garment District was established in the early 20th century and grew substantially between 1920 and 1950 (Barden, 2023). In 1950 it became a center for sportswear and women's clothing. In the mid '90s a group of businessmen changed the name from the Garment District to the LA Fashion District. It is known by this name today and encompasses 107 city blocks with 2,000 wholesalers. Today, the fashion and textile industry in Los Angeles County is the largest in the United States, with over 5,300 businesses, 67,600 people employed, and a $3.2 billion payroll (*The Beginning of the Fashion Industry in Los Angeles,* n.d.). With national pressure to maintain American manufacturing onshore, focusing on the health of the local textile industry, finding opportunities to fill gaps, and building upon what already exists—a longstanding industry with deep roots and irreplaceable native knowledge—should be a priority for the city as the industry moves forward.

As rich and colorful as the textiles and garments produced in LA's Fashion District are, the industry stands on an unstable economic structure with far less vibrant workplace realities. Under the constant threat of offshoring textile production, material sourcing, and labor to China, Southeast Asia, and South America, LA manufacturers and cut-and-sew shops are forced to keep costs at competitive rates to stay in business. This threat results in low wages, unauthorized workers, unregistered factories, and unsafe working conditions. Rebuilding the economic model from a linear system to a circular system not only has the potential to realize untapped value in the waste stream, it can also breathe new economic growth and stability into the entire industry.

Identifying financial gaps and opportunities in the current system is crucial to economic optimization. For example, textiles disposed of in the single-stream recycling system cause millions of dollars of damage to MRF equipment annually. Removing textiles from this waste stream would save on hauling expenses, equipment repair, and environmental carbon capture costs. Increasing local sorting capabilities, either by hand or machine, would inevitably redirect some percentage of textile waste destined for landfill to alternate end uses. Establishing local mechanical and chemical textile recycling facilities would reduce the costs of sending the service across the country or to other countries. Employing locals to facilitate the process of maintaining textile inventories, sorting textiles, transporting textiles, and keeping textile waste out of the general waste stream would assist in making a circular system function efficiently and effectively while creating new, "green" jobs. Inviting local designers to offtake deadstock fabrics from textile manufacturers would prevent them from entering the waste stream and encourage innovation and creativity. Compensating an aging workforce as they transition toward retirement would ensure that they pass on their skills to a new generation of workers, thereby preserving institutional knowledge and longevity. Keeping skilled workers employed and utilizing them to upskill a new workforce not only benefits the textile industry, but also the growing circular economy. The aging workforce could then shift into less intensive roles, such as hand sorting.

While some of these processes and services currently exist in LA, they do not exist at a scale which is able to handle the volume of waste generated and directed through the sanitation system.

6.3. Environmental Justice

The US Environmental Protection Agency (EPA), cites environmental justice (EJ) as "the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, tribal affiliation, or disability, in agency decision-making and other federal activities that affect human health and the environment" (US EPA, 2014). According to the California Environmental Justice Alliance, EJ communities are "neighborhoods surrounded by freeways and industrial facilities…where residents…are exposed to more pollution than others who live miles away" (California Environmental Justice, 2016). EJ communities are more likely to be composed of people of color and historically marginalized voices. These communities often experience pollution from multiple sources, and face health issues ranging from increased asthma to cancer.

In an interview with Denise Patel, US Program Director at the Global Alliance for Incinerator Alternatives (GAIA), a worldwide zero waste movement championing solutions in alignment with environmental justice, she states, "research shows that 79 percent of municipal solid waste incinerators are located in [EJ] communities" (Yang, 2021). This recognition highlights the negative impacts of pollution-creating waste management activities on the health of EJ communities. Patel goes on to state that burning and landfilling waste compounds air pollutants from industrial activities, while runoff contaminants from landfills can infiltrate local waterways and water sources in EJ communities.

As waste collection and disposal is addressed at the municipal level, LASAN has the opportunity to develop its textile recovery pilot in such a way that it aligns with the principles of EJ and makes pointed efforts to respect at-risk communities. Policy and appropriate infrastructure are key components that work to support this just transition.

7. Outreach

7.1. Summary

The outreach conducted for this project focused on engaging key stakeholders across the textile waste management ecosystem in Los Angeles. The primary aim of these outreach efforts was to gather comprehensive data on the quantity, type, and handling of post-industrial textile waste and to understand the potential for integrating circular recovery practices into the existing system from the point of view of its participants. Outreach efforts involved connecting with businesses in various roles, from textile and garment manufacturers who generate waste, to sorting facilities, recycling companies, and potential end users of repurposed and recycled textiles. These interactions provided valuable insights into the challenges, opportunities, and incentives within the textile waste ecosystem, informing our approach for developing viable circular scenarios. Through this process, the team identified areas where partnerships and strategies could be established to optimize the management and recovery of textile waste in Los Angeles. Our outreach also attempted to access and quantify missing data, such as flow rates, fiber types, and processing requirements, essential for developing circular strategies. The data collected through outreach informed our circular mapping and pathway analysis examples and formed the framework of the industrial ecosystem database and dashboard, two of several project deliverables discussed in this report.

7.2. Generators

An essential portion of our outreach focused on connecting with businesses in Los Angeles that generate post-industrial textile waste, ranging from textile manufacturers to garment manufacturers. Our outreach aimed to gain tangible data about the quantity, type, and flow rate of material moving through these businesses. Further, we wanted to understand how textile waste was disposed of and hauled away from these companies and whether LASAN's vision for circularity could fit within their operations. Through our outreach, we also identified concerns that could deter businesses from willingly participating in a circular system, mostly centered around increased costs and workload associated with processing their textile waste. To gain traction, meaningful incentives and penalties may be needed to ensure participation throughout the circular textile ecosystem in LA.

7.3. Sorters

The next step of our outreach focused on businesses that sort textile waste. In order to understand various aspects of their operations, we inquired about the size of their workforce, their manual or mechanical sorting methods, and the types of textile waste they accept. Some sorters were able to provide rough estimates of the material types they encountered—cotton, polyester, cotton-poly blends, etc.—and which types could most likely be diverted from landfills through alternate end-of-life pathways. We sought tangible data on their processing capacity, the quantity of textile waste handled on average per day or per week, and the various incentives they would require to scale their operations. Finally, we asked how sorted textiles leave their facilities, what third parties are involved in this process, and the associated costs. Finally, we inquired about an organization's willingness to participate in a circular textile waste system, and if they would be open to exploring partnership opportunities with LASAN.

7.4. Recyclers

We researched and contacted various textile recycling companies to learn about their operations. We requested information about their company backgrounds and whether their recycling methods were mechanical or chemical. We asked about their criteria for accepting textile waste, the predominant material types they handle, and their daily and weekly textile processing capacity. We sought to understand more about their final output products and who their target customers are. Additionally, we asked about their machinery and technology limitations, and what steps or financial incentives they would require to scale their operations.

7.5. End Users

The final outreach category researched was end users. Understanding the industries that currently use recycled textile products and identifying new industries that could potentially use these products was vital to ensure that offtakers exist to balance the flow of materials through a circular system. Our outreach aimed to understand what kind of textiles were needed by the particular end user, how much, and how often. Further, we wanted to understand any specifications, constraints, or technical requirements that might limit an end user's ability to accept recycled or upcycled textiles. Response rates varied within this portion of outreach, however, the insight gained still supported a stronger understanding of this component within the proposed ecosystem.

8. LA Trip and Site Visits

8.1. Summary

The team's March trip to Los Angeles proved incredibly valuable for understanding the city's textile and waste management landscape and identifying potential solutions for achieving a circular textile waste economy. Through site visits to various facilities and meetings with key stakeholders, we gained insight into the city's challenges and opportunities associated with textile recycling and sustainability. This on-the-ground experience helped us to identify operational gaps within the current waste management system and to make realistic and contextual recommendations to LASAN in their transition from a linear to a circular system.

Photo 1: Sorting Bins in the Homeboy Threads Warehouse (Wetters, 2024).

Photo 2: TOMRA Sorting Machine in the Homeboy Threads Warehouse (Wetters, 2024).

8.2. Site Visit Breakdown

8.2.1. Homeboy Threads

Our Los Angeles site visits began with a tour of Homeboy Threads, the newest branch of Homeboy Industries, opening just over 16 months ago. Homeboy Industries is a social enterprise dedicated to providing job training and support for the formerly incarcerated, and providing additional services such as mental health counseling and education for its employees (E. Johnson, personal communication, March 13, 2024).

Homeboy Threads was formed under the umbrella of Homeboy Electronics Recycling, as the entrepreneurs behind Homeboy Industries determined that the process of recycling e-waste is similar to those required to recycle apparel. However, the current operations of Homeboy Threads have led the business to be classified as a "sorter" (E. Johnson, personal communication, March 13, 2024).

As a sorter, Homeboy Threads receives both post-industrial and post-consumer textile waste from various sources, which they sort into groups for reuse, recycling, or landfill. Items are weighed before proceeding to the first round of sorting, which determines whether an item should be recycled or if it can be directed to the reuse market and resold on the Homeboy Threads website, eBay, Depop, or elsewhere. Reuse is the preferred pathway. Resale items are tracked with an asset tag and are prepared in the warehouse, whereas items destined for recycling proceed through further sorting stages. Homeboy Threads has had temporary use of a TOMRA sorting machine, engineered to separate items by their fiber makeup. The machine sorts through a process referred to as "negative sorting," and only identifies 100% polyester and 100% cotton textiles, while cotton-poly blended items and other items are rejected. Items that do not fall into the 100% cotton or 100% polyester categories must be manually sorted, and labels must be examined with a hand-held scanner. Items then move on to the final grading stage for quality, price, and any necessary debranding or hardware removal. Finally, items leave the Homeboy Threads warehouse for various destinations, including wholesale resellers, reuse, and upcycling.

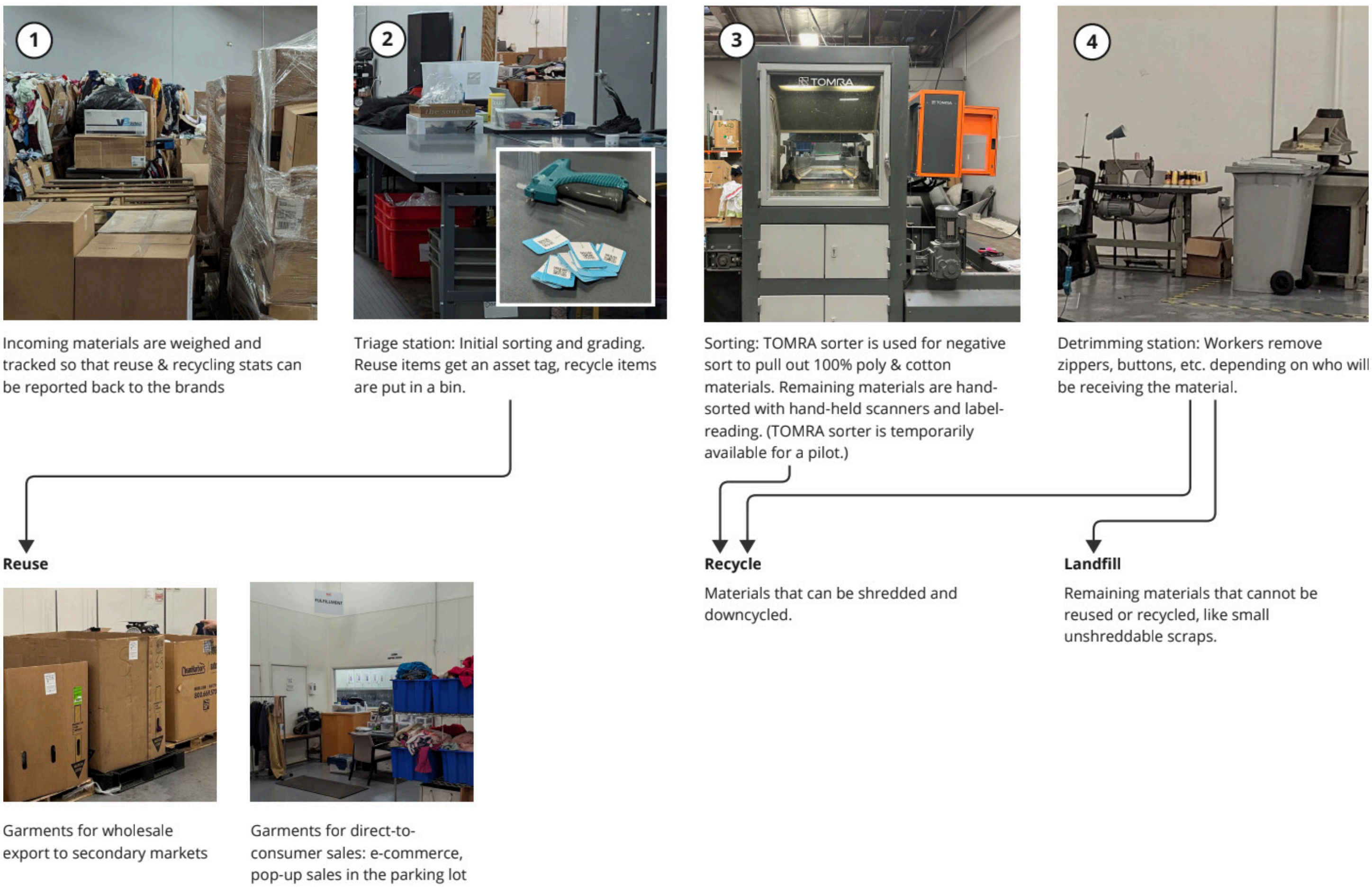

Figure 2: Diagram of Homeboy Threads sorting process (Hsiung, 2024).

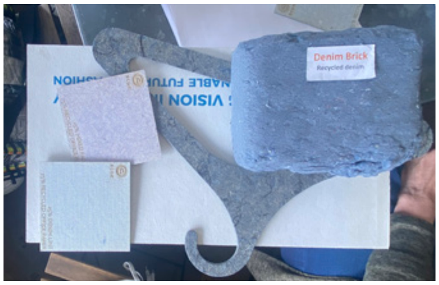

Photo 3: Products from recycled textiles (Weiner, 2024).

8.2.2. Meeting with Jennifer Gilbert

LASAN organized a lunch with Jennifer Gilbert, a sustainability consultant, and former executive at I:CO, a global waste collection network. I:CO is a subsidiary of SOEX, a textile and recycling group based in Germany that runs one of the largest textile sorting facilities in the world.

While at I:CO, Jennifer developed clothing take back programs for retailers like Urban Outfitters and H&M. She shared that businesses are motivated to create take back programs because they bring customers through the door (J. Gilbert, personal communication, March 13, 2024). Most consumers need incentives to participate in sustainability programs, such as coupons or discounts; environmental concern is often not enough of a driver to motivate consumer behavioral change. Employee education was also a major component in the launching and success of take back programs.

Jennifer had samples of products made from secondary materials, including a brick made from compressed cotton dust, a clothes hanger made from recycled denim, and acoustic tiles made from recycled cotton.

8.2.3. Los Angeles Cleantech Incubator (LACI)

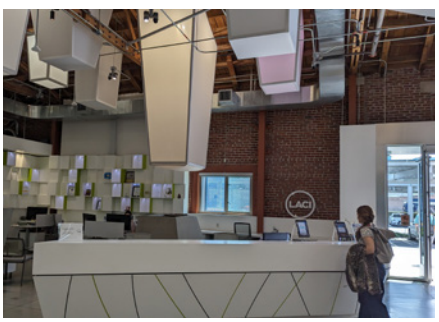

Photo 4: LACI Campus (Hsiung, 2024).

The Los Angeles Cleantech Incubator (LACI) is a hub for environmental change in the Los Angeles area. LACI specifically emphasizes supporting startups focusing on clean energy, electric vehicles, city sustainability, and community development (L. Harper, personal communication, March 13, 2024).

LACI is working alongside LASAN in attempts to facilitate a circular stream for textile waste produced in the LA area (Petersen, 2024). LACI's contribution to establishing textile circularity in LA is being created within their Sustainable Cities Partnership and focuses on a "materials marketplace pilot" for recycled textiles (Petersen, 2024).

To connect with other innovators in the textile space, LACI and LASAN partnered to organize a textile recycling charrette in early 2024. Several stakeholder groups, including multiple members from LASAN and our Capstone advisor, Lynnette Widder, were in attendance. These groups represented innovation hubs, sorters, generators, designers, recyclers, tech groups, academics and researchers, waste management professionals, and more.

Takeaways from the charrette along with progress and goals for LACI's materials marketplace were the focus of our discussion while visiting their offices. Lauren Harper, Director of Sustainable Cities at LACI and our guide for the day, also organized a creative exercise for our team: We were tasked with designing a holistic approach for creating a circular textile marketplace, considering end use cases for the textiles, and necessary technology and policy that would need to be in place to facilitate successful operations. This proved to be a useful and thought-provoking experiment and spurred us to emphasize innovation in our thought processes.

Our visit to LACI emphasized the importance of their thriving partnership with LASAN, as the two organizations work towards the advancement of textile recycling in Los Angeles in line with their mutual goals. As proven with the success of the charrette, LACI's extensive connections established through the support of relevant startups and community engagement activities will be a wonderful resource to LASAN as they seek to identify and make contact with key actors in the city's textile ecosystem.

8.2.4. Garment Worker Center

Our team set up a meeting with the Garment Worker Center (GWC) to deepen our understanding of how LASAN's textile recovery project could impact those working at the generation points of the city's textile waste. As stated in earlier sections of this report, Los Angeles is the center of garment manufacturing in the United States, with around 2,500-4,000 companies and contractors operating in LA's Fashion District (Kutz, 2023). Many of those companies are garment manufacturers, with over 45,000 workers that cut, sew, and finish garments locally (Garment Worker Center, n.d.). Most of these workers live locally and come from Latino and Asian immigrant communities.

The GWC is a worker-led organization that directs its efforts toward workers' rights and fair wages, while aiming to eliminate sweatshop labor in the industry. GWC helps to develop leaders and community organizers who demand enforcement of strong labor laws and accountability from factory owners, manufacturers, and fashion brands. Only half of the 2,000+ such businesses that operate with LA's garment manufacturing industry are registered with the state. Of the unregistered businesses, businesses, and many of their workers do not have legal citizenship.

We met with Nayantara Banerjee, a GWC representative who serves as an industry researcher and strategist. We were interested in her perspective on where opportunities and challenges for industry workers might lie within LASAN's pilot program. Nayantara made it clear that for the pilot program to be successful, additional pressures on small, independent, or family-owned mom-and-pop garment manufacturers already under significant pressure to meet quotas and pay employees fair wages could be detrimental (N. Banerjee, personal communication, March 13, 2024). If textile circularity were to be implemented, training factory workers on collection and sorting techniques would be essential if these tasks were added to their standard responsibilities. Furthermore, Nayantara emphasized a need to clarify where the costs associated with these additional responsibilities would fall. While discussing ways in which this collecting and sorting might be feasible, Nayantara suggested employing retirement-age workers—those who may no longer be as nimble or agile as younger workers, but who understand the factory operations—to help assist in this process. This conversation led to a discussion of potential workforce opportunities that could arise while transitioning to a circular textile economy.

The Garment Worker Center is the only organization in the United States that provides advocacy and services for textile industry workers (Kritzer, 2023). Their voices need to be heard, and their rights protected. Further, without the native knowledge and skilled workforce, this already tenuous industry would cease to exist.

8.2.5. Antex Knitting Mills / Matchmaster Dyeing and Finishing

Antex Knitting Mills is a vertical knitting, dyeing, printing, and finishing company established in Los Angeles in 1973 (*Antex Knitting - Matchmaster Dyeing and Finishing,* n.d.). As the largest textile manufacturer in North America, the company produces approximately 1.5 million yards of fabric per week for children, juniors, contemporary, outdoor, activewear, and military markets. Antex works with big-name

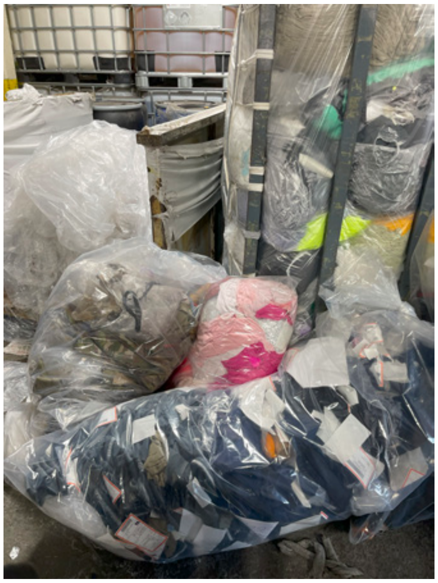

Photo 5: Factory floor scraps sorted and bagged at Matchmaster Dyeing and Finishing (Torpe, 2024).

Photo 6: Trimmings bagged directly from the production belt at Matchmaster Dyeing and Finishing (Wetters, 2024).

brands like Nike, Under Armour, SpaceX, Adidas, Walmart, Gap, and Target. They also hold contracts with the United States government and military for workwear and uniforms. Antex's fabrics are dyed, finished, or printed in the company's Matchmaster Dyeing and Finishing dye house. All company branches are co-located on two city blocks south of the LA Fashion District.

On average, Antex employs 500 people, and in its 50+ years in operation, it has never had a layoff. The average hourly employee makes $20 per hour, and the lowest annual salary is $50,000, which is above average for the textile industry. The company intentionally invests in its people, financially and intellectually, and has seen multi-generational growth in its stable workforce.

On a typical day, Antex generates four 2,500-pound containers of post-industrial textile scraps that are collected and taken away by private haulers. Some excess deadstock fabric is sold to jobbers for a fraction of the original cost. Other excess fabrics, such as virgin cotton, are sent to Texas for reprocessing, but most of their textile waste currently goes to landfills. While walking the factory floor, our team noticed that much of the textile scrap is already pre-sorted as it comes off the production-line and trimmings are placed in plastic bags (though currently mixed with other waste). If this textile waste were to be recycled, the sorting step could be done on-site, eliminating the need for hauling to an external site for this part of the process. "Given the right bins, we could do anything. Right now, it's all plastic bags. If there's a reason for us to do it, we'll do it. It's just the difference between putting it in one bag or another; we can do a significant amount of pre-sorting ourselves" (M. Hensley, personal communication, March 14, 2024).

