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HOW CAN THE FASHION INDUSTRY BEGIN TO ACHIEVE SUSTAINABILITY?

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SUSTAINABILITY EN VOGUE:

HOW CAN THE FASHION INDUSTRY BEGIN TO ACHIEVE SUSTAINABILITY?

A THESIS APPROVED FOR THE
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BY THE COMMITTEE CONSISTING OF

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Abstract:

Circularity and sustainability have become hot topics in the fashion industry, with corporations, brands, and designers all pledging to reduce their footprint, utilize more "natural" materials or even waste, and increase transparency. Despite not having methods to gauge and measure the sustainable impact of these commitments, fashion industry stakeholders strive to make and achieve incremental goals. Still, these stakeholders fail to consider the amassing amounts of textile waste that result from consumer practices in the fast fashion industry. Comparable sustainability measurements gauge the impact of sustainability initiatives and end of life alternatives allowing designers, brands, and corporations to plan for circularity and sustainability. This thesis explores the effectiveness of current sustainable impact measurements and proposes methods to improve the applicability of such calculators in driving sustainability transitions within the fashion industry.

Through a literature review of academic life cycle assessments (LCA), this thesis examines the comparability and possible applications of comprehensive sustainability impact calculations on a sustainable, and more circular, future for the fashion industry. Sustainability advocates who expect major brands to stop production and corporations who rely on consumer behavior change to achieve sustainability outcomes alone are negligent; therefore, a measurement system would allow the industry to explore sustainability initiatives which integrate solutions across production, retail, and consumer use. Such measurements allow the fashion industry to plan for consumer use and offer alternatives to polluting processes which occur outside of the current ownership schemes. By mindfully choosing less impactful materials and utilizing alternative end of life options, the fashion industry may be able to begin achieving strong sustainability outcomes.

Contents

"You think this has nothing to do with you. You go to your closet and you select out, oh I don't know, that lumpy blue sweater, for instance, because you're trying to tell the world that you take yourself too seriously to care about what you put on your back...However, that blue represents millions of dollars and countless jobs and so it's sort of comical how you think that you've made a choice that exempts you from the fashion industry when, in fact, you're wearing the sweater that was selected for you by the people in this room."

– *The Devil Wears Prada*

Chapter 1: Introduction

1.1 Why does measuring the sustainability impacts of the fashion industry matter?

The fashion industry is worth over $2.5 trillion (Maloney, 2019) with an annual growth rate between 3-5% (McKinsey&Co; Business of Fashion, 2019). This growth primarily occurs in the industry's top 20 companies, which account for approximately 97% of all industry profit (McKinsey&Co; Business of Fashion, 2019). The companies listed within the top 20 include major fast fashion distributors, such as Gap, H&M, Inditex, and the VF Corporation, indicating that fast fashion is the driving source of economic growth within the fashion industry (McKinsey&Co; Business of Fashion, 2019). In 2015, the Boston Consulting Group and the Global Fashion Agenda reported that approximately 92 million tons of waste and CO2 emissions created by fashion industry production practices are projected to hit 2.8 billion tons per year by 2030 (Kerr & Landry, 2018). Despite growing calls for sustainability and recognition of fast fashion's impacts (Fashion Revolution CIC, 2019; Maloney, 2019), top executives in the industry still use "fast" as one of their top three words to describe the future of the fashion industry (McKinsey&Co; Business of Fashion, 2019, p. 13).

The term fast fashion implies the speed of production and consumption in the clothing industry. By quickly replicating trending styles from runways and offering these designs at an accessible price, retailers have increased the speed of production, product availability, and consumption, i.e., fast fashion. To meet the needs of a rampant production pace and the low pricing demands associated with high turnover, fast fashion producers have reduced the quality of these garments. Therefore, fast also applies to the declining quality and expected lifetime of these fashions. The availability or rapidly changing styles and the low prices of these garments

encourages consumers to replace rather than repair or reuse their clothing leading to a disposable culture and accumulation of textile waste (Fashion Revolution CIC, 2018).

The relationship of global leaders in the fashion industry to fast fashion indicates that the perceptions and processes which drive corporations toward continuing fast fashion are not declining. Thus, the current process of relying on consumer behavior to change the production habits of the industry is not adequate. By creating comparable sustainable impact datasets, corporations can forward sustainability initiatives without relying solely on behavior change How then are corporations and brands convinced to undertake the scrupulous task of accurately measuring and assessing their impacts?

1.2 Why does fast matter?

In their "*State of the Industry"* report for the 2017 year, McKinsey & Company found, "The speed of fast fashion amplifies…and magnifies five fundamental problems for the fashion industry: high water consumption, discharge of hazardous chemicals, violation of human rights, labor standards, greenhouse-gas emissions, and waste production" (McKinsey & Company; Business of Fashion, 2017, p. 32). Such impacts stem from unaccountable growth and a lack of sustainability planning. However, fashion was not always fast. Mechanization, enhanced production, streamlined shipping, and increased consumer culture have all led to the rapid growth and expansion of the fashion industry.