The spirit of Antex is both a longstanding family-owned business and markedly progressive. Antex is planning for future generations and is ahead of its competitors regarding sustainability efforts in an industry that struggles to ensure workplace safety and fair wages. Their factories are ISO 2400 certified and adhere to HIGG standards. While their operations generate 21,000 tons of CO_2e annually, which is below the 25,000-ton threshold for requiring offset carbon credits, they voluntarily purchase them anyway. Antex uses Cyclonic air cleaners to filter out volatile organic compounds (VOCs) and PM10 air particles before the air is exhausted back into the environment. This process sequesters 2 tons of CO_2e per day.

In addition to air filtration, Matchmaster Dyeing and Finishing treats its wastewater from on-site dyeing. A typical dye machine historically used a 1:12 fabric-to-water ratio; today, it uses a 1:6 fabric-to-water ratio. With technological advancements, air dye machines now use a 1:2 fabric-to-water ratio. Changing out older, less efficient, and costly production equipment takes time, but Antex is actively transitioning (M. Hensley, personal communication, March 14, 2024).

Photo 7: Hyperion (Wetters, 2024).

Photo 8: Hyperion (Wetters, 2024).

8.2.6. Hyperion

Hyperion is a LASAN operated water reclamation plant, producing potable water for the city of Los Angeles, recovering, treating, and recycling water, and protecting the coastal aquatic environment.

LASAN serves as the water supplier, treating the water to meet strict drinking water standards. Once treated, it is distributed by the Los Angeles Department of Water and Power (LADWP) to customers throughout the city, including Los Angeles World Airports (LAWA), which operates LAX and other city airports (LA Sanitation and Environment, personal communication, March 14, 2024). By continuously monitoring water quality and proactively identifying and addressing any potential issues, Hyperion ensures that the water delivered to Los Angeles residents and businesses is consistently safe and reliable.

Looking ahead, LASAN and LADWP are collaborating on the Hyperion 2035 Program, which aims to upgrade the Hyperion Water Reclamation Plant (LA Sanitation and Environment, n.d.-b). The plant treats 450 million gallons daily, but currently only recycles 27% for non-potable uses. Hyperion's goal is to implement advanced treatment technologies that will allow 100% of the plant's wastewater to be recycled, producing up to 174 million gallons of purified water for potable reuse daily by 2035.

Seeing firsthand how LA invests in its future by revamping its water treatment infrastructure was eye-opening. The Hyperion 2035 Program showcases the city's commitment to innovation and environmental stewardship, by securing a sustainable water supply for the future amidst challenges such as climate change and population growth.

8.2.7. Athens Materials Recovery Facility

Athens' Sun Valley is a Materials Recovery Facility (MRF) that processes residential and single-stream recycling. Our tour through the facility provided eye-opening insights into the types of materials that can or cannot be processed at these types of facilities. The Sun Valley MRF is designed to process recyclable waste which typically includes materials such as paper, cardboard, plastic containers, metal cans, and glass bottles. The facility's advanced sorting technologies, including optical sorters, robotics, and artificial intelligence, are specifically designed to efficiently separate and process these traditional recyclable waste streams.

However, the Sun Valley MRF, like most other MRFs, is not equipped to handle textile waste. Textiles, such as clothing, fabrics, and linens, can cause significant problems when they end up in the blue-bin recycling stream. These materials can jam sorting equipment, cause contamination of other recyclables, and reduce the overall efficiency of the recycling process. One of the primary issues with textiles in the recycling stream is that they are often "mis-binned," meaning consumers place them in recycling bins when they should be disposed of separately. This contamination not only hinders the efficiency of the sorting process but also diminishes the quality of the recovered textiles, making them less attractive to potential buyers. Marc, the facility's General Manager, explained that there is currently no market for textiles coming out of MRFs as these facilities are not suitable for textiles. Textiles recovered from the current single-stream recycling system are often soiled, torn, or mixed with various materials, making them difficult to sort and repurpose (M. Harismendy,

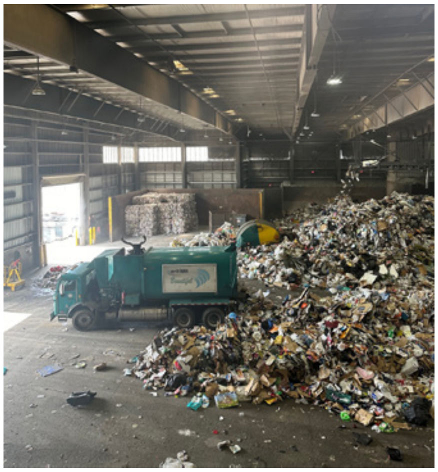

Photo 9: Athens Materials Recovery Facility MRF (Wetters, 2024).

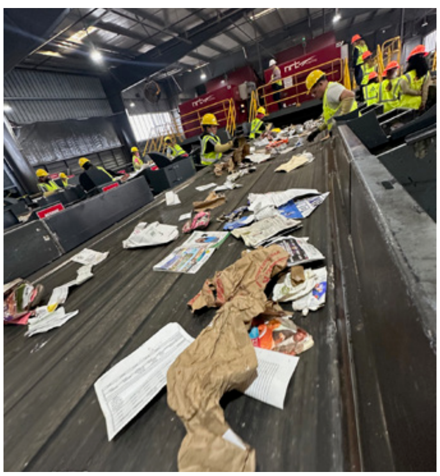

Photo 10: Athens Materials Recovery Facility MRF (Wetters, 2024).

Photo 11: Lopez Canyon Composting Facility (Weiner, 2024)

personal communication, March 14, 2024). As a result, most textiles end up in the residue line, which accounts for 20-25% of the outbound materials sent to landfills—making textiles the number one trash product by weight leaving the facility. The team at Athens Services believes that textiles should be collected through a separate, graded system by a third party. This would allow for cleaner, more homogeneous textile streams that could be more easily sorted and recycled.

Despite these obstacles, the Sun Valley MRF remains committed to diverting as much waste from landfills as possible. The facility processes an impressive 16,000 tons of recycling waste streams such as paper, plastic, metal, and glass per month and employs 150 people, most of whom are contract laborers. The MRF also boasts an energy-efficient design, with features like solar panels and negative pressure to minimize its environmental impact on the surrounding community.

Our visit to the Sun Valley MRF highlighted the complex challenges associated with textile recycling and the need for innovative solutions to address this growing problem. By raising awareness about the importance of proper textile disposal and exploring new approaches to collection and sorting, facilities like the Sun Valley MRF can play a crucial role in promoting a more sustainable future for the Los Angeles region and beyond (Athens Service, n.d.).

8.2.8. Lopez Canyon Composting Facility

Thania Flors, Environmental Engineering Associate, and Rodger Hill Jr., Equipment Supervisor and Solid Resource Processing & Construction, led our team on an informative tour of Lopez Canyon Composting Facility. This closed landfill is about two years shy of meeting its state-mandated 30-year monitoring period (F. Thania & R. Hill Jr., personal communication, March 15, 2024). Upon completion, assuming the site is deemed safe, it will be transitioned into nature preserves and public-use spaces, including parks with hiking and riding trails.

Learning about the requirements to harness landfill gas for energy proved particularly interesting. As landfilled organic waste decomposes, it produces gases (F. Thania & R. Hill Jr., personal communication, March 15, 2024). Through underground pipes, these gases can be harnessed and converted into energy, though the gas must contain about 50% methane to be suitable for energy generation. Gas that meets these requirements can then be sold back to the city for use in the electrical grid. If the methane content is insufficient, it loses its value for sale. The gas produced at Lopez Canyon typically consists of about 50% methane, 50% carbon dioxide, and trace amounts of other gases, most often rendering it suitable for sale.

In addition to energy recovery through methane gas, Lopez Canyon also functions as a compost facility. At present, Lopez Canyon can only accept tree and landscaping waste for its composting program (F. Thania & R. Hill Jr., personal communication, March 15, 2024). A recent legislative modification to the definition of “trash” has re-categorized organics (food waste) as such, which Lopez Canyon cannot accept. Consequently, this has resulted in a reduction in compost volume, though efforts are underway to lobby the city to amend the new definition.

For the local community, compost and mulch are available for free. Educational events are also held onsite, to encourage composting efforts and engage the community.

9. Case Studies

9.1. Summary

As part of our final deliverables, we've compiled a curated list of companies operating in the circular textile recycling sector, presented in a case study format. Most case studies presented here were identified through our research, while several included were discovered through our outreach efforts. Our objectives were to understand the current business landscape, and identify successes, failures, and exciting innovations in the textile recycling space. Each case study offers background information, an analysis (as relating to the needs of LASAN), lessons learned, and a conclusion. Further, these case studies were used to support the formulation of some of our Circular Mapping & Analysis examples.

9.2. Phoenix Fibers / Bonded Logic / United Fibers - Chandler, AZ

Background

The Kean family has established a closed-loop circular textile recovery system through a trio of companies in Chandler, AZ: Phoenix Fibers, Bonded Logic, and United Fibers.

Phoenix Fibers is an internal closed-loop textile recycling company that opened in 2011. Each month, they convert over 300 tons of denim and other cotton fabrics into shoddy fiber, which is then manufactured into new consumer products, including denim building insulation, appliance insulation, automotive insulation, acoustic sound-dampening products, mattresses, floor and furniture padding, and thermal shipping insulation (BondedLogicInc, 2014). Phoenix Fibers collects textiles from all over the country in various ways: community donations, clothing sorters and graders, state and local prison systems, commercial laundries, and retail chains nationwide. They have had a longstanding relationship with Cotton Inc. and their Cotton from Blue to Green Campaign, where cotton is collected from all over the US and shipped to their facility in Chandler, AZ, for recycling. Within their 90,000 square foot facility, they can process a variety of materials, including post-industrial cotton scrap, post-industrial and post-consumer denim, and cotton-poly blends. Phoenix Fibers has managed to substantially eliminate waste from manufacturers, to ensure that the materials don't end up in landfills, by forging relationships with manufacturers and retailers that trust them to recycle their products.

Bonded Logic is a company that manufactures natural fiber thermal and acoustic insulation products for multiple industries, using the shoddy fiber produced by its partner, Phoenix Fibers. Their patented manufacturing process allows for a wide range of product densities and thicknesses, while maintaining health and safety regulations. All products are Class-A fire-rated, which represents the highest level of fire protection, and contain no chemicals, irritants, or off-gassing VOCs. UltraTouch™ Denim Insulation, their proprietary brand of denim building insulation, contains 80% post-consumer recycled natural fibers, making it an ideal choice for anyone looking to use a high-quality, sustainable building material. With further attention to environmental impact, Bonded Logic installed a 330 kW solar field—one of Arizona's largest private solar installations—which provides 25% of the energy needed to operate the facility.

United Fibers is a MRF founded in 2006 that specializes in recycling waste materials, including aluminum cans, plastic bottles, paper, pallets, and cardboard, and is similar to Athens Materials Recovery Facility in Los Angeles. United Fibers, within the same facility, has two separate processing lines, which utilize recycled paper to make acoustical and thermal cellulose insulation. Their ability to manufacture two unique product lines sets their facility apart from other cellulose manufacturers. Curbside recycled waste is delivered to the facility, where all recovered paper is processed into acoustic and thermal cellulose insulation at the same location. The process starts with a visual inspection of commingled recyclables. Materials are then decontaminated and go through a series of mechanical screens that remove all other waste streams except paper. The other waste streams (aluminum, plastic, and metal) are baled and shipped to end users globally. At the same time, the recovered paper remains at the facility and is moved directly to the cellulose manufacturing plant. Their equipment then pulverizes, sizes, and refiberizes recovered waste paper into green building insulation. Fire retardants, anti-mold inhibitors, and anti-microbes are added to the mix, yielding a Class-1 insulation product (United Fibers, 2012). The product is then packaged and shipped to consumers in the western US.

Analysis

Phoenix Fibers, Bonded Logic, and United Fibers are private companies that process and recycle textile and paper waste from local and national sources. For comparison, Phoenix Fibers recycles 300 tons, or 600,000 pounds of waste per month, while LASAN is looking to recycle 200 tons, or 400,000 pounds per day. These figures give a sense of the volume of textile waste generated daily in Los Angeles. It would take approximately 20 recycling facilities, similar in size to Phoenix Fibers, to recycle all the waste annually. This is not an impossibility and should be considered a possible solution by LASAN.

Lessons Learned

Traditionally, MRF recycling facilities only handle paper, plastic, and metals; textile waste is directed to a textile recycler. While the Kean family trio of businesses focuses on textile and paper recycling, having an MRF facility under their corporate roof allows them to effectively sort out the paper and direct the plastics and metals to proper end users. This is an example of a true circular waste economy whereby all waste streams are recycled, and materials are used in the on-site production of new consumer products.

While visiting Athens Sun Valley Materials Recovery Facility in LA, we witnessed textile waste being separated from the recyclables and put aside for landfill disposal. If LASAN could solve the problem of separating textile waste streams before reaching recycling facilities or utilizing local facilities that can handle multiple types of waste, including textiles, it could significantly reduce the volume of textiles diverted to landfills.

Conclusion

If LASAN does not have the capacity or desire to establish a circular textile economy under its own roof (one that effectively collects, sorts, recycles, and produces new products), establishing public-private partnerships with local stakeholders at a scale

Photo 12 and 13: RE;CODE bag with sustainability statement (Weiner, 2024)

large enough to handle LA's annual textile waste volume is a viable path to pursue. We strongly encourage LASAN to look at Phoenix Fibers, Bonded Logic, and United Fibers as a highly effective solution that co-locates all necessary services within a local proximity.

9.3. Circular Library - Venice Beach, CA

Background

Circular Library is a concept store in Venice Beach, CA that opened on December 17, 2023. The store houses two South Korean-based brands, Le Cashmere and RE;CODE, which are focused on circularity and sustainable design practices.

The products in Le Cashmere's line are 100% cashmere, and their textiles are all sourced from Mongolian villages. Le Cashmere strongly emphasizes how it interacts with its sourcing locations. Notably, the village goats are never sheared for the cashmere used in the brand's products – rather, all the materials are collected from goat hair that has been naturally shed. Furthermore, Le Cashmere actively cares for the sites where they harvest their materials, planting trees to ensure an ideal ecosystem and grazing pasture for the village goats. Le Cashmere also strongly considers the reuse of their products during production – with scraps – and after the post-consumer stage of a product's life cycle – with collection and eventually reuse (About: Sustainability, n.d.).

RE;CODE, however, takes a different approach to conscious sourcing. The brand uses factory floor cutoffs and deadstock material to produce its products, which fall into three product lines: ZERO COLLECTION, RCD, and ACCESSORY LINE. ZERO COLLECTION loops designers into the process of creating pieces from deadstock. RCD's pieces are created from whatever is left over from the ZERO COLLECTION production process, and ACCESSORY LINE focuses on the production of accessories such as "bags and DIY kits" made of "industrial fabrics, such as airbag materials" (PRODUCT LINE (Pamphlet), n.d.). Additionally, Box Atelier / Re;Table", and "MOL (Memory Of Love) are under the RE;CODE umbrella. Box Atelier / Re;Table is a space that hosts events and classes focusing on textile production and repair, whereas MOL creates custom designs by taking no longer-worn pieces of clothing and turning them into something new.

Analysis

Le Cashmere and RE;CODE are housed under Kolon Industries, based in South Korea. Kolon Industries considers itself to be in the "industrial field…[with] four major business divisions; Industrial Materials, Chemicals, Film/electronic Materials, and Fashion", with Le Cashmere and RE;CODE falling under the Fashion business division (*Intro: We the First & Best, Everywhere in Your Life,* n.d.). Sustainability is integrated into RE;CODE from the start, as Kolon industries sends their "deadstock and various industrial wastes" to RE;CODE and other branches of its fashion division to be given a second life as apparel in the RE;CODE product lines (*Korea's Leading Brand House Where Fashion and Culture Co-Exist,* n.d.).

Photo 14: MOL clothing at Circular Library in Venice (Weiner, 2024)

Photo 15: Close up of MOL's "I Was" button (Weiner, 2024)

Lessons Learned

In the Circular Library and on Le Cashmere's website, most tops sell for $90-795 per item, with pants ranging from $130-650 per item. Likewise, RE;CODE products range from $101-914 for clothing, with accessories starting at $19. Products created under MOL are priced individually. The brand's expansion to the Circular Library in Venice implies they are doing well; it also shows that products made from sustainable and repurposed deadstock materials can sustain a high-end market. However, if LASAN were to attempt to enter such a market, it is unlikely that they would wish to mimic these price levels to ensure that a more economically diverse range of buyers can enjoy their products.

RE;CODE uses innovative marketing techniques to emphasize the creative and individual nature of their one-of-a-kind apparel garments designed for a recycled textiles marketplace. For example, several pieces in the Circular Library had tags that noted the number of similar pieces made, similar to the way original artwork prints are labeled. This exclusivity lets potential buyers know that all products are unique and limited, and justifies a higher price tag. MOL makes new garments from old clothes; each newly designed product has a button showing a photo of the original clothing item and the words "I Was" written over the image. These marketing techniques are innovative, and a similar approach could benefit LASAN by creating a storytelling aspect for products made through their textile recovery project.

Conclusion

Circular Library and the brands showcased at their Venice Beach retail store are great examples of the potential for fabric-to-apparel recycling that a circular system implemented by LASAN could achieve. A proposal like this may be possible once LASAN's textile recovery project is fully functional. Considering local designers for small capsule collections, using post-industrial textile waste, directly aligns with LASAN's current pilot project. LASAN could adopt the marketing and storytelling strategies used by the Circular Library to assist in creating a marketplace and demand for post-industrial textile products.

9.4. Evrnu: Nucycl® | Bevans 360 Hoodie Case Study - Seattle, WA

Background

Evrnu is an advanced material innovation company working to reshape industry resource utilization through infrastructure and technology. Their main technology, Nucycl®, converts textile waste materials into newly engineered fibers that can be recycled countless times (Evrnu, n.d.-b). The patented technology mechanically and chemically reduces virgin cotton into pulp and reconstitutes it into fibers for new clothes. A grading machine separates garments to select those with the highest percentage of cotton, and all other garments are discarded for traditional downcycling (shredded to be used in rugs, insulation, or other lesser-quality products) (Klein, 2023). Evrnu receives cotton-rich waste from production scraps and discarded consumer items (sourced from textile recyclers, brands, and retailers) to engineer their Nucycl® fiber (Evrnu, n.d.-b). Unlike most mechanically recycled cotton, Nucycl® does not require cotton waste to be blended with virgin cotton, resulting in a stronger, more durable fiber that performs similarly or better than virgin cotton or a recycled alternative.

The Seattle-based company is in the process of developing its first commercial manufacturing facility in Spartanburg, South Carolina. This facility is expected to be completed in 2024 and fully operational by 2025 (Deczynski, 2023). Once completed, production of Nucycl® fiber is anticipated to be around 18,000 tons per year, reducing cotton waste and landfill emissions, with a carbon footprint of less than 25,000 CO_2e per year (Evrnu, n.d.-c). Furthermore, typical cotton production consumes 36 million tons of water, whereas Nucycl® consumes less than half a million.

Evrnu assembles prototype fibers for brands whose products require high-quality performance specifications using their Nucycl® technology. In addition, they license this technology to textile mills and supply chain systems for future large-scale manufacturing projects (Benedict, n.d.).

Analysis

The Bevans 360 Hoodie was designed by Christopher Bevans of Bevans Creative Studio, in collaboration with Evrnu (Cernasky, 2024). The hoodie was released as a limited edition product, to introduce the establishment of Evrnu's own in-house brand. While launching a brand is a novel approach for a textile recycler, the hoodie was developed to help create demand for the Nucycl® fiber, showcase its luxe fabric properties, and bypass the need for brand commitments as offtakers of the recycled fiber. Evrnu co-founder and CEO Stacy Flynn acknowledges that brands (offtakers) are willing to pay commodity pricing for fibers but not development pricing, which comes with a high price tag (Cernasky, 2024).

Designed through 3D seamless technology, the Bevans 360 Hoodie was constructed with a blend of Nucycl® fiber and traditional Supima cotton (No Kill Mag, 2024). It exemplifies circular textile innovation with the elimination of production waste, and by featuring a fully compostable, biodegradable, or recyclable material composition. A QR code on the hoodie's label instructs customers of proper end-of-life care, to facilitate the garment's return to a circular system. The hoodie does, however, come with a $600 premium price tag.

Lessons Learned

The fashion industry is often reluctant or unable to act quickly when adopting next-gen materials. One main reason is a lack of commitment from brands and retailers, with a limited ability to allocate funds for early-stage innovation. These challenges are evident in the adoption of Nucycl®, hence the Evrnu's launch of its own brand. Slow uptake from offtakers has the power to bankrupt a company, as seen recently with chemical textile recycling brand Renewcell, once considered a budding industry behemoth (Cernasky, 2024).

Currently, Evrnu's recycling technology only works with 100% cotton fabrics. However, they are working to expand the technology's functionality to include blend-separation technology, which would allow for the recycling of cotton-poly blends and textiles containing stretch (Evrnu, n.d.-a).

Conclusion

Evrnu drives industry change by creating a closed-loop supply chain through effective textile-to-textile recycling. Their technology is well-suited to piggyback onto existing manufacturing infrastructure, however current costs pose a significant barrier for most brands looking to adopt Nucycl® technology into their products. By creating the Bevans 360 Hoodie, Evrnu has changed the game of how a textile recycler can participate in the market, leading as an example in circular fashion and paving the way for other brands to adopt their recycled fibers.

9.5. FABSCRAP - Brooklyn, NY

Background

FABSCRAP is a 501(c)3 company with 12 employees between its Brooklyn headquarters and Philadelphia outpost. They receive approximately 7,000 pounds of pre-consumer textile waste weekly from the tri-state area, generated from independent designers, clothing and furniture brands, and theater productions (H. Willner, personal communication, April 2, 2024). This waste includes fabric headers, swatches, scraps, bolts, upholstery, trim, notions (i.e. buttons, snaps, etc.), and deadstock. Post-industrial textile waste is processed on a case-by-case basis.

Employees and volunteers sort all incoming textiles. Proprietary textiles, meaning fabrics with brand logos or trademarked designs, are managed solely by employees, while volunteers assist with all non-proprietary textiles (H. Willner, personal communication, April 2, 2024). Volunteers receive up to five pounds of materials or garments in exchange for their time. Waste-generating partners are asked to pre-sort materials as proprietary or nonproprietary before arrival at the FABSCRAP facilities. Color-coded bags distinguish between the two types, with only non-proprietary textiles eligible for reuse or resale.

Pickups are regularly scheduled by FABSCRAP using a third-party hauling service and are paid for by the participating partners. While loosely enforced, New York City mandates textile recycling or reuse if waste exceeds 10% of a commercial waste stream (New York City Department of Sanitation, n.d.). Sending waste to landfills is a less costly option, but FABSCRAP encourages partner participation by highlighting environmental and reputational benefits (FABSCRAP, n.d.).

The fate of sorted materials varies weekly, with most being processed for resale in FABSCRAP stores or downcycled into shoddy (H. Willner, personal communication, April 2, 2024). Due to the diverse materials received, including leathers and furs, incoming and outgoing fiber types are not tracked.

Whole and mangled garments, bolts of fabric, fabric scraps, notions, and trims are sold in-store. Unusable scraps are sent to North Carolina for shredding and turned into shoddy (H. Willner, personal communication, March 22, 2024). Shredding operations relocated from New York City to North Carolina due to issues with spandex damaging local shredding machinery, whereas North Carolina-based machinery has superior processing capabilities. FABSCRAP covers the cost of hauling these textiles to the downcycling facility and any related service fees, but receives payment from the downcycler for denim fabric containing less than 10% stretch fiber (H. Willner, personal communication, March 22, 2024).

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Analysis

FABSCRAP's main challenges revolve around spatial and temporal constraints within their recycling services (H. Willner, personal communication, April 2, 2024). Efficient processing is crucial due to the high volume of textile waste, requiring a delicate operational balance between incoming and processed materials. The relentless influx of textile waste underscores the magnitude of the textile waste stream. While sorting technology could help optimize the process, seamless integration with FABSCRAP's manual sorting methods would be key to adoption. According to Hayley Willner, FABSCRAP Community Lead,

> "It is less important for us to identify fabrics through sorting tech and more important to deal with the case-by-case deconstruction necessary to recycle our materials. Tech would need to [understand] the intricacies of our sorting style. Additionally, we are sorting to decide what to resell [versus] downcycle, and each bag/box is diverse" (H. Willner, personal communication, April 2, 2024).

Over 80% of non-proprietary materials have been sorted to date, demonstrating the effectiveness of their current hand-sorting method.

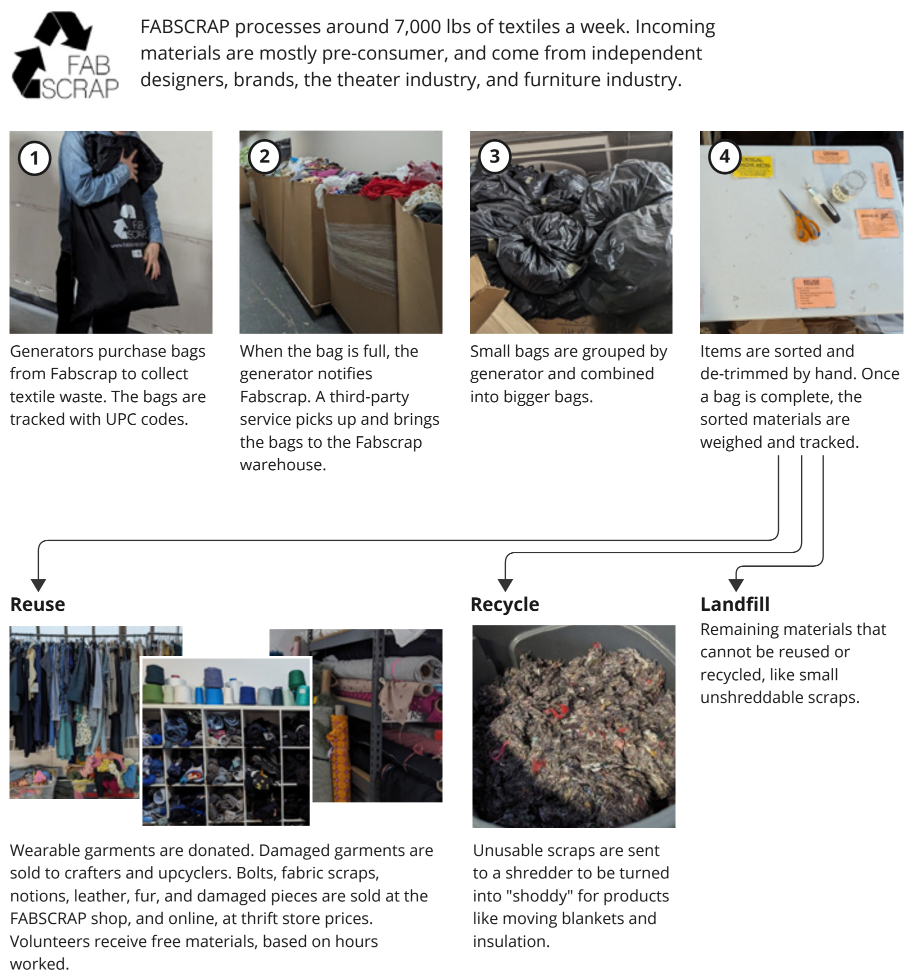

Figure 3: FABSCRAP processing map (Hsiung,Weiner, 2024).

FABSCRAP is committed to monthly education initiatives, including classroom sessions, corporate presentations, panel discussions, and informational interviews. As stated in its 2022 Annual Report, "in encouraging our community to be more mindful of waste, we believe it is equally important to teach skills and techniques required to upcycle, mend, and create with textile waste" (FABSCRAP, 2022).

Lessons Learned

Volunteer engagement and community education on textile waste management are key to FABSCRAP's long-term strategy of textile waste reduction. Additionally, access to sorting technology as a non-profit would require support through incentives, grants, or additional funding. The integration of such technology must align with existing operational processes to be effective. Lastly, additional funding would be necessary to support this technology adoption.

Conclusion

The FABSCRAP model can support process optimization for the proposed LASAN sorting facility or a potential FABSCRAP partnership. Although FABSCRAP does not currently operate in the Los Angeles area, they are open to a LASAN partnership with a caveat: textile waste must be shipped to their warehouse (H. Willner, personal communication, April 2, 2024). While FABSCRAP has been approached regarding West Coast expansion, no plans are being considered at this time. More information on FABSCRAP's recycling program can be found on its website and in its annual report.

9.6. H&M - Stockholm, Sweden

Background

Syre is a textile impact venture co-founded by H&M Group and Vargas Holding in 2023, with a mission to decarbonize and decrease waste in the textile industry through textile-to-textile recycling at hyper-scale (TPG, 2024). H&M Group has secured an offtake agreement with Syre worth $600 million, covering a significant portion of H&M Group's long-term demand for recycled polyester. TPG Rise Climate, the dedicated climate investing strategy of global alternative asset manager TPG, has joined this venture as a founding investor to help bring global climate solutions to scale, focusing on a circular economy.

With this venture, H&M Group hopes to avoid using virgin polyester and the current industry standard of bottle-to-textile recycling, also known as rPET (recycled polyester). Polyester clothing is popular for its many benefits, including durability, wrinkle resistance, elasticity, low cost, and land cultivation, and pesticides aren't required for production. However, polyester is one of the worst fabrics for the planet, as it is a petroleum derivative, reliant on carbon-intensive production, and does not biodegrade (Nizzoli, 2022).

H&M Group has a goal to use 30% recycled materials by 2025, with an ambition of at least 50%, and a total goal to use 100% recycled or sustainably sourced materials by 2030 (H&M Group, n.d.).

Analysis

Scalable technology and infrastructure are significant barriers for any company in the textile industry. Syre aims to provide recycled polyester yarn, of equivalent or better quality to virgin polyester, with a lower environmental impact. Syre is building a production plant in North Carolina, set to be fully operational this year (Syre, 2024). This production plant, along with several others, will provide textile-to-textile circular polyester (cPET) with qualities similar to oil-based virgin polyester, and outstanding sustainability performance, as it reduces CO_2e emissions up to 85% (as compared with the production of virgin polyester fibers) (*Syre | The Rise Fund,* 2024). Their goal is to have 12 plants across the globe by 2034, producing more than three million metric tons of recycled polyester per year (Scott, 2024).

Lessons Learned

Less than 1% of the global textile fiber market comes from recycled textiles, presenting a vast and untapped market (Textile Exchange, 2023b). The textile industry today accounts for 7- 10% of global CO_2e, with polyester being the largest emitter and fastest-growing fiber.

Although North Carolina is on the opposite coast from Los Angeles, and 38 hours away via truck transport, LASAN has an opportunity to foster a relationship with Syre, which is looking for collaborative partnerships across industries.

Conclusion

This venture with Syre is part of H&M's goal to integrate circularity across its business. With their decision to rapidly scale textile-to-textile recycling, they continue to drive and inspire more industry players to help close the loop and shift towards a more sustainable future.

By implementing true textile-to-textile recycling at hyper-scale, there is a drive to transition to a circular supply chain by repeatedly using what would otherwise be discarded textile waste. There ***is*** room in a circular economy for old polyester textiles, and this venture is just one example of where they might fit.

9.7. Olympics - Tokyo, Japan

Background

The 2020 Tokyo Olympics showcased a significant emphasis on sustainability, integrating various eco-friendly initiatives throughout the event. The Games implemented numerous sustainable practices, including using recycled textiles for Team Japan outfits, producing medals from electronic waste, constructing podiums from recycled plastic (Liu, 2020), and aiming to "reuse or recycle 99 percent of all the items and goods procured, and to reuse or recycle 65 percent of all waste" (International Olympic Committee, 2021). Initiatives like the ASICS Reborn Wear Project (Liu, 2020) and Nike's sustainable athleticwear for Team USA (Falk, 2020) exemplified circular production models and corporate partnerships promoting sustainability.

Analysis

The sustainability strategies executed at the Tokyo Olympic games brought environmental efforts to the global stage. Embedding sustainability into all aspects of the games—from team apparel to stage podiums—showcased the range of possibilities for utilizing recycled materials. Vowing to collect and process the majority of the waste created at the event demonstrated Tokyo's commitment to tackling sustainability from all stages of the waste cycle. Leading by example, Tokyo not only elevated the global discourse surrounding sustainability, but also sparked conversations and initiatives that will continue to reverberate long after the Olympic flame has been extinguished.

Lessons Learned

The sustainability initiatives showcased at the Tokyo 2020 Olympics provide invaluable insights for future Olympic host cities like Los Angeles, particularly in the realm of textile recycling and circular economy principles. These initiatives not only align with the Olympic Games' mandate for sustainability, but also set a precedent for innovative collaborations between corporations, organizers, and local communities.

One notable opportunity lies in partnering with apparel brands such as Ralph Lauren, who have been selected as official outfitters for Team USA, to incorporate recycled or upcycled materials into Olympic merchandise. By leveraging the city's textile waste, LASAN can facilitate the production of sustainable apparel items while raising awareness about the importance of circularity and waste reduction, as well as creating local jobs. Further, through collecting textile waste from the event, LASAN can continue to fuel their circular marketplace within the city.

Conclusion

LASAN has the opportunity to leverage the sustainability strategies of the 2020 Tokyo Olympics to enhance their own strategies for the 2028 Los Angeles Olympics. By implementing circular production models, forging strategic partnerships, and prioritizing eco-friendly practices, LASAN can contribute to a more sustainable and impactful Olympic Games.

9.8. OsomTex vs. Säntis - Portland, OR / Paya Lebar Square, Singapore

Background

OsomTex is a textile recycling company founded in Miami, FL and based in Oregon, with a focus on mechanical recycling processes. OsomTex operates on a vertically integrated model, managing the entire recycling process from collection to product sale. Their operations include eco-friendly practices, such as solar power usage and chemical-free and waterless recycling processes. OsomTex specializes in producing longer fibers, allowing them to manufacture yarn and textiles with higher percentages of recycled material. They have established partnerships with brands like Reformation (Osom Brand Media Center, 2019) and Nike to efficiently collect and recycle textile waste, particularly in the Los Angeles market (OsomBrand, n.d.).

Säntis is a Switzerland and Singapore based company specializing in cotton recycling through their Fiber Friendly Textile Recycling technology. Säntis focuses solely on cotton recycling, but achieves impressive results with their technology, preserving the original structure of fibers and fiber length. This technique allows Säntis to produce yarns and textiles with 100% recycled material (Säntis Textiles, n.d.-b). They have partnered with companies like Tommy Hilfiger and Patagonia and utilize FiberTrace for enhanced transparency (Säntis Textiles, 2022). They strategically position themselves near Asian and European manufacturing hubs to facilitate market integration.

Analysis

Both Säntis and Osomtex are examples of mechanical textile recyclers that could play a pivotal role in addressing LASAN's textile waste management needs. Osomtex distinguishes itself with its comprehensive approach to waste processing, accepting a diverse array of materials beyond textiles, including footwear and leather goods. This expansive acceptance policy underscores Osomtex's commitment to maximizing resource utilization and minimizing waste within the fashion industry. Further, Osomtex operates a solar-powered facility, demonstrating a dedication to sustainable energy practices. By harnessing solar energy to power its operations, Osomtex not only reduces its environmental footprint but also contributes to renewable energy generation.

In terms of product composition, Osomtex's recycled textiles stand out for containing up to 95% recycled materials, showcasing the company's emphasis on circularity and resource efficiency (Karan, 2021). By incorporating such a high proportion of recycled materials into its products, Osomtex reduces its reliance on virgin resources and mitigates environmental impact, aligning with principles of sustainability and conservation.

On the other hand, Säntis specializes in producing virgin-like fibers from recycled materials. This capability enables Säntis to offer textiles containing 100% recycled materials, eliminating the need for virgin fibers in textile production (Textile Exchange, 2023a). By providing high-quality textiles made entirely from recycled materials, Säntis contributes significantly to resource conservation and waste reduction, driving the transition towards a circular economy within the fashion industry.

Lessons Learned

In building a circular textile ecosystem, deciding what companies to partner with is complex. While Säntis' advanced technology may offer superior recycling capabilities, the associated transportation emissions must be weighed against the benefits. Localized solutions, such as partnering with Osomtex, can minimize transportation-related emissions but may come with trade-offs in recycling efficiency.

Conclusion

This case study highlights the complex trade-offs inherent in establishing a circular textile system. By exploring various examples like this, LASAN can make informed decisions to drive sustainable practices in textile waste management.

9.9. Prato Manufacturing Hub - Prato, Italy

Background

The Prato textile recycling cluster known as Corertex is a consortium of companies in Prato, Italy, dedicated to textile recycling. It was established by eight companies—six focused on reuse and two on recycling—to collectively address the green transition promoted by the European Union (Corertex, n.d.). The cluster comprises "primary facilities" responsible for recovering post-consumer textiles from the companies involved, sorting them by type and color, sanitizing, and processing them for reuse. Approximately 65% of processed textiles are reused, while the remaining 35% are recycled (Corertex, n.d.). The cluster specializes in mechanical recycling, through a process that transforms used garments back into fibers without additional dyeing. They utilize recycled water from an industrial purification plant and conduct thorough post-processing testing for pathogens. The fibers can then be spun back into yarn and utilized by the associated companies in their supply chain.

Analysis

Corertex's innovative model of co-location exemplifies a paradigm shift in the textile recycling landscape, showcasing effective collaboration among multiple stakeholders within the industry. By bringing together various companies involved in different stages of the recycling process, Corertex not only streamlines operations, but also fosters a holistic approach towards sustainability.

In the context of LASAN's pilot project, which aims to establish a circular industrial ecosystem in Los Angeles, Corertex's model aligns seamlessly with LASAN's overarching goals. Through its collaborative framework, Corertex facilitates the integration of diverse entities, from textile manufacturers to recycling facilities, promoting the efficient utilization of resources and reducing waste generation.

Further, Corertex's emphasis on collaboration echoes the ethos of circularity central to LASAN's initiative. Rather than operating in silos, participating companies within Corertex's network engage in synergistic partnerships, exchanging materials and knowledge to optimize the recycling process. This not only enhances resource efficiency, but also cultivates a culture of innovation and continuous improvement within the ecosystem.

By leveraging the collective expertise and resources of multiple companies, Corertex's model embodies the spirit of collaboration essential for the success of LASAN's pilot project. Together, these initiatives pave the way for a more sustainable future, where industrial ecosystems operate in harmony with the environment, fostering economic growth while minimizing ecological footprint.

Lessons Learned

Corertex demonstrates the effectiveness of co-location and collaboration in building a robust circular ecosystem. LASAN can learn from this model, understanding the value of incentivizing participation and fostering partnerships. By creating a system where stakeholders can interact, LASAN can encourage organic collaboration. Additionally, adopting incentives like financial rewards and preferential access can motivate participation. LASAN can also prioritize partnerships across the textile industry value chain to ensure comprehensive coverage in its efforts towards a circular economy.

Conclusion

Corertex serves as a compelling example of how collaboration among stakeholders can drive innovation and sustainability within the textile recycling industry. Its success in establishing a cohesive cluster of companies dedicated to recycling and reuse showcases the potential for similar models to thrive in other regions. Corertex exemplifies how collaborative frameworks can effectively integrate diverse entities, streamline operations, and reduce waste generation. LASAN can draw valuable insights from Corertex's emphasis on co-location, incentivization, and partnership building as it seeks to replicate and adapt these strategies to its own initiatives.

9.10. Renewcell - Sundsvall, Sweden

Background

Renewcell is a Swedish textile recycling company. In November 2022, Renewcell built the world's first-ever industrial-scale textile-to-textile chemical recycling facility in Sundsvall, Sweden (Renewcell, 2023). At this facility, Renewcell produces CIRCULOSE® pulp—a biodegradable next-gen material made from cotton textile waste—used to create virgin quality viscose, lyocell, and other man-made cellulosic fibers. Renewcell's advanced chemical recycling process requires a highly specific waste input of at least 95% virgin cotton, sourced through post-industrial and post-consumer textile waste.

Canopy—a company that works with brands across multiple industries, including fashion, to bring forest-saving solutions from the margins to the mainstream—introduced Renewcell to a major viscose producer, in turn facilitating its first offtake agreement (Hudema, 2022). From there, major brands like H&M, PVH (parent company of Tommy Hilfiger), and Inditex (parent company of Zara) also agreed to buy CIRCULOSE® in multi-year offtake agreements, leading to waves of media buzz and anticipation in the capabilities of Renewcell's recycling technology (Wenzel, 2024).

Renewcell received this attention from major brands and retailers because of its ability to scale faster and further than other, similar companies. It had what can be best described as an "early-mover advantage" in the textile-to-textile recycling space. This head start was possible thanks to existing knowledge and experience from within the company, as well as access to existing machinery and infrastructure such as pulp factories, with processes and equipment similar to that which was needed for Renewcell's operations (Holding, 2024).

Renewcell filed for bankruptcy in November 2023 due to its inability to secure the funds needed to complete its strategic review. These strategic reviews included advanced negotiations with Renewcell's largest shareholders, existing lenders, potential new investors, and other stakeholders regarding long-term financing solutions. These negotiations ended unsuccessfully, unable to achieve plans for a long-term solution that would give Renewcell the necessary liquidity and capital to move forward with its business operations.

Analysis

Renewcell's main function was to chemically recycle post-consumer textile waste into CIRCULOSE®, which was then sold to textile manufacturers and producers. Renewcell's business model was designed to place the burden of ordering CIRCULOSE® on brands. This is different from typical apparel supply chain structures, where very few brands purchase production materials directly from the source. Furthermore, CIRCULOSE® pulp, which is sold to other companies for yarn and fabric production, did not have vertical integration. This meant that third-party spinners and weavers had to adapt their existing processes in order to use CIRCULOSE®, leading to increased expenses for interested brands.

CIRCULOSE® was twice as expensive as other recycled materials, making it less attractive to potential offtakers (Wenzel, 2024). At its peak, Renewcell sold its product to 116 companies, and although there was plenty of interest, orders were slow to materialize.

Lessons Learned

The company's financial instability was reportedly due to a lack of brand orders. The reluctance to place orders indicates the absence of a business case for Renewcell's CIRCULOSE® fibers in the competitive and price-driven textile supply chain. Renewcell had supply agreements with two major fiber manufacturers to produce their CIRCULOSE®, but only sold 18,000 of the 60,000 metric tons of the materials they produced, which was not enough for Renewcell to break even (Hernanz Lizarraga, 2024). While other manufacturers expressed interest in CIRCULOSE®, they were only willing to buy more feedstock with secured brand orders. Renewcell simply ran out of money before it could iron out production issues and secure consistent purchase orders. While inadequate access to capital has been a roadblock for many companies seeking to integrate sustainable solutions into their production supply chains, relying on fiber demand from brands was Renewcell's fatal flaw.

Additionally, the adjustments to existing production equipment due to the composition of CIRCULOSE® pulp resulted in significant disruptions to manufacturing operations, which ultimately led to inconsistent product output. Further, without a stable supply of CIRCULOSE® pulp, convincing spinners to overhaul their operations and invest in new equipment was difficult.

Conclusion

Renewcell's main reasons for failure can be summed up in three reasons. First, they lacked basic economics; CIRCULOSE® costs twice the price of alternative materials, and textile factories already operate on thin margins, making it difficult to sell and thus make a profit. Second, the fashion industry's mindset has traditionally been based on a "take, make, and waste" linear model, where companies claim to want more sustainable manufacturing but don't have the capacity or resources for the transitions necessary to make it happen. Finally, Renewcell was unable to persuade global supply chains to retool operations in favor of its product (Wenzel, 2024). Major brands were excited about this next-gen material, but the complexities of implementation ultimately outweighed the interest.