Understanding why the fashion industry began to speed up helps illuminate the impacts of growth and speed without sustainability. The history of fast fashion also illustrates the potential benefits of comparative measurements in guiding the industry towards an environmental, social, and economic balance. Through a historical analysis in chapter 2, this thesis outlines how the fashion industry evolved from a mix of design houses, readymade

garments, and homemade apparel to the global industry we recognize today. Understanding the evolution of fashion, the major events that propelled it forward, and the fashion industry's place in global economies demonstrates how important sustainable impact measurements are in reducing the waste behaviors of the industry and consumers alike.

1.3 Sustainable research links between fashion industry and academic literature.

Chapter 3 examines the fashion industry's breadth of research in alternative end of life scenarios. Through a systematic literature review using distance reading and data mining of industry literature chapter 3 identifies the key terms, trends, and concerns within the fashion industry and links these themes to topics to academic literature. Chapter 4 examines how these key terms, trends, and concerns identified through the methodology in chapter 3 link existing literature to quantifiable measurements of alternative end of life impacts. Utilizing the similarities between industry terminology and academic literature, chapter 3 creates a library data bank. This analysis also exposes the gaps in sustainability data and proposes areas where the industry can begin to expand research interests.

1.4 Life Cycle Analysis as a sustainable impact measurement

Increased supply chain transparency is the most obvious solution to helping the industry reduce emissions and increase the accountability of labor standards. Fashion Revolution, one of the fashion industry's active voices for transparency, explains transparency as a necessary endeavor aimed at improvement, growth, and redefining accountability within the industry (Fashion Revolution CIC, 2018). However, companies may argue that such transparency requires unprecedented supplier vetting, inspection, and oversight staffing, which is not only costly but requires structures, certification, and documentation which will need to exist across different

companies and countries to be valuable. Transparency in this manner will require a complete reassessment of industry standards within companies and across the fashion industry.

Comparable sustainable impact calculations, primarily Life Cycle Analysis, are the most appropriate method to meet transparency expectations without the associated expenditure of launching and investing in international programs that threaten intellectual property and economic prosperity. Life cycle analysis (LCA) yields comparable sustainable impact calculations which help inform transparency and sustainability initiatives. LCA is a comprehensive approach to purposeful design and planning. Standardized by the ISO 14040 and 14044 guidelines (International Organization for Standardization,, 2017) and further defined by the European Union's "International Life Cycle Data System Handbook" (ILCD) (European Comission, 2005-2012), LCA is comprised of five primary processes goal definition, scope definition, life cycle inventory analysis (LCI), and life cycle impact analysis (LCIA) (International Organization for Standardization, 2006). The LCA calculates the impact of a production system from cradle to cradle, cradle to gate, gate to gate, gate to grave, and cradle to grave, giving corporations the option to assess the entire supply chain, induvial processes, or the full life and use cycle of textiles. LCA accounts for raw materials, water, energy, emissions, logistics, and social inputs assigning expected impacts to selected sustainable impact indicators. The data is then rendered to reflect the impacts of these flows, functions, and processes on the surrounding environment at either a midpoint or endpoint level.

The LCA calculation method allows stakeholders to break processes and products into a series of functional units and flows, which indicate where primary responsibility for impacts should be assigned. These results help stakeholders assess impacts across indicators such as water eutrophication, contribution to climate change, human health, and labor. The LCA is

a cumulative report which analyses the efficiency and potential for improvement within the LCI. The LCA non biasedly asserts the outcome of the calculations and impacts considered in the LCIA.

A shortcoming of LCA is that the impacts indicators chosen for measurement are not always standardized in the fashion industry (de Saxcé, et al., 2011). Hauschild et al. explore the variability within LCI and LCIA calculation, suggesting that out of all assessment methods and indicators available, only ten midpoint indicators and three endpoint indicators are consistently reliable (Hauschild, et al., 2013). These indicators rely on consistent data to track the entirety of a supply chain, which presents a problem when applying this method to the fashion industry. Due to the size, rate of expansion, and speed of the fashion industry, available data is often only enough to generate gate to gate scenarios, and data that does exist is variant across the industry.

Chapter 4 investigates the effects of these limitations through a literature review of academic LCAs on textiles. In chapter 4, the literature bank developed in chapter 3 is refined to include LCA. These LCAs are critically reviewed to identify common themes, methods, and gaps in current textile sustainable impact calculations. This review leads to a series of proposals outlining methods and actions which allow better comparative assessments of alternative production, use, and end of life scenarios.

1.5 Forwarding sustainability initiatives in the fashion industry

LCA is a tool which if utilized across the industry, will help corporations, designers, and brands asses the sustainability impacts of alternative materials and end of life options providing an economic incentive for participation in post-consumer textile programs. LCA integration into the fashion industry's sustainability initiatives means supply chains do not have to be a burden for companies to manage, as much as a partner that they can leverage. By increasing their

interaction with post-consumer textiles, brands have the unique opportunity to make returns on previously owned clothing. Through rental, second hand, and reuse programs, corporations, brands, and designers can take accountability for post-consumer textile emissions and reduce consumption, all while making a second or third return on a single garment. Mechanical and chemical recycling initiatives allow the fashion industry to supplement its feedstock of raw materials reducing costs and virgin material reliance dramatically reducing environmental emissions.

Chapter 5 presents a path forward for the fashion industry that does not rely merely on changing consumer behavior but activates companies, brands, and designers to reevaluate their material selections and assess alternative end of life scenarios using data gathered from sustainable impact calculations. Linking the historical perspective on the growth of the industry, to a systematic review of available literature, and a methodological literature review of academic textile LCAs, this thesis assesses the applicability, quantity, and quality of current sustainability impact calculations, and proposes alterations to calculation and measurement methodology which will help guide the fashion industry towards more transparent and sustainable decision making.

Chapter 2: How did we end up with so much clothing?

To understand why the fashion industry is so impactful it is important to understand the influence of garments beyond consumption. Garments do not exist merely to create fashion plates[1] but serve physiological, social, and cultural needs. Expecting consumers to buy clothing without changing production methods and equity incentives is asking individuals to negate their ability to fill these visceral and socio-economic needs adequately. Therefore, establishing how clothing consumption evolved into fast fashion and why the problem of fast fashion persists strengthens the argument for exploring alternative methods to calculate and measure the sustainability impacts of the fashion industry.

2.1 Human adoption of clothing

While clothing has become an integral piece of human identity over the millennia, the use of clothing by humans likely arose from the need to protect the wearer from the elements, enabling both physical and perceived comfort (Gilligan, 2010). Gilligan argued that the general evolution of clothing is studied through archeological findings, human dispersal patterns, and climate data (Gilligan, 2010). Gilligan's work provides a broad overview of early humans' clothing behavior and has proven consistent across the breadth of documented history.[2] Gilligan finds that this increased tolerance would permit humans to settle in environments that would have been uninhabitable through earlier behavior and permitted adaptation to a multitude of climates, allowing communities to separate and populate greater areas as the hominin population grew (Gilligan, 2010) .

[1] A fashion plate is either an illustration of fashionable clothing or is a description of a person who dresses in the latest fashions (Webster Dictionary).
[2] As a note, any evidence of clothing adaptation to climate signals in history is an informed generalization from models and historical analysis. Such generalizations do not necessarily reflect every individual's unique needs.

2.2 Why humans adapt clothing

Why humans wear clothing is as essential a question as when and why clothing was invented. If it can be hypothesized that Pleistocene hominins adopted clothing to protect themselves from the elements, can the same theory be applied to the modern uses of clothing? After all, fashion history indicates the change in textile and garment preferences correlate with significant shifts in climate. This conscious calculation of human vulnerability to climate based on clothing choice indicates that clothing is indeed vital to human physiological wellbeing. In early human history, clothing was thus a "functional necessity" versus an "ornamental accessory" (Salata, et al., 2018). Garments were designed to be functional and made with the intention of the owner's specific needs, functionality, and daily use. For example, Victorian layering fashions and fabric choice directly correlated with the extended periods of wet weather that populated the end of the Little Ice Age in England (Drake & Rabun, 1983). In contrast, clothing today is often termed as fast fashion implying the speed of production and consumption in the clothing industry.

In 1979, Steadman created the Heat Index to measure the impacts of clothing behavior to human perception of temperature and humidity. The heat index was the first environmental monitoring system that linked measurements for how humans perceived weather based on their clothing choices to safety advisories (Steadman, 1979). Steadman's system created a standardization of clothing behaviors in a variety of climates and provided humanity with a warning system to assist in creating "comfortable" interactions between humans and their environments based, in part, on clothing choices (Steadman, 1984). The Heat Index gave scientific credibility to the necessity of clothing to indicate human climate perception and standardized "weather appropriate" clothing recommendations. While there is a cultural

inclination towards adapting clothing, fast fashion would decline if clothing lasted longer and did not need to be replaced or changed to meet physiological comfort needs.

2.3 Shift in clothing necessity to a commodity for the average consumer

Clothing excess has existed as a delineator between social classes throughout recorded history. Access to excess relied upon certain levels of wealth. With the combination of high material, finishing, and dressmaker costs, excess in dress was regulated to a minuscule percent of the population until the reduction in material production costs, brought on by the American Revolution, and decreased labor costs, associated with the mechanization of the Industrial Revolution.

Following the American Revolution, Americans felt the need to separate themselves from Britain's economy and the systems they felt represented the oppressive monarchy, in particular, Britain's textile market (Bekke, 2005). The desire to separate the American market from the British would discourage and dissuade the desire for British styles and sparked a manufacturing feud between Britain, France, and the United States (US) (Bekke, 2005). Britain, however, had the technology to create affordable, lightweight textiles, which despite even the most substantial resentment, quickly enabled American people, regardless of socio-economic status, to consume textiles at an unprecedented rate (Bekke, 2005). Bekke asserts that despite the social interest in the common good of the new republic, Americans continued to buy the lighter cheaper textiles from Britain, explaining that Americans were surprised and encouraged by the change in perception and local influence they encountered as they were able to buy finer fabrics and make more extravagant clothing (Bekke, 2005). Thus, the desire for affordable excess for the masses won out.