10. Circular Mapping & Analysis

10.1. Summary

This section explores pathways for post-industrial textile waste through open and closed-loop circular systems. Given the current textile reuse and recycling landscape, we have developed five scenarios to consider how textile waste can flow through these systems. Scenarios include open-loop through reuse, open-loop through mechanical recycling, closed-loop through mechanical recycling, open-loop through chemical recycling, and closed-loop through chemical recycling.

We have mapped several pathways within each scenario to illustrate the various possibilities within these circular systems. These pathways are not meant to be prescriptive, but rather to highlight potential routes for post-industrial textile waste. In practice, there are numerous potential pathways.

We have highlighted the benefits and drawbacks of each pathway based on LA-specific local versus non-local solutions and different recycling technologies through the lenses of GHG emissions, economic impact, and environmental justice. The three lenses were chosen based on what we felt were the most impactful criteria to analyze and consider when developing a new circular economy. We chose specific industry actors in each pathway for several reasons, including the availability of data, ease of example, and our desire to spotlight a particular company or technology. In practice, any relevant partner (current or future) could be switched to another that performs the same service. It is important to point out that each step within a pathway introduces a new set of variables which need to be considered through local versus non-local solutions, recycling technologies, and the lenses mentioned above in order to optimize each pathway. Trade-offs will always need to be considered.

We have assessed GHG emissions through quantitative data and assumptions based on distance traveled and activities performed. We have also designed a greenhouse gas estimating tool to provide a baseline carbon footprint account for each pathway and compare pathways for potential emissions saved. Our efforts to calculate GHG emissions are limited to one sample pathway that looks at a closed-loop, textile-to-textile system that mechanically recycles cotton with local and national stakeholders. The overview of this tool, as exemplified through a scenario pathway, can be found in the GHG Emissions Estimator section 11.

We have assessed economic development and environmental justice through quantitative and qualitative data, including geographic location and proximity to other industry actors, size of business, number of employees, economic stability, and sustainable practice. We have examined the different scenarios and provided feedback on their benefits and drawbacks relative to the specific pathways and chosen stakeholders.

10.2. Scenario 1: Open-Loop through Reuse/Upcycle

Example Pathways:

A. PDR Knitting - Knit Mill, Development, and Small-Scale Production *(local)* - Cotton/Poly Blend > LASAN Sorting Facility *(local)* > Local Designer Limited Drop *(local)*

Figure 4: Diagram of circular pathway (Weiner, 2024).

B. Laguna Fabrics - Textile Manufacture *(local)* - Cotton/Poly Blend > Homeboy *(local)* > Online Marketplace - Poshmark > Sale *(non-local)*

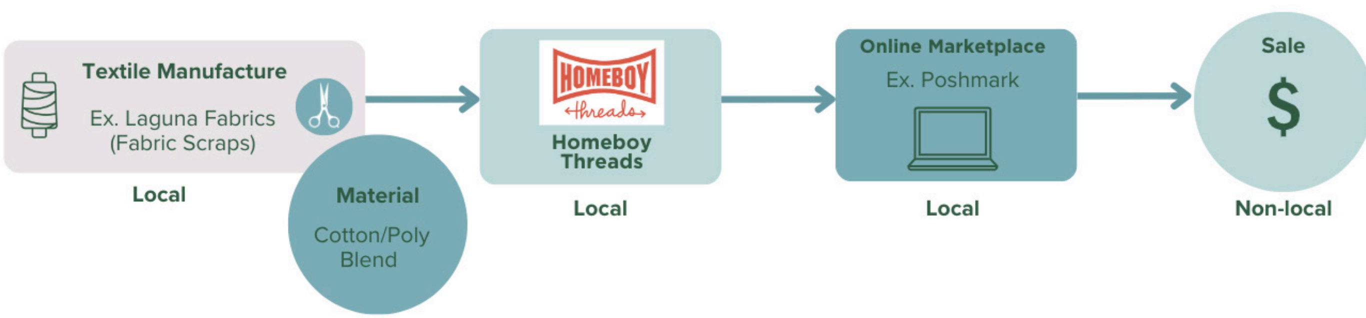

Figure 5: Diagram of circular pathway (Weiner, 2024).

C. F&F Knitting Mills - Textile Manufacturer *(local)* - Mixed Fibers/Unknown > LASAN Sorting Facility *(local)* > Earth Angel Partnership *(local)*

Figure 6: Diagram of circular pathway (Weiner, 2024).

Scenario Notes:

- Reuse is a preferred pathway, as no additional processing is required for the textile waste.
- Based on current textile recycling capabilities, reuse is preferred for mixed fiber fabrics or fabrics with unknown contents, which may have processing limitations.
- Pathway A considers a small-scale solution to repurpose factory floor cut-offs or an unknown influx of fabrics, where limited-release drops can use these unknowns, and smaller brands/designers can be more agile in production planning. The *Circular Library Case Study* (section 9.3) spotlights this potential within this model.
- Pathway C explores partnerships with alternative industries. See Literature Review/Alternative Uses (section 5.5) and Outreach/End Users (section7.5) for further details on this end-use proposal. This pathway example features Earth Angel, a mission-driven LLC that aims to reduce the carbon footprint of TV and film productions—a significant industry in Los Angeles and a major producer of waste (Earth Angel, 2024). Further, Earth Angel works to encourage and facilitate the uptake of material reuse on set.

Lens Considerations:

GHG: Local solutions can significantly reduce the impact of GHG emissions through a more localized supply chain. Additionally, while reuse is ideal for not further processing textile waste, future end-of-life should also be considered. Ideally, any offtakers under this scenario would entertain a responsible end-of-life pathway at the end of the reused textile waste's secondary life cycle.

Economic Development: Local solutions offer the possibility of creating local jobs. Increased capacity for local sorting, whether through the proposed implementation of a LASAN sorting facility, an outsourced partner facility, or bringing sorting tech to Los Angeles, would add new positions to the current local workforce. An interview with Lynn Wagner, founder of Luna reFab, a California-based textile-waste recycler and fabric regenerator and HUB participant, highlights the need for a more optimized sorting system to support better recycler uptake of textile waste (L. Wagner, personal communication, March 28, 2024). Partnerships with local designers, brands, and NGOs contribute to the local economy. They can be a storytelling opportunity—highlighting the benefits of this program at the city, state, and national level.

Environmental Justice: Considerations must be given to the neighborhoods most affected by the routes of haulers, particularly if additional pickups are added. During a tour of Matchmaster, a Los Angeles-based dyehouse, we noted that four dumpsters are filled and emptied daily (M. Hensley, personal communication, March 14, 2024). A separate textile waste stream, while potentially reducing trash accumulation and pick up, would add an additional hauler pickup from the waste generator facility. Conversely, environmental justice communities, most commonly living in close proximity to landfills and burn facilities, could see a potential improvement in both air and water quality with a reduction in activity at these facilities (Yang, 2021).

10.3. Scenario 2: Open-Loop through Mechanical Recycling

Example Pathways:

A. Pacific Blue Denim - fabric wholesaler *(local)* - Denim > LASAN Sorting Facility *(local)* > Phoenix Fibers - Recycling/Shredding Facility *(national - Chandler, AZ)* > Bonded Logic - UltraTouch Denim Insulation *(national - Chandler, AZ)*

Figure 7: Diagram of circular pathway (Weiner, 2024).

B. Antex Knitting Mills / Matchmaster - Textile Manufacturer *(local)* - Polyester > LASAN Sorting Facility *(local)* > UNIFI *(national - Madison, NC)* > Solmax Geotextiles *(national - Houston, TX)*

Figure 8: Diagram of circular pathway (Weiner, 2024).

Scenario Notes:

- Scenario 2 pathways explore partnerships with alternative industries beyond fashion and apparel.
- Pathway A employs denim as an alternative to conventional fiberglass insulation. For more information on this process, see the Phoenix Fibers / Bonded Logic / United Fibers case study (section 9.2).
- Pathway B looks at using recycled post-industrial poly scrap and deadstock to produce agrotextiles and geosynthetic textiles. These textiles have many industrial uses, including agriculture, land conservation, and aquatics. Post-industrial polyester is chemically recycled and turned into fiber and yarn, which can be used to reproduce new textiles, including agro and geosynthetic products.

- UNIFI is a global mechanical textile recycler with production capabilities worldwide. Within the United States, they have facilities in Madison, Reidsville, and Yadkinville, NC. UNIFI's unique Textile Takeback™ process takes textiles "from the factory floor to the sales floor" by processing fabric waste into fiber and then into yarn sold under the brand name Repreve™, which can be used to make anything from clothing to shoes, bags, and geotextiles. (*Sustainable. Certifiable. Recycled. High-Quality Performance Fiber.,* n.d.).
- Phoenix Fibers and Bonded Logic's internal language considers their denim recycling process to be closed-loop—which varies from general sustainability language that defines this pathway (from textile to alternate use) as open-loop.
- Solmax is a global geosynthetic textile company that uses, on average, 13% pre-consumer recycled poly to produce new geotextile products. (*Solmax | Home - Geosynthetics for Civil + Environmental Infrastructure,* n.d.)

Lens Considerations:

GHG: Calculations would need to be performed to best assess the total carbon impact of these pathways. However, it can be assumed—based on an average building lifetime of over 50 years (Bathurst, 2023)—that the carbon impact could be amortized over the building's lifetime, possibly yielding a GHG impact less than that of a more traditional circular scenario. Both pathways include local- and national-based solutions, which further reduce GHG impacts, as opposed to closed-loop solutions that rely on global production partners.

Economic Development: In alignment with California's leadership in environmental progress and standards, spearheading open-loop textile recycling supports Los Angeles's goal to divert 90% of its solid waste by 2025 and achieve net zero by 2045 ("Zero Waste LA County," n.d.). Addressing this locally (or nationally) also bolsters the creation of green jobs and supports the economy.

Environmental Justice: As with the above scenario pathways, considerations must be given to the neighborhoods most affected by haulers' routes, particularly if additional pickups need to occur. Conversely, as mentioned in Scenario 1, environmental justice communities, typically located near waste facilities, could experience improvement in air and water quality through a meaningful reduction of landfill and waste-burning activities. Additionally, to support the growth and use of recycled textiles in alternate industries, communities previously impacted by environmental injustice should be given priority for training and employment in the growing field of green jobs (Potter, 2023).

10.4. Scenario 3: Closed-Loop through Mechanical Recycling

Example Pathways:

A. Matchmaster - Textile Manufacturer *(local)* - Cotton > LASAN Sorting Facility *(local)* > OsomTex *(national - Oregon)* > Matchmaster *(local) to knit into new fabric*

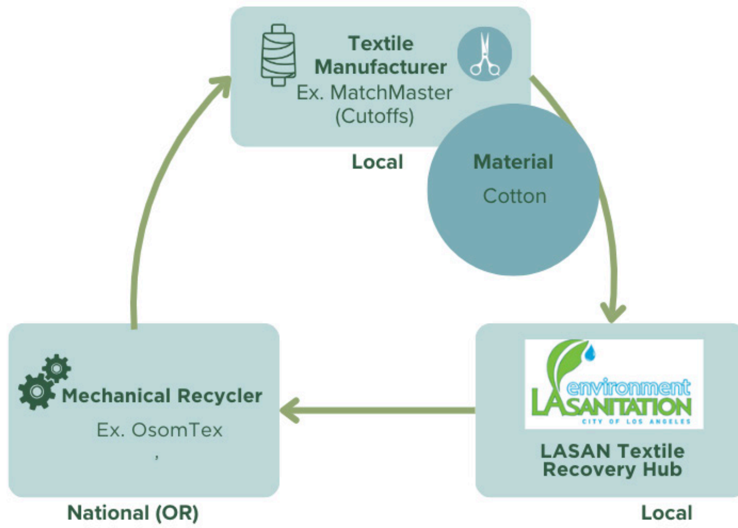

Figure 9: Diagram of circular pathway (Weiner, 2024).

B. Antex Knitting Mills / Matchmaster - Textile Manufacturer *(local)* - Cotton > LASAN Sorting Facility *(local)* > Säntis *(global - Switzerland/Singapore)* > Antex Knitting Mills / Matchmaster *(local) to knit into new fabric*

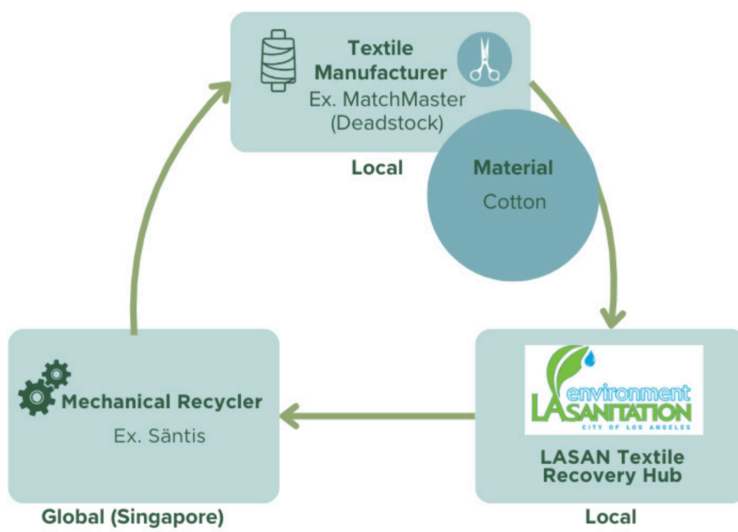

Figure 10: Diagram of circular pathway (Weiner, 2024).

Scenario Notes:

- Mechanical recycling usually requires reducing fiber staple length (Pandit et al., 2020). Continued fiber length degradation limits the number of times a previously recycled textile can be recycled again. Further, reducing fiber length equates to reducing tensile strength, resulting in the need to mix with virgin fibers.
- Matchmaster represents a textile waste generator and a textile knit/weave facility in the above pathways, highlighting the potential for a fully closed-loop pathway.
- Both mechanical recyclers, Osom and Säntis, can spin yarn. In the above pathways, it is assumed this is done on-site, with yarn sent back to Matchmaster for inclusion in new knitted fabrics.
- Both Osom and Säntis produce fabric from their feedstock in addition to yarns. This process could be considered if the original waste generator is not interested or incentivized to reinvest in the recycled yarn as new feedstock. Further, yarn-to-fabric at the recycling site has the potential to reduce GHG impact, depending on the fabric's final destination.
- OsomTex accepts post-consumer and post-industrial textile waste. Their recycling process eliminates water, dyes, and harsh chemicals. Recycling facilities are located in Miami, FL, with brand production in Guatemala. Some brand fabrics are 100% recycled, some are mixed with virgin fibers or recycled plastic bottles (OsomBrand, n.d.).
- Säntis accepts post-industrial textile waste and pre/post-consumer garments. They sort by color and composition. No chemicals or water are used in their recycling process, which creates long staple fibers, in line with virgin fiber length. They produce recycled cotton, cotton/poly, viscose, and viscose blends (Säntis Textiles, n.d.-b).

Lens Considerations:

GHG: Besides GHG emissions stemming from transportation, emissions from production and end-of-life must also be considered. The above pathways spotlight two mechanical recyclers with different capacities. A more local solution: OsomTex, a US-based HUB-listed partner, states that its recycling methods produce an "improved fiber length," enabling more recycled materials to be used in its products (OsomTex, n.d.-a). However, many of its products are still mixed with virgin fibers, as traditional mechanical recycling techniques shorten the fiber staple length (Celep et al., 2022). While offshore, Säntis, a Swiss-based mechanical recycler, highlights the potential for increased circularity through technology that enables maximum fiber staple length through its RC100 recycling system (Wilson, 2023). See the *Osom vs Säntis Case Study* (section 9.8), for a more in-depth look at these two companies.

Economic Development: The above pathways may increase the need for local haulers. If not, these pathways contribute little to local job creation. However, if implemented at scale, establishing a local LA-based mechanical recycling facility would have the potential to help build a green job market. Säntis, for example, licenses out its technology, though its method is limited to cotton recycling (Säntis

Textiles, n.d.-b). While unable to get an exact number of employees from either business, LinkedIn lists 11-51 employees with OsomTex (OsomTex, n.d.-b) and 51-200 employees with Säntis (Säntis Textiles, n.d.-a). Further, Kipas—a Säntis production partner—is part of Kipas Holdings, a conglomerate of 25 companies with over 10,000 employees, and 400,000 tons of yarn and 100 million meters of woven fabrics passing through its vertical operations annually (Wilson, 2023). These figures help paint a picture of how many jobs could be created through local textile recycling. A successful textile recovery pilot could help position Los Angeles as an attractive host for further textile recycling activities. Incentives could help lure businesses to Los Angeles to partake in this circular textile ecosystem.

Environmental Justice: As with the above scenario pathways, considerations must be given to the neighborhoods most affected by haulers' routes, particularly if additional pickups need to occur, while neighborhoods close to waste management facilities could improve air and water quality.

10.5. Scenario 4: Open-Loop through Chemical Recycling

Example Pathways:

A. Ari Jogel - Cut-and-Sew Shop *(local)* - Polyester > LASAN Sorting Facility *(local)* > Ambercycle *(local)* > Electronic/Automotive *(local)*

Figure 11: Diagram of circular pathway (Weiner, 2024).

Scenario Notes:

- This pathway explores partnerships with alternative industries. Ambercycle, a local Los Angeles company that reconstitutes PET into virgin-grade pellets through its recycling and recovery process, has applications in the electronic, automotive, and apparel industries (Ambercycle, 2024).
- At present, all Ambercycle processing facilities are overseas, with the exception of a small LA-based lab. While Ambercycle has hopes of building out a local factory, funding such has been an issue (Billington, 2020). This pathway assumes the establishment of an LA-based processing facility.
- A partnership with Ambercycle could be an opportunity to champion their aspirations to build-out a local processing facility at scale.

Lens Considerations:

GHG: In an entirely local pathway, emissions are reduced to local transportation routes, leaving the bulk of emissions related to the recycling and production processes.

Economic Development: As mentioned in the above scenarios, local pathways contribute to local job creation and economies. Ambercycle was contacted; however, as their interview answers are confidential, LinkedIn states the company has 11-50 employees (Ambercycle, 2024). Establishment of a local processing facility, at scale, has the potential for the establishment of new jobs within the textile recycling ecosystem. Partnership with a local recycler, such as Ambercycle, could support the company's development and success, leading to further growth and local job creation.

Environmental Justice: As with the above scenario pathways, considerations must be given to the neighborhoods most affected by haulers' routes, particularly if additional pickups need to occur, while neighborhoods close to waste management facilities could improve air and water quality.

10.6. Scenario 5: Closed-Loop through Chemical Recycling

Example Pathways:

A. 9B Apparel - Cut-and-Sew Shop *(local)* - Polyester > LASAN Sorting Facility *(local)* > Ambercycle *(local)* > Shinkong Synthetics - Spinner *(global - Taiwan)* > F&F Knitting Mills - Textile Manufacturer *(local)* > LA Based Brand *(local)* > 9B Apparel - Cut-and-Sew Shop *(local)*

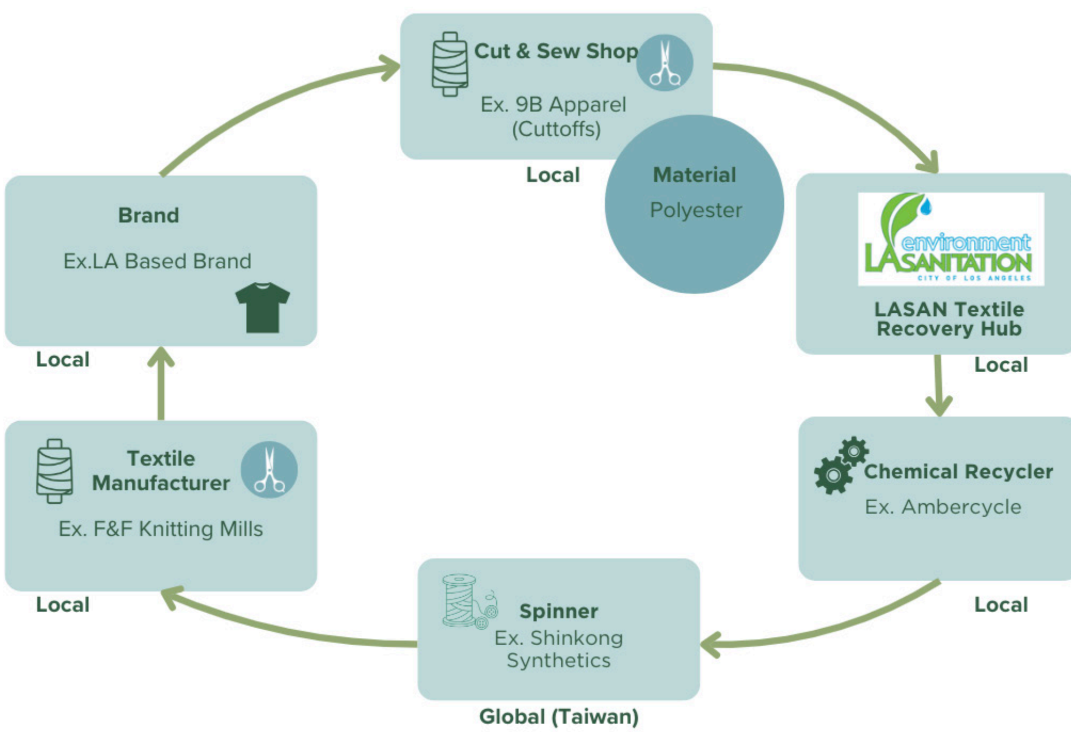

Figure 12: Diagram of circular pathway (Weiner, 2024).