In 1846, at the end of the British Industrial Revolution, retailors claimed that they had irrevocably changed the textile industry by introducing readymade clothing at an accessible price point (Chapman, 2013). Contrary to the common assumption that the shift in consumption of clothing began with the advent of the sewing machine, the power loom partnered with the infrastructure provided by textile mills of the Industrial Revolution streamlined clothing production. The efficiency of textile mills, coupled with the reduced prices in garment manufacturing achieved at the turn of the century, increased the availability of affordable and fashionable readymade clothing (Chapman, 2013). Evidence from early department stores and textile factories indicates that the increased efficiency provided by technology and a bolstered workforce streamlined production and employed workers who wished to wear what they made (Elahi, 2009). This class of workers had unique access to readymade garments and a desire to dress towards their aspiring class (Chapman, 2013). The impacts of the American Revolution, French Revolution, and the War of 1812 had given this newly rising class the ability to leverage desperate economic markets, which combated the falling prices of textiles by competing with each other to produce newer and more affordable textiles and garments (Chapman, 2013). Retailers seized this opportunity to market and sell clothing to the masses.

Playing off the competition of foreign markets and advertising readymade clothing as essential to leveraging socio-economic change, department stores grew to record sizes from 1850-1890. Brands such as Macy's, Field's, Sears, Wannamaker's and Woodward & Lothrop pioneered customer service models and advertising campaigns that expanded access to readymade clothing while simultaneously encouraging consumers to indulge in luxury items such as Parisian silks and elegant lace (Benson, 1988). Even department store goliaths such as Niemen Marcus and Selfridge's came to market during the explosion of retailer growth at the

turn of the twentieth century. However, the economic downturns of the early twentieth century crippled the exponential growth of the retail market (Cohen, 2004). Department stores resorted to stocking even more extensive selections of goods to avoid deflation and offer protection during lulls and downturns (Benson, 1988). This reaction to the Scare of 1907, the Post-Great War Recession, and the Great Depression would lay the foundation for overconsumption, clearance sales, and discount drivers in the post-war era. Despite the increased ease in production and marketing efforts of department stores, it took an even bigger global phenomenon for clothing to become easily accessible to the masses.

Following nearly two decades of uncertainty and war, the US was desperate to ensure an era of prosperity and peace following the second world war (Cohen, 2004). After ramping up manufacturing capabilities using vertical and horizontal integration, a method pioneered in manufacturing in order to win the second World War, Americans had greater access to raw materials, improved mass management capabilities, and an abundance of decommissioned processing facilities (Benson, 1988). The US stood in a unique place following the end of the second world war. Due to the US's geographical location, it had been separated from the devastation of both world wars. While former global leaders in production and manufacturing focused on rebuilding transportation networks, cities, and other necessities, the US had newly built manufacturing infrastructure that simply needed to be adapted to new products (Cohen, 2004). With the innovation in manufacturing, US retailers were able to control product design and create trends at an unprecedented speed (Doeringer & Crean, 2006). The US quickly became the leader in textile manufacturing due to its unique position and capability to focus on economic growth and production (Press, 2018; Doeringer & Crean, 2006).

2.4 Clothing access and socio-economic status in the post-war era

Although the influx of wealth in the US following the second world war encouraged consumption, it was the coupled conception of garments and consumerism denoting status, equality, and freedom that altered the relationship between the average consumer and their clothing. Department stores, government agencies, labor unions, and mass media launched campaigns insisting that consumption of garments and other readymade goods was not an indulgence but a civic responsibility (Benson, 1988; Cohen, 2004; Cline, 2012; Press, 2018). This strategy was particularly successful as it advocated that a growing economy "promised a socially progressive end of social equality without requiring politically progressive means of redistributing existing wealth within the US" (Cohen, 2004, p. 237). Overconsumption was an attempt to spur economic growth and led to the development of cultural norms regarding the ownership of property and appearance of dress.

While these cultural norms associated garment consumption with freedom, peace, and prosperity and increased status fluidity through consumption, the social norms of acceptance and approval were deeply discriminatory among racial and cultural lines (Cohen, 2004). Cohen writes, "The economic and social stratification of metropolitan America was reinforced by marketers and advertisers, who simultaneously discovered the greater profits to be made in segmenting the market into distinctive submarkets based on gender, class, age, race, ethnicity, and lifestyle" (Cohen, 2004, p. 238). Through the 1960s, these separations drove political associations, economic opportunity, and played a significant role in the American Civil Rights Movement (Cohen, 2004). Key decision-makers at major retailers leveraged greater economic gains by dividing and marketing to these distinct social groups and adapted their

messaging to encourage consumption by creating multiple lines, styles, and color variations that could be marketed across social groups (Cohen, 2004).

As shopping malls began to populate the United States in the 1960s, brands and retailers would pick up on these distinctions and incorporate specific brands and lines, which would include or exclude the desired socio-economic groups (Cohen, 2004). Associations with clothing among groups became intimately ingrained with socio-economic status as much as an individual's residential address and type of employment (Oakes & Kaufman, 2017)). As production centers began to shift and brands became multi-national corporations, from 1970 until the 2000s, the associations between clothing, status, and wealth became increasingly predominant.