B. Balance Pattern - Sample and Pattern Making Shop *(local)* - Cotton > LASAN Sorting Facility *(local)* > Evrnu *(national - Seattle, WA)* > Cut & Sew - Evrnu Nucycl® | Bevans 360 Hoodie *(national - USA)* > Customer *(national - USA)* > Evrnu *(national - Seattle, WA)*

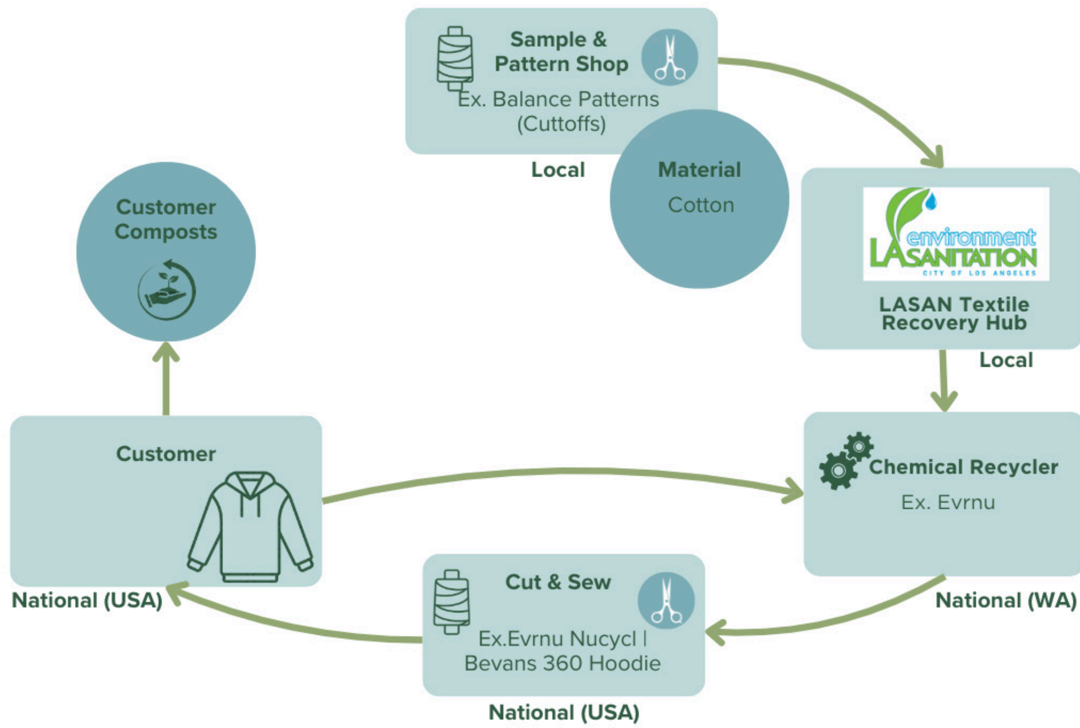

Figure 13: Diagram of circular pathway (Weiner, 2024).

C. Lefty Production Co. *(for LA-based brand)* - Cut and Sew Shop *(local)* - Cotton/Poly Blend > Worn Again Technologies - Sorter/Recycler/Textile Manufacture *(global - Switzerland)* > Lefty Production Co *(for LA-based brand)* - Cut and Sew Shop *(local)*

Figure 14: Diagram of circular pathway (Weiner, 2024).

Scenario Notes:

- Chemical recycling enables fibers to be recycled multiple times without reducing their quality, and has the capability to produce fibers on par with or stronger than virgin materials (Pandit et al., 2020).
- As mentioned in the summary, textile-to-textile recycling is considered closed-loop. To further highlight the potential for fully circular pathways, the above three pathways assume partnerships between all players to enable this fully circular system. As the status of this partnership is unknown, other players may need to be substituted to achieve such.
- Various fiber contents are highlighted in these pathways based on each chemical recycler's specialty.
- Pathway A requires processed PET pellets to be turned back into fiber and spun into yarn. While Ambercycle is a local company, there are no spinners in Los Angeles with this capability. Shinkong Synthetics is identified as the spinner based on its known partnership with Ambercycle (Ambercycle, 2023).

- Pathway B explores a newly innovative solution to combat the need for brand buy-in for the offtake of recycled materials (for further details, see the Evrnu Case Study (section 9.4). In this pathway, sampling is assumed to be done via 3D design, and therefore, no physical product sampling of the garment is required.
- Pathway B has two circular garment end-of-use options: return to Evrnu for recycling or compost the garment by burying it in an at-home backyard setting, which is a biologically circular activity.
- While global in scope, Pathway C features Worn Again Technologies, which acts as a sorter in addition to its textile recycling services and textile manufacturing. This pathway could eliminate the need for an outside sorting facility, proving potentially useful for “mom-and-pop” cut-and-sew shops that cannot integrate pre-sorting into their workflow. Further, this option could be useful for brands willing to place consistent purchase orders as offtakers.
- Ambercycle accepts post-industrial and post-consumer textiles (Ambercycle, n.d.). From recycled feedstock, they produce Cycora®, a high-quality regenerated polyester. In 2023, Inditex committed to a three-year purchase partnership for Cycora® (Ndure, 2023).
- Evrnu accepts “cotton-rich textiles and production waste” (Deczynski, 2023), from which they produce Nucycl®, a lyocell fiber. Their commercial manufacturing facility is open as of 2024 and is slated to be fully operational by 2025, with the ability to manufacture 18,000 tons of Nucycl® fiber per year (Deczynski, 2023).
- Worn Again Technologies is a sorter and recycler. They accept post-industrial and post-consumer textile waste, and sort onsite with automated sorting technology. A preprocessing step removes “disrupters” (buttons or zippers) and downsizes material to Worn Again’s requirements (Worn Again Technologies, n.d.). From waste inputs, they produce cotton and polyester yarns and fabrics. They are a UK-based company with an industrial-scale facility in Switzerland. While a partnership with a company like Worn Again could reduce the need for a sorting facility, collection from a waste generator to Worn Again would need to be coordinated.

Lens Considerations:

GHG: Due to the fragmented nature of the Los Angeles apparel industry, the impact of the above example pathways on emissions could vary greatly. Industry outreach and interviews revealed closed-loop textile-to-textile recycling to be a preferred scenario. However, as exemplified in the above pathways, these scenarios could have significant GHG emissions impact based on their national or global scale.

Economic Development: As mentioned in the above scenarios, local pathways enforce local economies. However, if the recycled yarns or fabrics return to Los Angeles for production, these pathways would still support the LA garment manufacturing hub, which, according to Nayantara Banerjee of The Garment Worker Center, employs around 30,000 industry-based workers (N. Banerjee, personal communication, March 13, 2024).

Environmental Justice: As with the above scenario pathways, considerations must be given to the neighborhoods most affected by haulers' routes, particularly if additional pickups need to occur, while neighborhoods close to waste management facilities could improve air and water quality.

10.7. Scenario Spotlight

Pre-Sorting/Generator Sorting On-Site

Matchmaster is an example of a waste generator that expressed the capacity and willingness to pre-sort on-site. While pre-sorting on-site may eliminate the need to transport textile waste to an external sorting facility, thereby reducing a step (and, as a result, potentially reducing GHG emissions) in the circular process, several elements need to be considered:

- Appropriate collection bins would need to be provided.
- Regular coordinated pickups would need to be arranged. Matchmaster, for example, fills four dumpsters a day with mixed waste, which are emptied daily. As square footage is in short supply for LA-based factories, consistent waste pickup is a vital part of daily factory operations.
- Hauling and determining the party that is responsible for paying for hauling services would need to be arranged.
- Depending on the end use, pre-sorting on the factory floor may still require additional sorting.
- Pre-sorted waste may still need to be transported to the LASAN facility to enable proper delivery to the recycler.
- If the contents of pre-sorted waste can be tracked appropriately, it may be possible to transport the waste directly to the recycler, bypassing the step of an external sorter.

Benefits:

- Reduced transportation GHG emissions by reducing the need for an external sorting facility.
- Reduce energy consumption at external sorting facilities.

Drawbacks:

- Waste may not be properly sorted.
- Waste may contain contaminants.
- Waste may still require transfer to an intermediary facility for further processing/shipping preparation.

Incentives:

- In addition to the necessary infrastructure to facilitate on-site textile waste sorting, incentives should be considered to encourage factory participation. Potential incentives could include subsidized collection, tax breaks, penalties for lack of program uptake, and penalties for non-compliance.

11. GHG Emissions Estimator

11.1. Summary

To assist LASAN in analyzing the environmental impact of waste recovery approaches with regards to GHG emissions, we have developed a GHG Emissions Estimator. This tool is a comprehensive Excel-based solution tailored to compare potential GHG emissions reductions achievable between a base case scenario and alternative waste recovery approaches for post-industrial textile waste in Los Angeles. By providing LASAN with actionable insights into the environmental implications of different strategies, the GHG Emissions Estimator plays a pivotal role in guiding informed decision-making towards achieving a more sustainable circular economy.

11.2. Data Management

The GHG Emissions Estimator is designed to be a user-friendly tool that supports LASAN's sustainability initiatives in multiple ways. It incorporates a robust data management framework to streamline the collection, organizing, and analysis of key information relevant to emissions calculations and scenario comparisons. While not a database, the tool relies on structured data input and management to ensure accuracy and consistency in emissions assessments. Users are guided to input activity data, emission factors, and scenario parameters within the Excel interface, facilitating efficient data handling and manipulation. Definitions of key terms such as Process Map, Functional Unit, Emissions Avoided, and Emissions Created provide clarity and understanding of the terminology used throughout the Estimator, enhancing user comprehension and utilization. Adherence to guidance such as the GHG Protocol further underscores the Estimator's commitment to compliance and accuracy in reporting. This structured approach enables LASAN to track and compare emissions across different scenarios, empowering them to make informed decisions aligned with their sustainability objectives.

11.3. Use

To understand the impact of shifting to a circular approach on GHG emissions, and to understand the utility of the GHG Emissions Estimator, we have considered an example that presents a base case of a 100% cotton fabric production process (business-as-usual scenario) with an alternative scenario of circular waste recovery for 100% cotton fabric.

In the base case scenario, 10,000 pounds of cotton textile waste are generated daily at the manufacturing stage and are directly discarded through landfilling without any recovery or recycling processes. Conversely, in the alternative circular scenario, waste generated at the textile manufacturing stage is diverted to LASAN's sorting facility, where it undergoes mechanical recycling into cotton fiber (assuming a 100% conversion rate), and is reintroduced into the textile manufacturing process, effectively closing the loop. The 10,000 pounds of cotton textile waste generated at the textile manufacturing stage is the common functional unit for both scenarios, facilitating comparison.

The first step in using the Estimator involves developing process maps for both scenarios to identify all emission points, as shown below.

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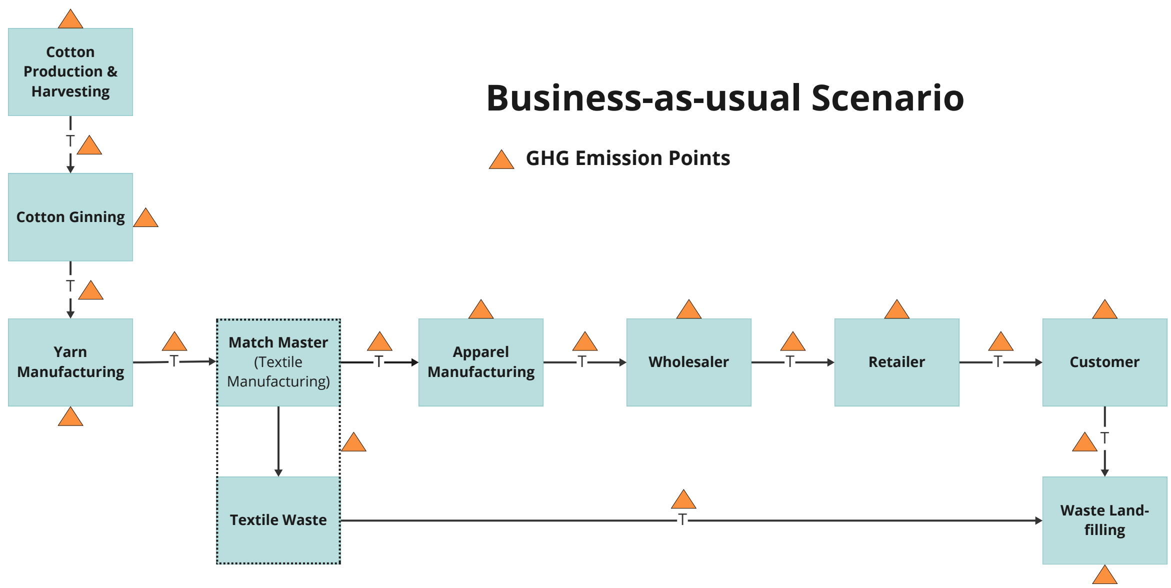

Figure 15: GHG Estimator Process Map Sheet, Business-as-Usual (Dabur, 2024)

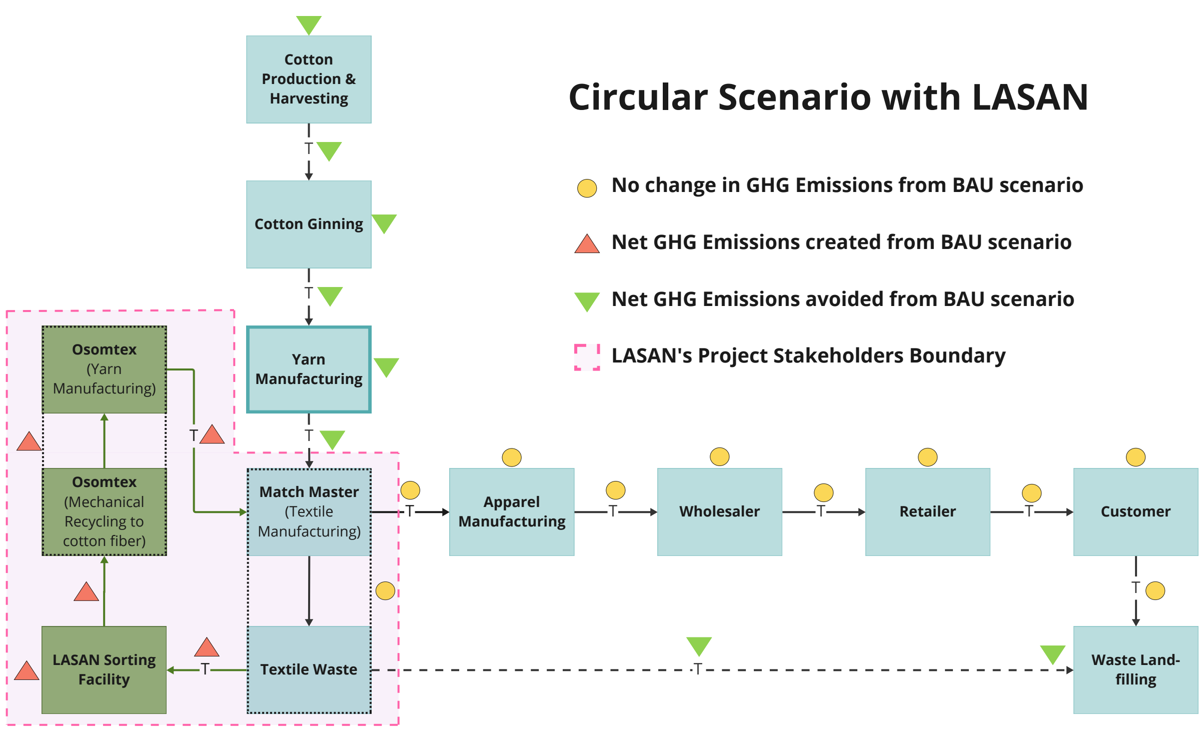

Figure 16: GHG Estimator Process Map Sheet, Circular Scenario (Dabur, 2024)

As shown in the process maps, all the identified emission points in the circular scenario are categorized into three categories: Net GHG Emissions Created, Net GHG Emissions Avoided, and No Change in GHG Emissions. Emissions Created are the activities leading to increased emissions from the business-as-usual scenario to the circular scenario. It could be possible due to an increase in material use, the addition of new activity in the system, etc. Emissions Avoided are the activities resulting in reduced emissions from the business-as-usual scenario to the circular scenario which could be possible due to reduced material use, deployment of an energy efficiency strategy, etc. No Change in Emissions are the activities showing no net change in emissions between the scenarios as all the variables of these activities remained unchanged between the business-as-usual scenario and the circular scenario. Once all the emission points are identified and categorized, product life cycle activities are listed in the corresponding sheets of the Estimator based on these categories. Next, activity data based on the variables associated with each activity is collected and inserted into the relevant columns of the Emissions Created and Emissions Avoided sheets. Because primary data for the given example was unavailable during the project, some assumptions and estimations were made, as shown in Table 2. For future use, LASAN must gather the necessary data for accurate calculations. When primary data cannot be obtained, secondary data can be used as a proxy, adhering to the GHG Protocol. However, secondary data may reduce the accuracy of calculations.

Sl. No	Activity Data	Assumed Value	Estimation	Justification
1	Quantity of textile waste generated at textile manufacturing stage	10,000 lbs/ day	-	LASAN's plan is to handle 10000 lbs waste per day
2	Quantity of textile waste sorted in LASAN's facility	10,000 lbs/ day	-	LASAN's plan is to handle 10000 lbs waste per day
3	Quantity of recycled cotton fiber produced by recycler	10,000 lbs	100% Conversion rate	Highly efficient textile-to-textile recycling can achieve 100% conversion rate
4	Quantity of recycled cotton yarn produced by recycler	10,000 lbs	100% Conversion rate	Highly efficient textile-to-textile recycling can achieve 100% conversion rate
5	Quantity of virgin cotton yarn replaced due to circular waste recovery	10,000 lbs	1 to 1 replacement	High-quality recycled cotton have shown 1 on 1 replacement
6	Quantity of virgin cotton fiber replaced due to circular waste recovery	11,750 lbs	1.175 lbs cotton fiber required to produce 1 lbs cotton yarn	Referred from SimaPro Ecoinvent Data
7	Quantity of virgin Seed Cotton replaced due to circular waste recovery	24,487 lbs	2.084 lbs Seed Cotton required to produce 1 lbs cotton fiber	Referred from SimaPro Ecoinvent Data
8	Distance from Textile Manufacturer to LASAN sorting facility	10 miles	Distance from MatchMaster to Homeboy	Matchmaster is used as proxy for Textile Manufacturer, and HomeBoy as a proxy to LASAN's sorting facility

Table 2: List of assumptions and estimations made to develop the example used in GHG Emissions Estimator (Dabur, 2024)

9	Distance from LASAN sorting facility to Recycler	1,000 miles	Distance from Homeboy to OsomTex	HomeBoy as a proxy to LASAN's sorting facility and Osomtex as a proxy to Mechanical Recycler
10	Distance from Recycler to Textile Manufacturer	1,000 miles	Distance from OsomTex to MatchMaster	Osomtex as a proxy to Mechanical Recycler and Match Master used as proxy for Textile Manufacturer
11	Distance from cotton field to Cotton Ginning Mill	7 miles	Average distance between cotton field and Ginning Mill in Texas	Texas is the highest cotton producing state in US
12	Distance from Ginning Mills to Yarn Manufacturer	25 miles	Average distance between Ginning Mill and Yarn manufacturer in Texas	Texas is the highest cotton producing state in US
13	Distance from Yarn Manufacturer to Textile Manufacturer	1,250 miles	Distance between Yarn manufacturer in Texas to MatchMaster	MatchMaster used as proxy for Textile Manufacturer
14	Distance from Textile Manufacturer to Landfill Site	30 miles	Distance from MatchMaster to Lopez Canyon Landfilling site	MatchMaster used as proxy for Textile Manufacturer and Lopez Canyon as a proxy to Landfilling site

Table 2 cont'd: List of assumptions and estimations made to develop the example used in GHG Emissions Estimator (Dabur, 2024)

Once all activity data has been collected and inserted into the Estimator, appropriate emission factors are identified for each activity and placed in Column L of the sheets. Emission factors can be sourced from international organizations like Intergovernmental Panel on Climate Change, World Resources Institute, national organizations like United States Environmental Protection Agency, The Climate Registry, or credible third-party life cycle assessment software like SimaPro. A short list of emission factors sourced from reputable organizations is provided for comparison in the Estimator, but LASAN should further develop the list for comprehensive scenario comparisons. Also, LASAN must ensure alignment of activity data and emission factors with the units specified in the Estimator for accurate calculation.

After properly inserting all activity data and emission factors, the Estimator will automatically calculate results, with a summary in the Summary sheet and graphical depictions. A negative value of Net GHG Emission Change from Base Case to Alternative Case in the summary sheet means a reduction in GHG emissions by switching to an alternative scenario from a base case scenario, as in the case of our example where a reduction of 27.37 metric tons of CO_2e was observed by switching to a circular waste recovery scenario from a business-as-usual scenario. On the other hand, a positive value of Net GHG Emission Change from Base Case to Alternative Case in the summary sheet means an increase in GHG emissions by switching to an alternative scenario.

Through the GHG Emissions Estimator, LASAN can quantitatively assess the change in greenhouse gas emissions associated with a switch from business-as-usual scenario to a circular scenario or between a presumed ideal circular pathway and an alternative pathway. This empowers LASAN to make informed decisions, guiding the transition towards more sustainable waste management practices. By leveraging the insights provided by the Estimator, LASAN can optimize waste recovery processes, identify strategic opportunities for emissions reduction, and drive progress toward its sustainability goals. The Estimator's adaptability and scalability ensure its seamless integration into LASAN's evolving initiatives, making it a cornerstone asset in pursuing a greener, more resilient future for Los Angeles.

12. Industrial Ecosystem Database and Dashboard

12.1. Summary

When beginning our work with LASAN, we were supplied with an Excel document listing various businesses and organizations that were already or could be potential partners for developing LASAN's textile recovery pilot project. This document was developed by CPSC and is referred to as the HUB. The HUB is broken up into tabs by business type (e.g., generator, sorter, recycler), with each row within the tab listing a different business along with its contact information. The HUB was incredibly helpful as we began research into LASAN's progress and became familiar with other actors within the industry. However, when our team began to conduct outreach with industry professionals, starting with some of the organizations listed in the HUB, we realized data inconsistencies. Whether the information was outdated or missing from the HUB, we developed a plan to expand on, and update what the HUB had previously provided LASAN. Thus, the Industrial Ecosystem Database and Dashboard became one of our Capstone deliverables.