2.5 Socio-economic distinction and the rise of fast fashion

As brands and mass retailers continued to expand to multiple lines and advertise to distinct groups, the methods of stocking and mass ordering continued to increase in clothing stores across the world. As department stores grew in size from the 1890s until the 1940s, they had spread from the United States to Europe, bringing American customer service, stocking habits, and annual sales with them (Benson, 1988). From the 1970s to the 1990s, these department stores continued to grow, and many of the brands and designers they stocked expanded into their own brick and motor stores (Press, 2018). Such expansion resulted in the evolution of the mass retailer.

Mass retailers began to emerge as the smaller brands and designers morphed into multi-location corporations, often housing multiple brands and lines across a variety of storefronts. These retailers differed from department stores because mass retailers design for and produce the garments sold throughout their locations and brands. Mass retailers, such as Gap and the Limited

outsourced supply chains in order to compete within a crowded and growing retail market throughout the 1970s and 1980s (Doeringer & Crean, 2006). Cheaper production allowed mass retailers to lower the prices of basic garments. These brands combatted the increased lag time and logistical demands resulting from outsourced supply chains by increasing the sizes of their orders ensuring profit even at rock bottom prices (Doeringer & Crean, 2006). During the 1980s, retailers moved away from American made textiles and capitalized on cheaper offshore production. The result awakened economies in south, southeast, and east Asia, as well as in Latin America (Cline, 2012; Press, 2018).

Offshore production alone is not the core cause of fast fashion, although it did spur the decline of the American Textile Association. When mass retailers accepted the increased orders, stocking demands, decreased quality, and logistical complications that accompanied lower price production at offshore locations, they also set a precedent for the fashion economy (Doeringer & Crean, 2006). The shift in production also changed the types of garments that would be available and affordable for the consumer. Fast fashion companies sell "basics," i.e., denim, t-shirts, sweaters, and other street style commodities. Due to the low production cost of these basics, retailers were able to offer these styles in greater quantity and variety, and the American public responded favorably (Doeringer & Crean, 2006). As mass retailers expanded these offerings to their global stores, they became dependent upon a supply chain that was, in turn, dependent upon mass production, discounts, and low-cost labor (Doeringer & Crean, 2006). Consumers globally began to adapt to the ease and accessibility of mass-produced offshore basics. Basics such as denim, t-shirts, and knit sweaters became more acceptable in social situations globally, and the fast fashion market prospered. As consumers bought more, retailers continued to convert and produce to meet consumers' needs.

Soon even high fashion and luxury design houses began the shift to offshore production in order to keep up with the mass retailers (Doeringer & Crean, 2006). Just-in-time supply chains allowed the fashion industry to speed up their orders and respond to trends in the market by the end of the 1980s, which increased the profitability of fast fashion and allowed mass retailers to shift the fashion industry from bi-annual releases to quarterly and eventually bi-weekly product releases (Doeringer & Crean, 2006). In order to balance the massive inventories required with mass production and increased speeds, retailers increased the occurrence of price incentives to reward over consumption and drive consumers to buy unwanted or dead stock (Doeringer & Crean, 2006; Press, 2018). Associations between status and clothing also drove how consumers purchased garments throughout the rise of fast fashion.

While price incentives and access drove the increased speed in consumption from the 1980s to the present day, clothing consumption increased because 'basics' became more commonplace. Clothing allows people to change their appearance to change outward perception of their socio-economic status. While outsourced garments were initially cheap in both appearance and cost, low- and middle-class families could buy affordable clothing, which with a few alterations looked just like the suits, uniforms, and styles that had previously separated socio-economic groups (Cline, 2012; Press, 2018). As technology improved, the quality of these garments continued to increase as prices decreased, and more styles became readily available (Doeringer & Crean, 2006). Clothing leveled the classes by allowing all socio-economic classes to choose how they dress and appear with little differentiation in cost and quality.

When corporations rely on consumers to change behavior or scientists advocate for consumers to reduce consumption, they ignore the impacts clothing reduction or increases in price would have on the lower and middle class. By expecting consumers to reduce consumption,

they are asking lower socio-economic groups to unequally sacrifice the quality of their daily interactions, job opportunities, and personal appearance in order to preserve the environment without expecting the same sacrifices from the wealthier groups who can afford the higher quality, environmentally conscious materials. Therefore, relying upon consumer behavior change is not an adequate solution to fast fashion, because such behavior requires exclusion and unequally burdens social groups.

2.6 The importance of alternative sustainability pathways

By analyzing and recognizing the influence and importance of garments to physiological, social, and cultural needs, a clear link between the importance of garments and general reluctance to reduce consumption can be identified. Lorek and Fuchs argue that consumption-based strategies fail to consider justice, long term impacts, and focuses primarily on technological improvements (Lorek & Fuchs, 2013). The authors assert that such strategies fail to consider the uneven global use patterns (Lorek & Fuchs, 2013). Consumer behavior-based strategies fail to consider the needs, desires, and actions of developing economies, and unevenly place burdens on consumer groups. The fashion industry has taught consumers, for nearly 200 years, that consuming garments equals both a social responsibility and indicates a consumer's socio-economic worth.

Thus, the fashion industry should first change the production methods and equity incentives. Lorek and Fuchs suggest there are two primary routes in sustainable decision making. They write, "the 'weak sustainable consumption' approach is rooted in market approaches and technological optimism. Strong sustainable consumption, in turn, emphasizes social innovation as a starting point and strategically takes a technologically pessimistic position" (Lorek & Fuchs, 2013, p. 37). In the case of the fashion industry, these paths are the consumer behavior and

technology-based approach, and the informed decision-making process strengthened by such methods as sustainable impact calculations. Sustainability impact measurements enable the fashion industry to transition from the weak sustainable consumption course to the strong sustainable consumption approach by providing the industry with accurate, comparable measurements of alternative use cases, material selection, and technology improvements alike through linking environmental social, and economic indicators to help the industry make informed sustainability transitions. Comparable sustainable impact calculations allow the industry to choose alternative materials and end of life options which reduce their emissions, stimulate economic growth, and reduce their dependence on virgin materials, while simultaneously assessing social impact.

Chapter 3: Linking sustainability impact measurements to themes in fashion industry literature

Chapter 3 identifies the key terms in sustainable fashion initiatives and links these terms to existing academic research. As evidenced in chapter 2, fast fashion companies have encouraged excess and demanded minimal accountability for the expedited lifespan of clothing. This thesis proposes that sustainable impact measurements of alternative methods to end of life scenarios enabling the fashion industry to reduce textile waste, cut emissions, and produce alternative revenue streams to mass production without assigning undue burden on consumers. By employing a systematic review utilizing data mining and distance reading to determine key fashion industry terminology, chapter 3 establishes common themes in fashion industry literature and identifies opportunities for further sustainable research in academia through the creation of an article bank.

Primarily this chapter explores the themes of sustainable use cases in the literature, i.e., rental, resale, reuse, and recycling. The term used in this thesis to encapsulate all alternatives is REoptions[3] (McKinsey&Co; Business of Fashion, 2019; Menkes, 2009; Kerr & Landry, 2018). While the term REoptions is new, the ideology is not. The concept of reduce, reuse, recycle was entwined with recycling when in, 1970, Gary Anderson created the globally recognized recycling symbol using the Möbius loop (Astropekakis, 2008). Reduce, reuse, recycle was adopted by the environmental movement during the 1970s to influence consumer behavior

[3] "REoptions" is a term developed by the author to group alternative ends of life to incineration and landfill for garments. Many of these current strategies contain the word recycling or are a form of recycling or reuse, therefore, or the purpose of this chapter Recycling will only refer to the mechanical process involved in transforming garments back into fibers. To reduce confusion for the reader all extended use and alternative end of life scenario have been grouped together as REoptions when referred to as a general system for improvement.

and encourage corporations to adopt alternative end of life initiatives. REoptions serve a similar function. However, REoptions go further by encouraging the fashion industry to incorporate alternative end of life scenarios as part of their value chain. By conducting a systematic review of existing literature, chapter 3 examines how fashion industry leaders and academics research REoptions and identifies opportunities to expand research and incorporate sustainable impact measurements in the literature.

3.1 The importance of identifying REoption trends in fashion industry literature

Fast fashion has driven the total consumption of garments and textiles to unprecedented rates while decreasing use by 36% in fifteen years (McKinsey&Co; Business of Fashion, 2018). Furthermore, industry research indicates that less than 1% of all clothing ends up in circular recycling programs and costs the industry roughly $500 billion in value every year (McKinsey&Co; Business of Fashion, 2018). The industry is bleeding money from underutilized income sources, which will continue to amass as fashion increases production pace and consumption rates. The annual world consumption of fibers in 2012 was 82 million tonnes, which is equivalent to 12 kg of apparel per capita (Hvass, 2014). In the United States, nearly 13.2 million tonnes of textiles went directly to landfill in 2010 alone (Payne, 2015). In the European Union, 4.3 million tonnes of garments were sent to landfill in 2012 (Zamani, et al., 2014). The evaluation of current solutions highlights the opportunities for REoptions. Comparative research of REoptions allows the fashion industry to tailor their current value chains to incorporate alternative end of life opportunities. Assessment of the links in fashion industry literature highlights the perception of current REoptions by industry decision-makers. Insight into how fashion industry leaders view the benefits of REoptions and awareness of the

breadth of literature available to influence their perceptions is the foundation of changing the behaviors and sustainability pathways of the fashion industry.

3.2 Linking industry and academic terminology

The fashion industry is notoriously undocumented and underreported. Such freedom has allowed the fashion industry to protect trade secrets and intellectual property. However, as consumers and corporations increasingly demand greater transparency across the supply chain, the fashion industry is beginning to conduct more extensive research on the industry's practices. Today many of the fashion industry's guiding studies and reviews are conducted by consulting groups and private research firms. Utilizing the same syntax as the works produced by private and consulting groups will make academic outcomes easier for the fashion industry to find. By communicating in a common vernacular, academics can reduce the risk of misinterpretation and add value to the breadth of literature the fashion industry relies on to guide decision making.