12.2. Data Management

Our team has developed a comprehensive data management system and dashboard as part of our collaboration with LASAN to support their textile recovery efforts. This tool was designed to streamline the collection, organization, and analysis of key information related to textile waste generators, sorters, recyclers, and other stakeholders in the Los Angeles area.

Industrial Ecosystem Database and Dashboard

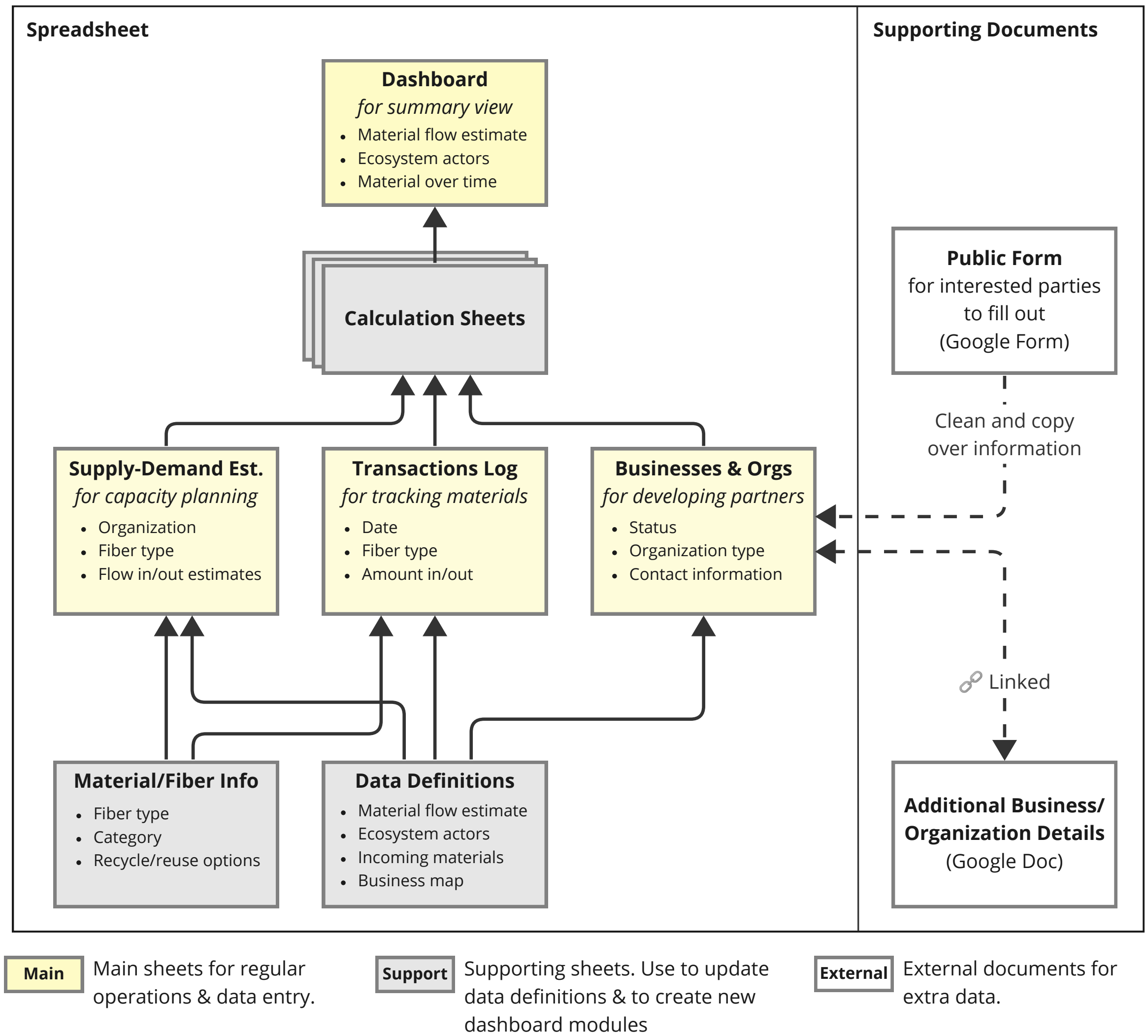

Figure 17: Industrial Ecosystem Database and Dashboard (Hsiung, 2024)

The core of the data management system is a centralized database that captures essential details about each organization involved in the textile recovery ecosystem. It includes contact information, location, type of business or organization, materials handled, capacity, information from the HUB, and additional information collected from the interviews conducted by our team. By consolidating this information in a single location, LASAN can more easily identify and connect with potential partners, track material flows, and identify gaps or opportunities in the system.

To ensure the database is user-friendly and accessible, we have built it using Google Sheets. The platform allows easy data entry, real-time collaboration, and seamless application integration. We have also developed a standardized data entry form that can be embedded on LASAN's website, enabling new organizations to submit their information and join the textile recovery network.

The data management system includes a supply and demand estimator tool and the core database. This feature will allow LASAN to input data on the types and volumes of textile materials available from generators and the capacity and material requirements of sorters and recyclers. By comparing supply and demand, LASAN can identify potential bottlenecks, surpluses, or shortages in the system and take proactive steps to address them. This will help address concerns of uncertainties or unknowns that may arise in the development of this burgeoning marketplace, enabling LASAN to facilitate the operation of a successful circular system.

To help LASAN track actual material flows and transactions, we have incorporated a transaction log into the data management system. This tab allows users to record details of each material transfer, including the source, destination, material type, volume, and date. Over time, this log will provide valuable insight into the movement of textile waste through the network and help identify opportunities for optimization.

Finally, to make all this information easily accessible and actionable, we have created a user-friendly dashboard that summarizes key metrics and visualizations. The dashboard includes charts and graphs that display the distribution of organizations by type, material flows by category, and progress toward textile recovery goals. Interactive filters allow users to specify subsets of data, such as transactions within a certain period or involving a particular material type.

Throughout the development process, we have sought feedback and input from LASAN to ensure the data management system meets their needs and aligns with existing processes. We have also provided documentation and training materials to support the system's ongoing use and maintenance.

12.3. Use

The data management system and dashboard are designed to be powerful yet user-friendly tools that support the textile recovery efforts in multiple ways.

The dashboard provides a user-friendly interface for exploring and visualizing the system's data. LASAN can use the dashboard to quickly get a high-level overview of the current state of textile recovery efforts, track progress toward goals, and identify areas for improvement. The interactive filters and charts allow users to look into specific aspects of the data, such as comparing material flows across different city regions or assessing the performance of individual generators or sorters.

One of the key benefits of the data management system is that it is designed to be flexible and scalable. As LASAN's textile recovery efforts grow and evolve, the system can be easily updated to accommodate new data sources, metrics, and features. Google Sheets also ensures the system can be accessed and updated from anywhere, facilitating collaboration and data-sharing among LASAN and its partners.

In addition to supporting day-to-day operations, the data management system will play a critical role in strategic planning and decision-making. By providing a comprehensive, data-driven view of the textile recovery landscape in Los Angeles, the system will help LASAN identify opportunities for growth, innovation, and impact.

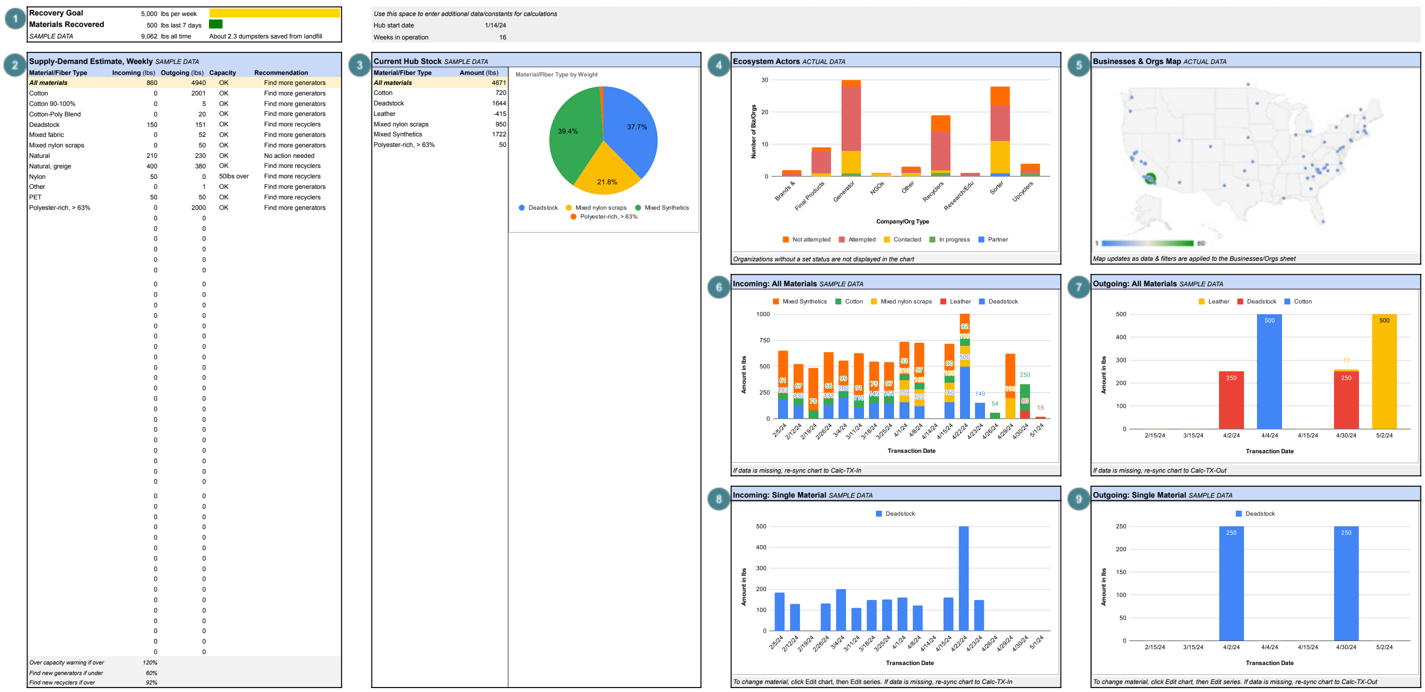

Figure 18: Industrial Ecosystem Database and Dashboard screenshot (Hsiung, 2024)

Whether it's identifying the need for new infrastructure, developing targeted education and outreach campaigns, or forging new partnerships with industry leaders, the insights generated by the data management system will be invaluable in guiding LASAN's efforts to create a more sustainable and circular economy for textiles in the region.

By implementing this robust data management system and dashboard, LASAN will be well-equipped to manage the complex network of stakeholders and material flows involved in textile recovery. Ultimately, the success of the data management system will depend on its adoption and use by LASAN and its partners. Our team is committed to ensuring that the system becomes valuable and integral to LASAN's textile recovery operations by providing training, documentation, and support. We believe that by leveraging the data and collaboration, LASAN can achieve its vision of a more sustainable, equitable, and resilient future for Los Angeles.

13. Insights

In the past four months, our team has gathered insights through research and stakeholder engagement that we believe will be helpful to LASAN. First and foremost, we have found that the LA garment district is in a tenuous position. Despite uncertainties within the current fragmented landscape, it is crucial to sustainably invest in the health and growth of the LA garment industry. In this context, we invoke sustainability to mean environmentally, economically, and socially.

Second, education is vital to a successful circular ecosystem. For financially or temporally constrained businesses and workers, sorting waste is difficult. Still, there is quantifiable value in sorting—both in the value of the waste itself and offsets to the current system's cost. Further, textiles must be rerouted out to the current single-stream (blue bin) recycling system and into a dedicated waste stream. This directive will require both education and infrastructure. However, there is money to reclaim if issues like recycling equipment jamming in MRFs or otherwise valuable textiles losing value in the current waste stream are avoided. The net cost savings could be applied to new programming redirecting textile waste.

Third, this can also be an opportunity for relationship-building with the various actors within the Los Angeles garment industry and beyond. Initially, the focus should be on organizations which share in LASAN's goal of textile recovery and a circular system and are excited to participate in program uptake. These organizations will be more willing to invest in worker buy-in and workflow adjustments. Once the program proves successful, obtaining buy-in from remaining players will be easier.

Finally, stakeholders will need meaningful incentives or substantial penalties or taxes to enable behavior change. During interviews with multiple stakeholders, the overwhelming response to what would be needed to adopt more circular practices was government support. Yet, for incentives or penalties to be successful, the implementation structure must be significant enough to promote change.

Transitioning the industry to a circular system will require time, money, education, and coordination. However, this initiative will enhance industry resilience, establish LA as a leader in responsible garment manufacturing, improve workers' quality of life, and set a positive example of onshoring.

14. Next Steps

For immediate next steps, we recommend that LASAN prioritize impact categories explored in this report, including GHG emissions, economic development, and environmental justice. We also recommend determining ideal end-use cases to best assess circular waste economy optimization. Acceptable trade-offs should be established, and GHG reduction goals should be set. However, data gaps need to be filled to properly assess preferred pathways. Next, LASAN should identify ideal ecosystem actors and potential partners based on priority lenses to narrow down which category of stakeholders to focus on. Leaning into support from LA-based Garment Worker Center (GWC) will help ensure that the systems in place do not rely on worker exploitation for program viability. Engaging GWC may also bolster pilot activities in line with principles of a just transition, furthering environmental justice efforts. As a next step, LASAN should connect with brands and alternate-use industries for pilot partnerships. Offtakers, as vital to the successful flow of materials through a circular system, will need to be identified and engaged.

The above steps should lay the groundwork for a successful Phase III of LASAN's textile recovery program. Our report and tools will help to collect, manage, and interpret data so LASAN can plan and implement a resilient industrial ecosystem.

15. Conclusion

This report analyzes the current textile waste ecosystem and opportunities for circularity within this system, specific to Los Angeles. The analysis notes current challenges, opportunities, stakeholders, and the current and potential role of LASAN. With these findings, we attempt to uncover the best options for advancing LASAN's textile recovery project to create textile circularity within LA. Through the course of this research, significant data gaps, issues with market creation, stakeholder concerns, and unclear system boundaries were uncovered. Our textile recovery case studies shed light on the current industry landscape by noting the success, failure, and innovation of other actors in the textile recovery space. The details outlined in our circular mapping and analysis research provide a framework for sample scenarios showing how textiles might move through a circular system. Depending on LASAN's priority impact areas or areas of materiality, this deliverable assists in choosing the best route for textile recovery based on the lenses of GHG emissions, economic development, and environmental justice. The GHG Emissions Estimator provides a means of calculating emissions by tracking inputs and evaluating various circular scenario pathways. Finally, the Industrial Ecosystem Database and Dashboard tool compiles and centralizes data on industry actors and their capacity to participate in LASAN's textile recovery ecosystem.

Successfully transitioning the city of Los Angeles from a linear waste economy to a circular system cannot happen overnight. However, by using the deliverables outlined in this report alongside the pilot project, LASAN has the ability to establish itself as a leader in textile waste recovery, enhance the resilience of LA's fashion district, and establish Los Angeles as a leader in responsible garment manufacturing and textile circularity.

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17. Appendix

17.1. Excel Spreadsheets

17.1.1. Literature Review

The diagram below illustrates how the literature review is designed, as well as sample spreadsheets.

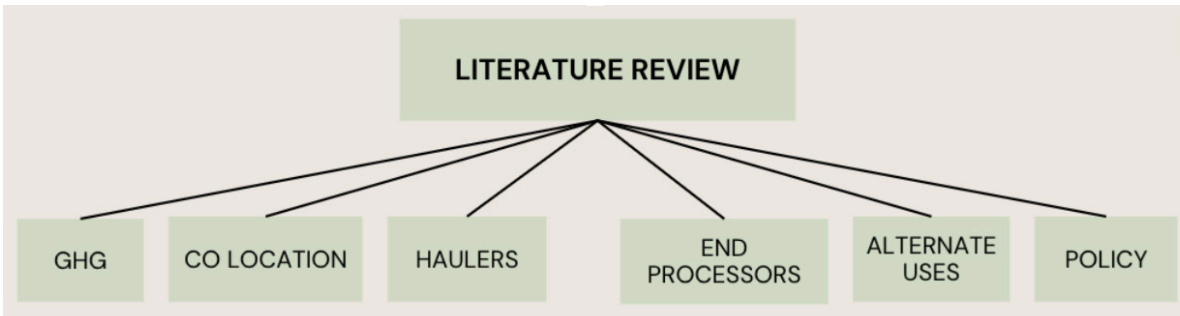


Figure 19: Literature Review Overview

17.1.2. GHG Emissions Estimator

The GHG Estimator section of the Appendix includes the following figures: GHG User Guide, Business-as-Usual Scenario and Circular Scrnarion Process Maps, Emissions Created and Emissions Avoided datainput sheets, and a Summary Sheet.

17.1.3. Industrial Ecosystem Database and Dashboard

To complement our Industrial Ecosystem Database and Dashboard, we are providing LASAN with a document titled "Additional Business / Organization Details". This document will be linked to the Notes column of the Businesses and Organizations tab of the Industrial Ecosystem Database and Dashboard. The document summarizes all additional details our team has collected on the organizations that are listed in the database, as well as any interview correspondence that was conducted during team outreach. Interviews contain stakeholder responses inclusive of additional feedback that may be useful to LASAN in building out the textile recovery pilot program. A copy of this document will not be included in the appendix of this report, as it includes sensitive company information.

Appendix:
Literature Review

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	A Technical Review of Emerging Technologies for Energy and Water Efficiency and Pollution Reduction in the Textile Industry	Ali Hasanbeigi Lynn Price	Journal of Cleaner Production	Journal	Emerging Technology, Energy Efficiency, Water Efficiency, Emissions Reduction, Textile Industry	3/11/15	1/28/24	A technical review of emerging technologies for energy and water efficiency and pollution reduction in the textile industry - ScienceDirect (columbia.edu)	Information on 18 emerging cleaner technologies for the textile industry. A well-structured database of information on the cutting-edge technologies. Information on energy savings, environmental and other benefits. Information on commercialization status of each technology.
2	A Carbon Footprint of Textile Recycling: A Case Study in Sweden	Bahareh Zamani, Magdalena Svanström, Gregory Peters, Tomas Rydberg	Journal od Industrial Ecology	Journal	Carbon Footprint, Environmental Assessment, Life Cycle Assessment (LCA), Industrial Ecology, Global Warming Potential (GWP), Textile Recycling	11/5/2014	1/28/24	https://onlinelibrary-wiley-com.ezproxy.cul.columbia.edu/doi/full/10.1111/jiec.12208	A case study in Sweden in which environmental life cycle assessment (LCA) was performed to quantify the energy usage and global warming potential (GWP) of different textile recycling options. The paper explores the potential environmental benefits of various textile recycling techniques and thereby direct textile waste management strategies toward more sustainable options. Three different recycling techniques for a model waste consisting of 50% cotton and 50% polyester were identified and a life cycle assessment (LCA) was made to assess the environmental performance of them. Studied technologies are: remanufacturing for material reuse; chemical separation of cellulose from polyester using NMMO; chemical recycling of polyester; and incineration with energy recovery.
3	Exergy Footprint Assessment of Cotton Textile Recycling to Polyethylene	Alexandra Plesu Popescu, Yen Keong Cheah, Petar Sabev Varbanov, Jiří Jaromír Klemeš, Mohammad Reda Kabli, Khurram Shahzad	Energies	Journal	Chemical Recycling, GHG Emissions, Exergy Footprint, Cotton Textile Recycling	12/29/2021	1/28/24	https://www.mdpi.com/1996-1073/15/1/205	Based on the Exergy Footprint concept, the presented work formulates a procedure for its application to industrial chemical recycling processes. It illustrates its application in the example of cotton waste recycling. This includes the evaluation of the entire process chain of polyethylene synthesis by recycling cotton waste. The chemical recycling stages are identified and used to construct the entire flowsheet that eliminates the cotton waste and its footprints at the expense of additional exergy input.
4	Textile and Apparel Industries Waste and its Sustainable Management Approaches	Chand, Sujata	Journal of Material Cycles and Waste Management	Journal	Textile and Apparel Industry, Waste, Recycling, Sustainability, Utilization, **Production Waste, Pre-Consumer Waste, Post-Industrial Waste**	7/21/2023	1/28/24	Textile and apparel industries waste and its sustainable management approaches | Journal of Material Cycles and Waste Management (columbia.edu); DOI https://doi-org.ezproxy.cul.columbia.edu/10.1007/s10163-023-01761-1	
5	Life cycle assessment of textile fibre-to-fibre recycling by cellulose carbamate technology	Torun Hammar, Diego Peñaloza, Anne-Charlotte Hanning, Noora Haatanen, Juhana Pakkasmaa	Journal of Cleaner Production	Journal	LCA Chemical recycling, Regenerated fibers, Environmental impact, Cellulose carbamate, Man-made cellulose fiber (MMCF)	11/10/2023	1/28/24	https://www-sciencedirect-com.ezproxy.cul.columbia.edu/science/article/pii/S0959652623033474?via%3Dihub	The aim of this study was to evaluate the environmental **impacts of post-consumer textile fibre-to-fibre recycling** by cellulose carbamate technology, in terms of climate impact, water scarcity impact, cumulative energy demand and land use impact. By performing life cycle assessment, it was shown that the chemically recycled cellulose carbamate fibre has a climate impact of about 2.2 kg CO2-eq per kg fibre, water scarcity impact of 1.6 m3 H2O-eq per kg fibre, cumulative energy demand of 90 MJ-eq per kg fibre and land use impact of about 92 Pt per kg fibre (when applying mass allocation of co-products). Hotspots identified during the fibre production technology were electricity use and production of sodium hydroxide

Figure 20: Literature Review, GHG

Appendix:
Literature Review

COLUMBIA UNIVERSITY
School of Professional Studies

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	Managing waste quality in industrial symbiosis: Insights on how to organize supplier integration	Ernst Johannes Prosman, Brian Vejrum Wæhrens	Journal of Cleaner Production / ScienceDirect	Journal Article	Industrial Ecology; Industrial Symbiosis; Waste Management; Supplier Integration	10/2019	1/26/2024	https://www.sciencedirect.com/science/article/abs/pii/S0959652619321304	Importance of establishing supplier integration in managing waste quality. Focuses on "optimizing the operation and supply chain processes of industrial symbiosis... importance of linking operational and supply chain processes as a means of making the symbiotic relationships more economically viable." Looks at a cement company and their waste being used in another business as an example
2	Supply chain collaboration in industrial symbiosis networks	Gábor Herczeg, Renzo Akkerman, Michael Zwicky Hauschild	Journal of Cleaner Production / ScienceDirect	Journal Article	Industrial Ecology; Industrial Symbiosis; Supply Chain Collaboration	1/2018	1/28/2024	https://www.sciencedirect.com/science/article/abs/pii/S0959652617323387	Study on effectiveness of "building bridges between operations management and industrial ecology." Looking at how companies of different industries may use the by-products of prodution, waste, and excess utilities in a circular regional economy. End results include "improving the companies' resource efficiency and competitiveness, creating new employment, and...contributing to a cleaner natural environment." Emphasizes importance of "transparency, shared cultural norms, social networking, and trust" between companies. Challenges of dealing with quality uncertainties, etc.
3	Industrial symbiosis in the forestry sector: A case study in southern Brazil	Júlia Wahrlich, Flávio José Simioni	Journal of Industrial Ecology / Wiley	Journal Article	Industrial Ecology; Industrial Symbiosis; Forestry Sector	12/2019	1/26/2024	https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12927	Looking at the success of industrial symbiosis (ecology) in a forestry companies in Brazil. Discusses what seem to have been the keys to successful industrial ecology relationships between companies: aims of "eco-efficiency, waste management, minimizing the waste of resources"; company incentives such as "market adequacy, internal management, favorable organizational climate for exchanges"; limitations: "poor logistics, few resources to invest...lack of adequate technology"; geographical proximity, members of the same industrial complex, need large number of companies to deal with waste
4	Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges	Murat Mirata	Journal of Cleaner Production / ScienceDirect	Journal Article	Industrial Ecology; Regional Examples; Industrial Symbiosis	2004	1/28/2024	https://www.sciencedirect.com/science/article/abs/pii/S0959652604000848	Looks at 3 regional industrial symbiosis programs that were underdevelopment in the UK. Discusses development and continued operation of the programs, as well as roles of coordinating bodies to facilitate success. Importance of history in the region of operation, proximity of companies, aligned characteristics/sustainability objectives in the companies operations

Figure 21: Literature Review, Industrial Ecology

Appendix:
Literature Review

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	On the move in China	KPMG	KPMG	Article	Haulers	2011	5/2/2024	https://assets.kpmg.com/content/dam/kpmg/pdf/2011/12/Transport-Logistics-in-China-201112.pdf	This report highlights the logistics in China and how a large portion of the government revenue is invested in haulers. In China there is a mix of trucks supplied by the government as well as companies having their own vehicles. In case of textile collectors have their own logistics and have separate haulers
2	California introduces Act for responsible textile disposal and reuse	Juststyle	Juststyle	Article	Policy	March 2023	5/2/2024	https://www.just-style.com/news/california-introduces-act-for-responsible-textile-disposal-and-reuse/?cf-view	This article explains about California's new Responsible Textile Recovery Act of 2023 would require producers to establish a stewardship programme for the collection and recycling of "covered products," which include any apparel, textile, or textile article that is unsuitable for reuse by a consumer in its current state or
3	Fabscrap	Fabscrap	Fabscrap	Fabscrap	Website	2016	5/2/2024	https://fabscrap.org/	FABSCRAP provides convenient pickup and recycling of textiles for businesses and upcycles textiles. Challenge: not sure if it is available in LA
4	Recover	webpage	webpage	webpage	textile waste recovery		2/5/2024	https://recoverfiber.com/process?utm_source=google&utm_medium=cpc&utm_campaign=adquisicion_usa_proceso_en&utm_term=textile%20recycling%20companies&utm_content=607518369491&gad_source=1&gclid=CjwKCAiAq4KuBhA6EiwArMAw1LsCfqfDTnLMm1E0GKvDagXbMuk_thgoDENZmjUp2yVOCJvCsD3HURoCi8AQAvD_BwE	Recover is a Spain-based company who specializes in taking textile waste and recyling it back into textile production
5	The world's first automatic large-scale textile sorting plant is in Sweden	Helena Nageler-Petritz	https://waste-management-world.com/	Article	Textile recyling	Jul 16, 2023	2/5/2024	https://waste-management-world.com/resource-use/the-worlds-first-automatic-large-scale-textile-sorting-plant-is-in-sweden/	Siptex - the world's first large-scale facility of its kind, is the world's first automated sorting plant for post-consumer textiles on an industrial scale. Using near-infrared and visual spectroscopy (NIR / VIS), Siptex sorts textile waste by fiber type and color. This is a form of automated sorting.
6	Helpsy	webpage	https://wv	webpage	Company who specializes in pick-up of post-consumer textiles		2/5/2024		The City of Stamford provides curbside textile recycling through its partner vendor, HELPSY. Helpsy is a for-profit B-corp company, and is the largest clothing collector in the Northeast US, HELPSY has over 2,400 collection containers across ten states, vast experience hosting clothing drives and we also offer curbside textile recycling.

Figure 22: Literature Review, Haulers

Appendix:
Literature Review

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	Recycling from Waste in Fashion and Textiles	Pandit, P., Ahmed, S., Singha, K.; Shrivastava, S.	CLEO	Book	Fashion design > Environmental aspects. Textile industry > Environmental aspects.	1/29/2020	1/28/24	https://onlinelibrary-wiley-com.ezproxy.cul.columbia.edu/doi/book/10.1002/9781119620532	An in-depth look at circular solutions for textile waste in the apparel industry. 15.4.2 discusses "Recycling of Textile Waste," with Table 15.1 offering several EU based case studies, that may be of use in assessing best practices in mapping current proposed parters.
2	Investigating postponement and speculation approaches to the end-of-life textile supply chain	Hinkka V., Aminoff A., Palmgren, R., Heikkilä P., Harlin A.	Journal of Cleaner Production / ScienceDirect	Journal Article	Textile industry, Recycling, Postponement, Reverse logistics	10/10/2023	1/28/24	https://doi.org/10.1016/j.jclepro.2023.138431	While focused on post-consumer textile waste, this article offers valuable research on the cost of collected materials vesrus the cost of end-of-life textile recycling, through a supply chain approach of "postponement-speculation." Findland, a country that relies on municipal collections of tectile waste, is used as a case study. Further, the article discusses geospatial considerations, and a brief comparison of the cost variance between mechanical, chemical, and thermoplastic recycling.
3	Recent advances in recycling technologies for waste textile fabrics: a review	Rivalani Baloyi Baloyi, Oluwatoyin Joseph Gbadeyan, Bruce Sithole, Viren Chunilal	Textile Research Journal / Sage Journals	Journal Article	Textile waste, textile recycling environmental impacts, waste management, valorization of textile waste	11/07/2023	1/28/24	https://journals-sagepub-com.ezproxy.cul.columbia.edu/doi/full/10.1177/00405175231210239	An overview of both mechanical and chemical textile recycling, along with process maps and input/output summaries to support further analysis of end process partners best suited for next steps. Further, the article suggests several policy levels to support the uptake and financial viability of textile recycing schemes.
4	Wasted Traces/Wasted Spaces Deploying Pre-Consumer Textile Waste to Activate Vacant Storefronts for Transitional Homeless Housing	Michelle Lei	Pratt Institute ProQuest Dissertations Publishing	Thesis	Pre-consumer textile waste, spatial activation, education & employment opportunity	5/2021	1/28/24	http://ezproxy.cul.columbia.edu/login?url=https://www.proquest.com/dissertations-theses/wasted-traces-spaces-deploying-pre-consumer/docview/2546080208/se-2?accountid=10226	A reimagining of "pre-consumer textile waste as a spatial tool for activation of vacant retail sites into spaces of habitation and learning." This thesis could present as prime opportunity to integrate a social justice aspect into textile waste divertment, through a LA based pilot program, utilizing empty retail space.
5	Industrial textile recycling and reuse in Brazil: case study and considerations concerning the circular economy	Mariana Correa do Amaral, Welton Fernando Zonatti, Karine Liotino da Silva, Dib Karam Junior, João Amato Neto, Julia Baruque-Ramos	SciFlow Brazil	Journal Article	Textile; Recycling; Reuse; Circular economy; Sustainability	Jul-Sep 2018	1/28/24	https://doi.org/10.1590/0104-530X3305	A case study on Brazil's textile manufacturing (as the fourth major producer of textiles products in the world) and textile recycling industry, focusing on process and main challenges.
6	Barriers and Drivers for Changes in Circular Business Models in a Textile Recycling Sector: Results of Qualitative Empirical Research.	Anna Wójcik-Karpacz, Jarosław Karpacz, Piotr Brzeziński, Anna Pietruszka-Ortyl and Bernard Ziębicki	Energies(Vol. 16, Issue 1)	Journal Article	Textile industry, Recycling, European Union	1/2023	1/28/24	https://www.mdpi.com/1996-1073/16/1/490	Discussion of the economic benefits of textile recycling, the need for industry ecosystems, and policy leavers to positively modify stakeholder behavior.

Figure 23: Literature Review, End Processors

Appendix:
Literature Review

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	Textile waste as an alternative thermal insulation building material solution	Briga-Sá, A., Nascimento, D., Teixeira, N., Pinto, J., Caldeira, F., Varum, H., Paiva, A.	Construction and Building Materials	Journal Article	Alternate uses for textile waste; Building uses	1/2013	2/4/2024	https://www.scopus.com/record/display.uri?eid=2-s2.0-84866495009&origin=inward&txGid=d1fc3d66afe363be1612c3eef7874dda	"In this research work, the potential applicability of woven fabric waste (WFW) and a waste of this residue, named woven fabric subwaste (WFS), as **thermal insulation building material** was studied." More focused on the success of this from the building perspective, not so much about how the waste was converted over.
2	Environment Protection by Textile Recycling	K. Saravanan	Fibre2Fashion	Published Paper	Alternate uses for textile waste; India	8/2011	2/4/2024	https://static.fibre2fashion.com/articleresources/PdfFiles/58/5781.pdf	Looks at alternate uses for textile waste, specifically in India. "Some of the uses as follow: Various **Yarn Spinning** Applications, **Paper Making**, **Automotive and Industrial Filters**, An Array of Non Wovem Products, **Medical products** (swabs, bandages), **Blankets**, **Diapers**, **Bleached Wadding**... **Mattress** Felt Pads, **Futon** Felt Pads, Oil Absorption Products, Various **Furniture Padding** and **Stuffing Applications**... "Home Furnishings, Padding, Mops, Wiping Cloth"
3	Thermal and acoustic performance in textile fibre-reinforced concrete: An analytical review	K.A.P. Wijesinghe, Chamila Gunasekara, David W. Law, H.D. Hidallana-Gamage, Nandula Wanasekara, Lijing Wang	Construction and Building Materials	Journal Article	Alternate uses for textile waste; Building uses	1/19/2024	2/4/2024	https://www.sciencedirect.com/science/article/pii/S0950061824000205	"Textile fibre-reinforced concrete based reviews have explored various engineering properties, such as **strengthening of concrete**, **enhancing strain capacity, crack control, durability, and energy absorption**." Looks more specifically at the success of textile fibre-reinforced concrete, not so much about the conversion of the waste.
4	An investigation into the minimum energy requirements for transforming end-of-life cotton textiles into carbon fibre in an Australian context	Charlotte Wesley, Farshid Pahlevani, Shahruk Nur-A-Tomal, Smitirupa Biswal, Veena Sahajwalla	Resources, Conservation & Recycling Advances	Journal Article	Alternate uses for textile waste; Australia; Carbon Fibre	5/2023	2/4/2024	https://www.sciencedirect.com/science/article/pii/S2667378922000608	"The more common recovery pathways are through re-use, repair and re-purposing for other applications such as **bags, rags and animal bedding**." Looking into textile upcycling in **Australia**, **composting cotton textile waste for nutrient cycling**, "examines the viability of end-of-life cotton textile as an alternate precursor to polyacrylonitrile (PAN) carbon fibre for certain applications." "the potential to **displace conventional carbon fibre** in certain applications could be promising in terms of **carbon abatement for the energy intensive carbon fibre market**"
5	Taking textiles from trash to treasure	Allyson Mann	UGA Today	University Newspaper Article	Alternate uses for textile waste; US; Denim waste; Building use	4/16/2020	2/4/2024	https://news.uga.edu/taking-textiles-trash-to-treasure/	A look into the process behind turning textile waste (specifically denim mix) into acoustically successful **building insulation** materials.

Figure 24: Literature Review, Alternate Uses

Appendix:
Literature Review

Number	Title	Author	Source	Source Type	Topic	Date Published	Date Retrieved	Link	Summary
1	STOP WASTE COLONIALISM! Leveraging Extended Producer Responsibility to Catalyze a Justice-led Circular Textiles Economy	Liz Ricketts and Branson Skinner (The Or Foundation)	The Or Foundation	NGO Report	EPR, Policy, Waste Colonialism, Textile Circular Economy	2/14/23	2/5/24	https://stopwastecolonialism.org/stopwastecolonialism.pdf	An in-depth look at EPR legislation; necessary components for crafting impactful policy from an environmental justice perspective. Further, financial data on textile waste management schemes.
2	Improving recycling of textiles based on lessons from policies for other recyclable materials: A minireview	Glenn Hole, Anastasia S. Hole	Science Direct	Academic Journal	Textile waste disposal, recycling policy & legislation	July 2020	2/5/24	https://doi.org/10.1016/j.spc.2020.04.005	An examination of policy and legislation in other recycling markets, as mini case study for potential legislation for textile waste. More focused on post-consumer waste, however some helpful insight into policy for industial textile waste.
3	California introduces Act for responsible textile disposal and reuse	Juststyle	Juststyle	Article	Policy	March 2023	2/5/2024	https://www.just-style.com/news/california-introduces-act-for-responsible-textile-disposal-and-reuse/?cf-view	This article explains about California's new Responsible Textile Recovery Act of 2023 would require producers to establish a stewardship programme for the collection and recycling of "covered products," which include any apparel, textile, or textile article that is unsuitable for reuse by a consumer in its current state or condition.
4	Comment: How the UK is paving the way for a more circular fashion industry	Adam Mansell	Reuters	Article	Green New Deal, Policy, Circular Economy, Textile Waste	August 29, 202	2/10/24	https://www.reuters.com/sustainability/climate-energy/comment-how-uk-is-paving-way-more-circular-fashion-industry-2023-08-29/	UK based, government funded and industry backed programming to support textile waste recovery. Highlights economics opportunities for domestic manufacturing
5	WRAP recommends UK gov adopt EPR for fashion and textiles	Peter Dennis	Circular. FOR RESOURCE AND WASTE PROFESSIONALS	Article	Extended Producer Responsibility, textiles, WRAP	24th March 20	2/10/24	https://www.waste360.com/textiles/california-launches-innovative-textiles-circularity-projects-part-1	WRAP (UK-based NGO) recomendations of EPR law adoption. Cites necessary/simple fee based modulation for successful uptake.
6	California Responsible Textile Recovery Act Seeks Path Forward Amid Lingering Questions	KATE NISHIMU	Sourcing Journal	Article	Extended Producer Responsibility, textiles	September 21,	2/10/24	https://sourcingjournal.com/sustainability/sustainability-news/california-responsible-textile-recovery-act-sb707-apparel-waste-recycling-456389/	A look at the reasonings behind the pulling of SB707, and what the bill would do if passed.
7	SB-707 Responsible Textile Recovery Act of 2024	California State Senator Josh Newman	California Legislative Information	Senate Bill	Extended Producer Responsibility, textiles, CA Legislation	7/3/24	2/10/24	https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB707	Text of SB707 - has been amended (4/3/24)
8	New York, It's Time to Act: The New York Fashion Act and Fashion Workers Act	SEORYUNG P	Fashion & Law Jo	Article	NY State, Legislation, Apparel Brands, GHG	2/8/24	2/15/24	https://fashionlawjournal.com/new-york-its-time-to-act-the-new-york-fashion-act-and-fashion-workers-act/	An overview of the NY Fashion Act and Fashion Workers Act

Figure 25: Literature Review, Policy

environment
LA SANITATION
CITY OF LOS ANGELES

GHG Emissions Estimator

Introduction

This GHG Emissions Estimator has been developed to facilitate high-level comparison of potential greenhouse gas (GHG) emissions reductions achievable between a base case scenario and alternative waste recovery approaches for post-industrial textile waste in Los Angeles. It may serve as a decision-making tool for LASAN to evaluate the environmental impact of different strategies.

Who should use this Estimator?
This estimator is developed for LASAN to estimate and compare the GHG emissions associated with different waste recovery approaches for post-industrial textile waste in Los Angeles. This estimator is a comparative tool rather than a comprehensive measurement tool.

What data do we need?
1. **Process Flow Map**: A visual representation detailing the flow of materials across different lifecycle stages, from raw material production to disposal, to identify emission points in the base case and alternative case.
2. **Activity Data**: For each emission point, gather relevant data such as weights, distances, reuse frequencies, etc.
3. **Emission Factors**: Identify appropriate emission factors corresponding to each activity. Emission Factors can be sourced from International bodies like IPCCC, WRI, National Bodies like USEPA, The Climate Registry's (TCR), or credible third party LCA software like SimaPro.

Using Estimator

1. Create comprehensive process maps illustrating both the Base Case and the Alternative Case for textile waste recovery. The process map is designed to visually represent complete life cycle stages of a textile in a Base Case and an Alternative Case.
2. Identify all the points in the Base Case which leads to GHG emissions and highlight them using an icon.
3. Compare each stage in the Alternative Case against the Base Case to identify points where GHG emissions are potentially impacted/changed. Categorize identified emission points into three categories: Emissions Created, Emissions Avoided, and Net No Change in Emissions. Different icons can be used to mark different categories of emission points such as
- Use a green triangle where the Alternative Case reduces the need for virgin materials or energy due to waste recovery.
- Use a red triangle for stages that are added in the Alternative Case, indicating increased emissions.
- Use a yellow circle where stages remain unchanged in terms of emissions. All the variables of these activity remained unchanged between the Base Case and the Alternative Case.
4. Place the process map diagram in the "Process Map" sheet.
5. List all activities categorized as Emissions Created and Emissions Avoided in the "Emissions Created" and "Emissions Avoided" sheets, respectively. Each activity should be placed under the relevant activity tab (e.g., transportation, raw material production, waste disposal) on each sheet, ensuring no duplication.
6. Collect activity data based on the variables associated with each activity and input the values in the relevant columns. This includes quantities of materials processed, energy used, distance travelled etc.
7. Identify suitable emission factors for each activity and input them in column L to calculate total emissions. The estimator will automatically calculate the GHG emissions once all the activity data is inserted.
8. Analyse the summarized emissions data in the summary sheet to facilitate comparisons between different scenarios and existing systems.

Notes

1. **Common Functional Unit:** The Functional unit for both the scenario in comparison should be same (see below for definition of Functional Unit).
2. **Consistency in Data:** Ensure that activity data and emission factors align with the units specified in the variable titles.
3. **Adding Multiple Activities:** Additional rows can be added to accommodate multiple activities.
4. **Compliance with GHG Protocols:** Adhere to GHG Protocols and Guidelines for boundary setting, estimation, and reporting of avoided emissions. For reference:
GHG Protocol Project Protocol: https://ghgprotocol.org/project-protocol
GHG Protocol Product Standard: https://ghgprotocol.org/product-standard
GHG Protocol Estimating and Reporting Avoided Emissions: https://ghgprotocol.org/estimating-and-reporting-avoided-emissions

Figure 26: GHG Estimator User Guide Sheet (Dabur, 2024)

Appendix:
Literature Review

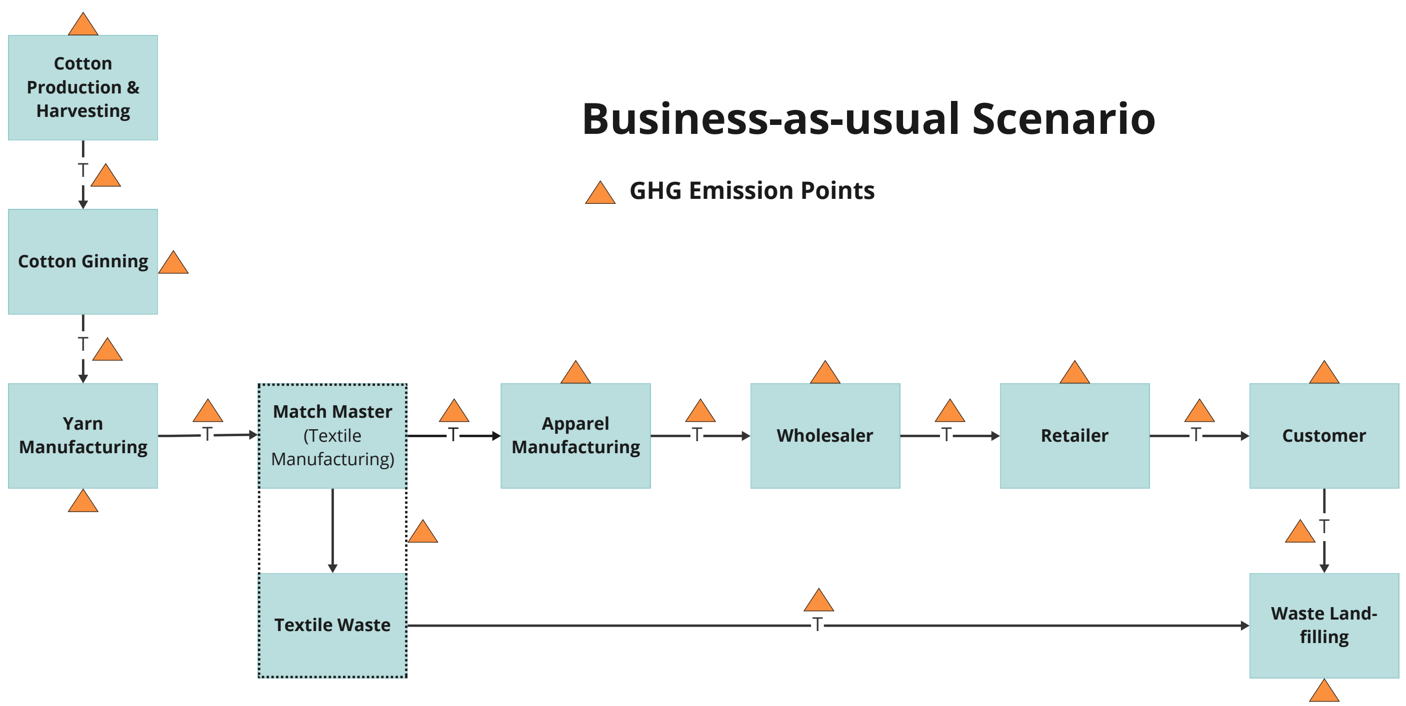


Figure 15: GHG Estimator Process Map Sheet, Business-as-Usual (Dabur, 2024)