Establishing a vernacular for sustainable fashion is especially important in informing sustainability transitions because terms, such as sustainable, circular, recycling, textile, and garment, have many different meanings across both academic and industry-specific literature. Narrowing terminology and conforming to the industry's preferred verbiage will assist academic researchers in producing data that can be easily absorbed and utilized by the fashion industry. Efforts by academics to accept industry definitions may lend credibility to the accepted definitions and help guide the adaptation and direction of terminology in an increasingly transparent fashion industry.

3.3 Selection of fashion industry literature

Systematic review is the primary method for this study as it eliminates concerns of selection and publication bias (Booth, et al., 2016). Selection and Publication bias results when

an author chooses to review only materials which will be favorable toward the research question or those materials that have a preferred results (Booth, et al., 2016). To avoid bias in keyword selection the author selected fashion industry literature using the criteria of industry reports released in the past four years and available on the platform Common Objective (CO) (https://www.commonobjective.co/). CO is a fashion industry innovation hub aimed at connecting actors, producers, and designers with solutions to forward sustainability initiatives within the fashion industry. CO was created by Tamsin Lejeune, the co-founder of the Fashion Revolution and longtime industry leader (Common Objective, 2020). CO works as a high-level social innovation amplifier connecting niche actors with fashion industry leaders and highlighting innovation for potential investment and partnership. This literature selection is exhaustive for the keyword selection process of the systematic review as it reviews all industry reports acquired through the CO platform and spans four years of industry research.

Utilizing fashion industry reports available through CO, chapter 3 presents an empirical literature analysis to determine common keywords and phrase associations that describe REoptions within the fashion industry. The text corpus is made up of the seventeen most recent reports available to fashion industry professionals through CO as of March 2020. The reports, listed in Table 1, guide decision-makers' choices regarding production, consumption, and business opportunities for upcoming seasons. The reports are made available through CO are representative of the words and phrases the fashion industry uses to discuss sustainability initiatives. The text corpus, Table 1, is analyzed using the open-source software Voyant Tools (https://Voyant-tools.org/), which identified keywords and phrases the industry utilizes to discuss REoptions and sustainability initiatives.

Table 1: Fashion industry literature text corpus

	REFERENCE	TITLE	YEAR
1	(World Economic Forum, 2020)	**The Global Risks Report**	2020
2	(Traidcraft Exchange; the World Fair Trade Organisation; Doherty, Bob; Haugh, Helen, 2019)	**Creating the New Economy: Business models that put people and planet first**	2019
3	(Platform for Accelerating Circular Economy (PACE), 2020)	**The Circularity Gap Report**	2020
4	(Ellen McArthur Foundation, 2017)	**A New Textiles Economy: Redesigning fashion's future**	2017
5	(Global Fashion Agenda, 2017)	**Pulse of the Fashion Industry**	2017
6	(Global Fashion Agenda, 2018)	**Pulse of the Fashion Industry**	2018
7	(Global Fashion Agenda, 2019)	**Pulse of the Fashion Industry**	2019
8	(Global Fashion Agenda, 2018)	**Seven Sustainability Priorities for Fashion Industry Leaders**	2018
9	(Global Fashion Agenda, 2019)	**Eight Sustainability Priorities for Fashion Industry Leaders**	2019
10	(Global Fashion Agenda, 2020)	**Eight Sustainability Priorities for Fashion Industry Leaders**	2020
11	(Fashion Revolution CIC, 2018)	**Fashion Transparency**	2018
12	(WRAP, 2017)	**Valuing Our Clothes: The cost of UK fashion**	2017
13	(UK House of Commons, 2019)	**Sustainability of the Fashion Industry**	2019
14	(MCKINSEY & CO APPAREL, FASHION, & LUXURY GROUP, 2018)	**Measuring the Fashion World**	2018
15	(McKinsey&Co: Business of Fashion, 2018)	**The State of Fashion**	2018
16	(McKinsey&Co; Business of Fashion, 2019)	**The State of Fashion**	2019
17	(McKinsey&Co; Business of Fashion , 2020)	**The State of Fashion**	2020

3.4 Text analysis method selection and process

The reports found on CO, guide fashion industry decision-makers by providing them with crucial data and predictions regarding significant trends in the fashion industry. In order to triangulate the key terminology utilized to describe REoptions, this study employs text analysis using the text visualization software Voyant Tools (https://voyant-tools.org/). While the use of textual analysis software has been controversial in academic studies (Fielding, 2002; Simanowski, 2016), previous studies within the field of geography have successfully employed data mining tools to enable a macro analysis of large text corpus in order to guide "close reading" or micro interpretations of themes in literature (Purcell & Moore, 2019). In fact, due to the global nature of the fashion industry and the sheer quantity of relevant industry, grey, and academic literature related to sustainability in fashion, a close reading of such extensive literature is impractical and inappropriate (Jockers, 2013; Bright & O'Connor, 2007). Bibliometric research and institutional research are also beginning to use datamining software to identify emerging trends in literature across large bodies of works (Fahimnia, et al., 2015; Hendrigan, 2019; Papamitsiou & Economides, 2014).