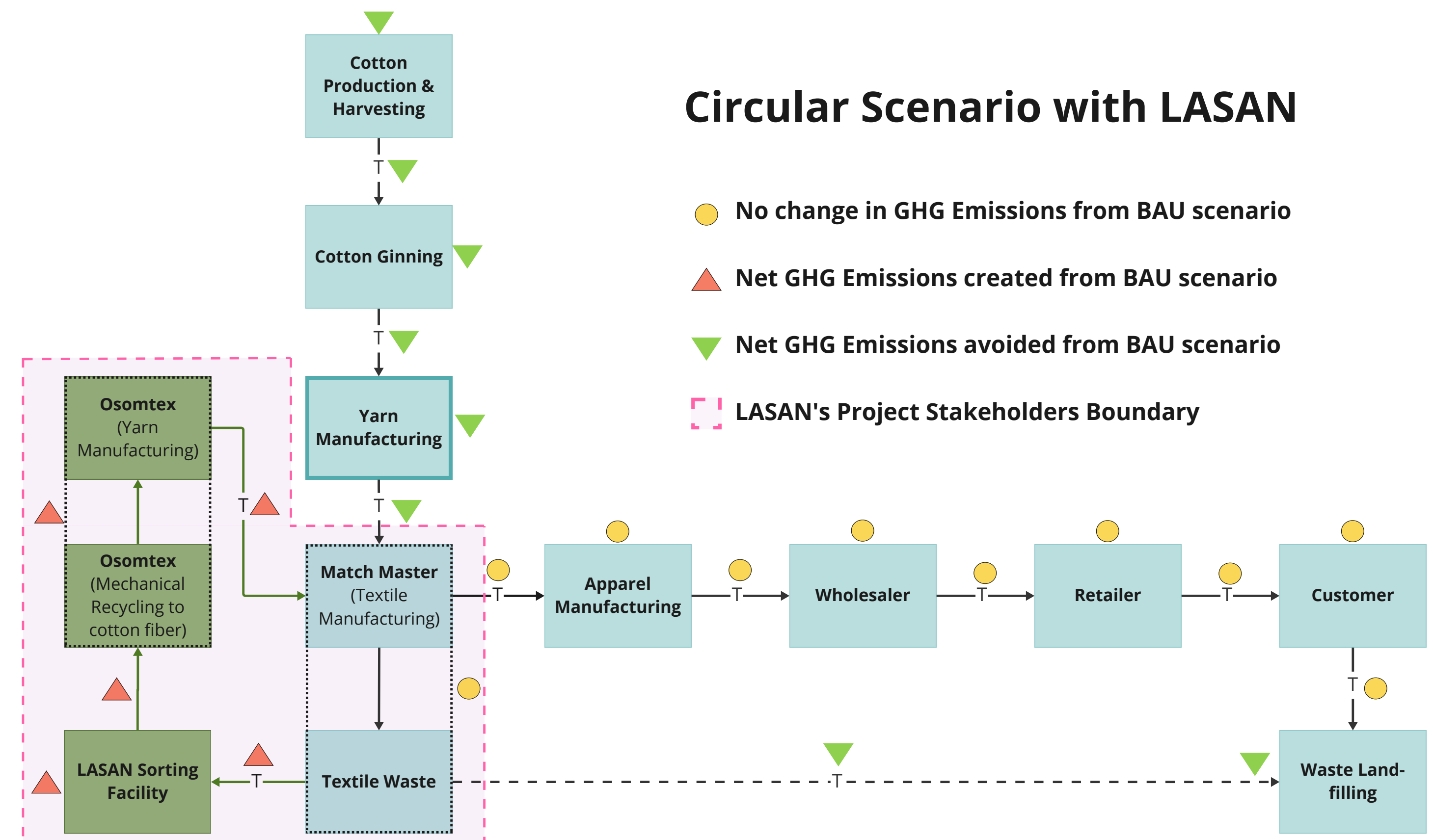


Figure 16: GHG Estimator Process Map Sheet, Circular Scenario (Dabur, 2024)

Appendix:
GHG Estimator

Total New Emissions Created from Base Case to Alternative Case (metric tons CO2e)	33.70

Emission from Transportation

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Mode of Transportation	Vehicle Type	Distance Travelled (mile)	Weight of shipment (ton)	kg CO2e/ ton.mile	metric tons CO2e
1	Transport of Textile waste from MatchMaster to LASAN Sorting Facility	Roadways	Medium to Heavy-Duty Truck	10.00	4.54	0.18	0.01
2	Transport of Textile waste from LASAN Sorting Facility to Osomtex	Roadways	Medium to Heavy-Duty Truck	1000.00	4.54	0.18	0.80
3	Transport of Recycled cotton yarn from Osomtex to Match Master	Roadways	Medium to Heavy-Duty Truck	1000.00	4.54	0.18	0.80
						Sub Total	1.604

Emission from Recycling

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Recycling Method	Type of Material	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
1	Recycling of Textile waste into Recycled Cotton Fibre	Osomtex, Oregon	Mechanical Recycling	Recycled Cotton Fibre	4535.92	0.21	0.971
							0
							0
						Sub Total	0.971

Emission from Raw Material Processing

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Processing Method	Type of Material	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
1	Sorting of Textile Waste	Los Angeles	Mechanical Sorting	Recycled Cotton yarn	4535.92	0.06	0.278
2	Recycled Cotton Yarn Production	Osomtex, Oregon	Spinning	Recycled Cotton yarn	4535.92	6.80	30.844
							0
						Sub Total	31.122

Emission from Additional material Use

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Type of Material	Number of Reuse	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
				1.00			0
				1.00			0
				1.00			0
						Sub Total	0

Figure 27: GHG Estimator Emissions Created Sheet (Dabur, 2024)

Appendix:
GHG Estimator

LA Sanitation environment — City of Los Angeles

Total Base Emissions Avoided from Base Case to Alternative Case (metric tons CO2e)	61.06

Emission from Transportation

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Mode of Transportation	Vehicle Type	Distance Travelled (mile)	Weight of shipment (ton)	kg CO2e/ ton.mile	metric tons CO2e
1	Transport of Seed Cotton from Cotton Field to Ginning Mill	Roadways	Medium to Heavy-Duty Truck	7.00	9.45	0.17	0.01
2	Transport of Cotton bales from Ginning Mills to Yarn Manufacturer	Roadways	Medium to Heavy-Duty Truck	25.00	4.54	0.17	0.02
3	Transport of Cotton Yarn from Yarn Manufacturer to Match Master	Roadways	Medium to Heavy-Duty Truck	1250.00	4.54	0.17	0.96
4	Transport of Textile waste from MatchMaster to Lopez Canyon Landfill	Roadways	Medium to Heavy-Duty Truck	30.00	4.54	0.17	0.02
						Sub Total	1.013

Emission from Raw Material Production

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Production Method	Type of Material	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
1	Seed Cotton Production	Texas, United States	Cultivation and harvesting of Cotton crop using inputs like seed, fertilizers, pesticides, irrigation water and harvestor	Inorganic Seed Cotton	11107.11	1.23	13.662
							0
						Sub Total	13.662

Emission from Raw Material Processing

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Processing Method	Type of Material	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
1	Cotton Fibre Production	Texas, United States	Standard Ginning with hydraulic pressing	Bales of cotton and separated cotton seeds	5329.71	2.64	14.070
2	Cotton Yarn Production	Texas, United States	Standard spinning	Cotton yarn for woven fabric	4535.92	6.80	30.844
							0
						Sub Total	44.915

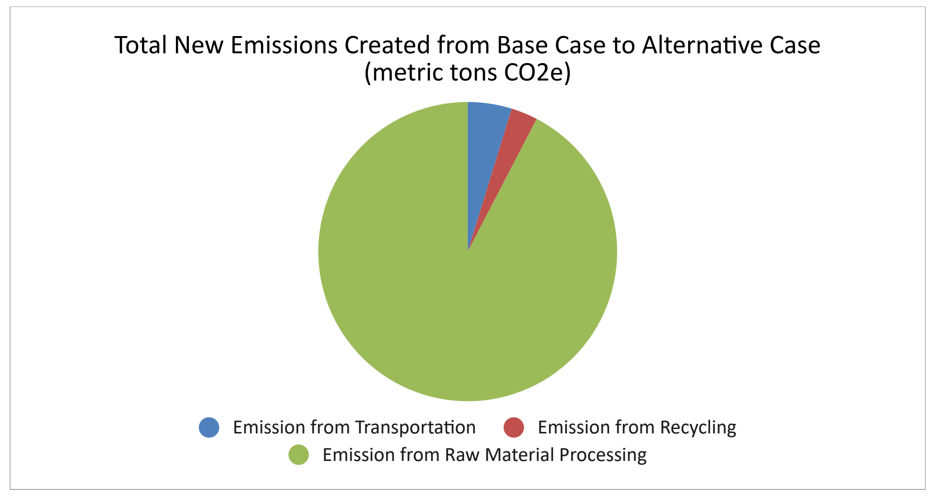
Emission from Additional material Use

S.No.	Activity Description	Activity Data				Emissions Factor	GHG Emissions
		Location	Type of Material	Number of Reuse	Quantity of Material (kg)	kg CO2e/ kg	metric tons CO2e
				1.00			0
				1.00			0
						Sub Total	0

Figure 28: GHG Estimator Emissions Avoided Sheet (Dabur, 2024)

Net GHG Emissions Change from Base Case to Alternative Case (metric tons CO2e)
-27.37

Total New Emissions Created from Base Case to Alternative Case (metric tons CO2e)	**33.697**
Emission from Transportation	1.604
Emission from Recycling	0.971
Emission from Raw Material Processing	31.122
Emission from Additional material Use	0
Emission from Waste Disposal	0
Other Emissions	0
Total Base Emissions Avoided from Base Case to Alternative Case (metric tons CO2e)	**61.064**
Emission from Transportation	1.013
Emission from Raw Material Production	13.662
Emission from Raw Material Processing	44.915
Emission from Additional material Use	0
Emission from Waste Disposal	1.474
Other Emissions	0



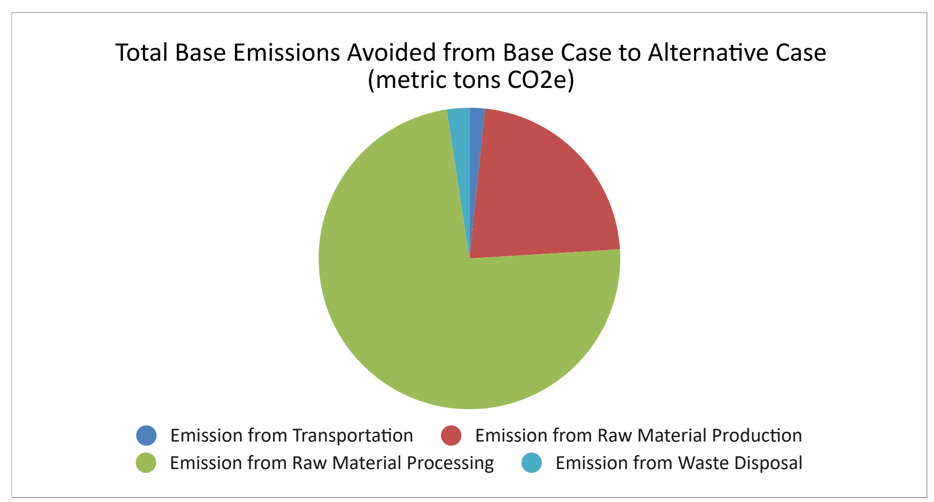


Figure 29: GHG Estimator Summary Sheet (Dabur, 2024)

Industrial Ecosystem Database and Dashboard

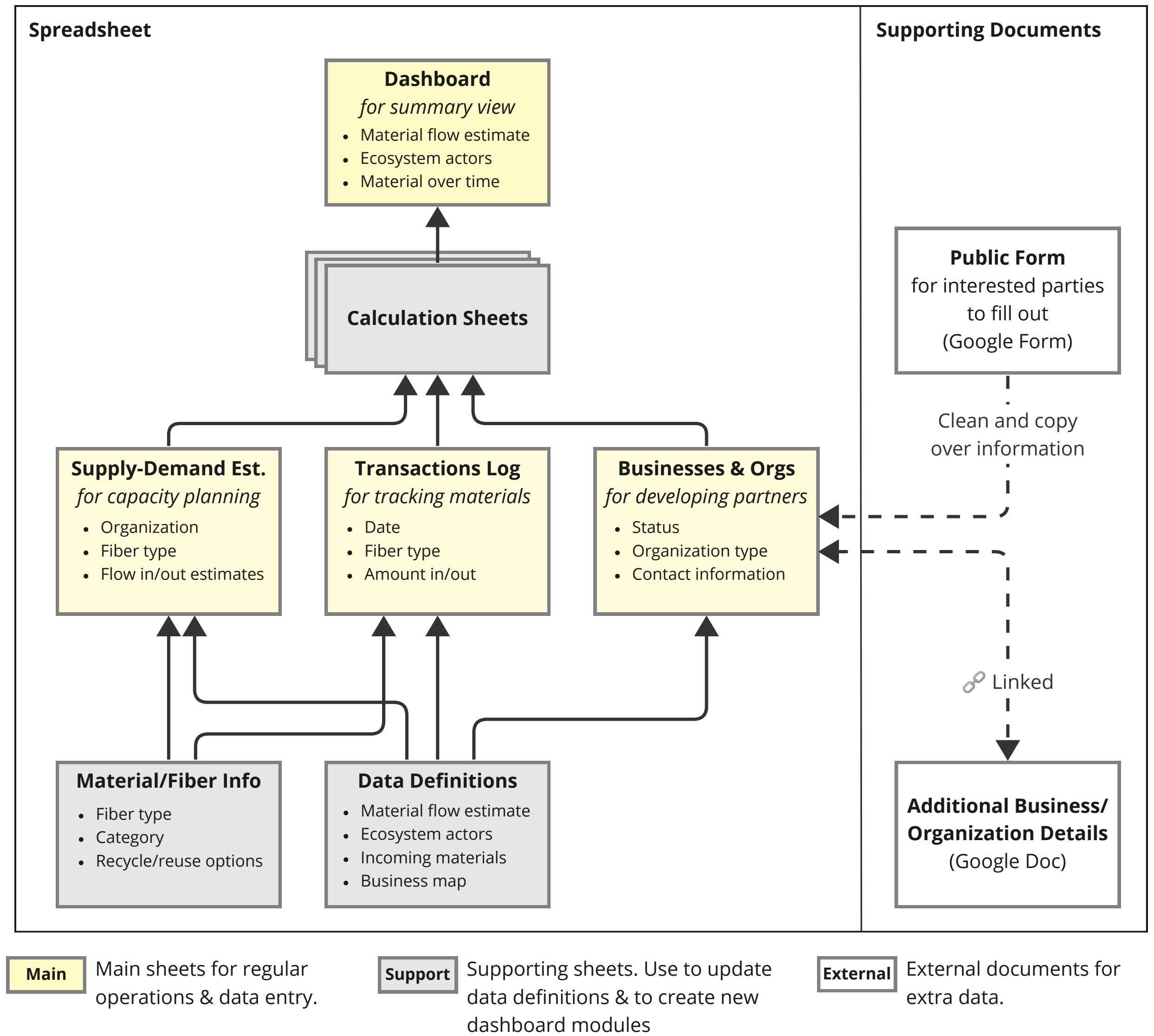


Figure 17: Industrial Ecosystem Database and Dashboard (Hsiung, 2024)

17.2. Industrial Ecosystem Database and Dashboard

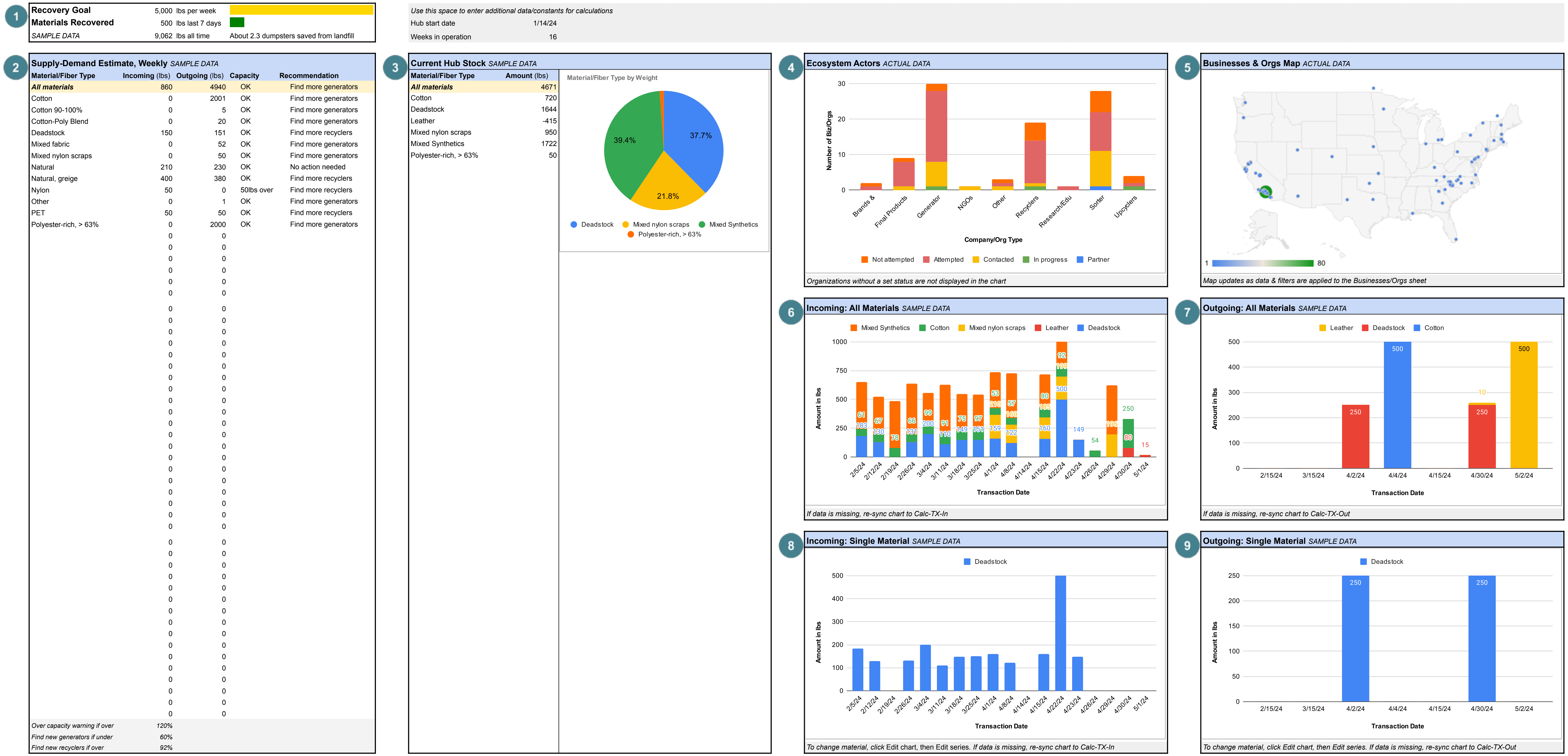
The diagram to the left illustrates how the spreadsheet is set up. The four main sheets for tracking actors and materials are highlighted in yellow. The supporting sheets for calculations and data definitions are in gray. The public-facing form for collecting additional data is highlighted in blue.

17.2.1. Dashboard Modules

The dashboard has several modules which update as data is entered in the spreadsheet. The screen capture below uses a mix of real and sample data. Module 1 displays the target waste diversion goal and current weekly diversion rate. Modules 2, 4, and 5 (Supply-Demand Estimate, Ecosystem Actors, and Business & Orgs Map) assist with planning and prioritizing outreach for project partners. Modules 3 and 6-9 (Current Hub Stock, Incoming: All Materials, Outgoing: All Materials, Incoming: Single Material, Outgoing: Single Material) display the current stock and flow of materials for the proposed LASAN physical textile recovery hub.

Images displaying the entirety of the Industrial Ecosystem Database and Dashboard are not included in the public report, as it contains proprietary information and personally identifiable information.

Appendix:
Industrial Ecosystem Database and Dashboard



Material/Fiber Type	Incoming (lbs)	Outgoing (lbs)	Capacity	Recommendation
All materials	860	4940	OK	Find more generators
Cotton	0	2001	OK	Find more generators
Cotton 90-100%	0	5	OK	Find more generators
Cotton-Poly Blend	0	20	OK	Find more generators
Deadstock	150	151	OK	Find more recyclers
Mixed fabric	0	52	OK	Find more generators
Mixed nylon scraps	0	50	OK	Find more generators
Natural	210	230	OK	No action needed
Natural, greige	400	380	OK	Find more recyclers
Nylon	50	0	50lbs over	Find more recyclers
Other	0	1	OK	Find more generators
PET	50	50	OK	Find more recyclers
Polyester-rich, > 63%	0	2000	OK	Find more generators

Material/Fiber Type	Amount (lbs)
All materials	4671
Cotton	720
Deadstock	1644
Leather	-415
Mixed nylon scraps	950
Mixed Synthetics	1722
Polyester-rich, > 63%	50

Figure 18: Industrial Ecosystem Database and Dashboard screenshot (Hsiung, 2024)