The systematic review conducted in chapter 3 serves to create a literature bank of the most relevant academic articles using industry vernacular. This literature bank is used as a basis for the methodological review of existing sustainable impact calculations conducted in chapter 4. A common critique of the use of systematic review in thesis work is that systematic review methodology in thesis work is not always perceived to represent the defending student's independent research (Puljak & Sapunar, 2017). However, the combined use of data mining, text visualization, and distance reading methods in the systematic review presented in this chapter

counters such concerns by demonstrating the value of targeted close reading and correlation analysis in creating literature banks.

The use of systematic review in an academic thesis has been verified across multiple institutions by Pulijak and Sapunar (2017). The use of the methods presented in this chapter are qualitative and follows the practice of systematic literature review (SLR) and bibliometric methods (Mengist, et al., 2020; Fatarella, et al., 2015). Bibliometric methods are ideal for researching newer topics, as they can help highlight emerging trends in large bodies of literature (Fatarella, et al., 2015). Bibliometric methods often recommend that structured systematic literature reviews begin by defining a set of keywords to then apply to the literature search. Educational Data Mining (EDM), also sets a precedent for conducting systematic review using keywords analysis. In particular EDM commonly uses data mining to conduct clustering, sensitivity analysis, and context analysis of keywords throughout a large literature base (Papamitsiou & Economides, 2014). Using Voyant Tools, this study identifies keywords using the word clusters, terms view, and contexts tools to identify occurrence, themes and use of phrases and terminology across the industry literature selected from CO. Use of these tools has precedence from bibliometric research into emerging themes in engineering and STEM literature (Hendrigan, 2019).

By utilizing the bank of literature gathered through systematic review in this chapter, this thesis then conducts close reading and critical analysis of existing methods for sustainable impact calculations in chapter 4, through the lens of LCA. Such critical review results in the propositions of new methods and alterations to practices which move the industry closer to achieving strong sustainability initiatives. The fashion industry literature selected from CO

contains the most recent, and highly regarded fashion sustainability guidance from industry leaders and private research conglomerates.

3.4.1 Primary title keyword identification

To begin finding relevant academic literature, this thesis determined that the first level of keywords needed to include a term descriptive of textiles. The purpose of chapter 3 is to identify trends in fashion industry terminology to guide the selection of academic literature, identifying trends and research opportunities throughout the process. Therefore, any article that does not contain a descriptive term for textiles in the title was eliminated from the search on the premise that the article would be less likely to be found by an industry professional using the fashion industry preferred vernacular.

When uploaded into Voyant Tools, the text corpus, Table 1, yielded five primary words to describe garment use. *Fashion* (3611), *clothing* (1080), *textile* (706), *apparel* (637), and *clothes* (628) appear as the highest recurring textile words in the word cloud represented in Figure 1. While it does not appear in Figure 1, the word *garment** was also selected, with 780 mentions across the corpus.[4] The word *fast fashion* was added to the terms appearing in Figure 1 as an additional qualifier for fashion to reflect trends in publication and media perceptions of the mass market fashion phenomena, as mentioned in chapter 2.

The value of these critical terms lies in their recurrence across the selected grey literature. Figure 2 depicts the occurrences of keywords across the literature. The term *fashion* occurs most commonly across the literature, 3611 times, and is the most used term across twelve of the

[4] Garment* may include garments, garment, and garmenting, this thesis combines all words utilizing garment as representative of the textile conversion to whole apparel.

seventeen selected pieces. *Fashion*, however, may not only refer to textiles and garments specifically but the industry in general or as a descriptive term. Therefore, the qualifier *fast fashion* was added despite its lower rate of occurrence throughout the literature to narrow the focus of discovered academic literature

Figure 1 – Commonly used terms in fashion industry literature

The term *textile* occurs 1195 times throughout the literature and is most mentioned in the "A New Textiles Economy: Redesigning fashion's future" by the Ellen McArthur Foundation. *Textile* may also refer to production and raw material construction; therefore, the author has added the clarifying terms *consumer* and *post-consumer* to the tertiary word bank to specify the use case for the word textile.

The term *clothing* occurs 1090 times, while *clothes* occurs 640 times throughout the literature. The terms are used at roughly the same rate across all reports spare two documents, "A New Textiles Economy: Redesigning fashion's future" and "Valuing Our Clothes: The cost of UK fashion." In both instances, *clothing* appears more often than *clothes*; this is mostly due to the use case associated with clothing during the consumer use phase. Due to the commonality in appearance between the two terms, the author chose to combine the terms clothing and clothes to reduce the potential redundancy of search terms.

The word *garment* occurs 780 times across the text corpus. The term's peak use occurs in "Valuing Our Clothes: The cost of UK fashion" and "Sustainability of the Fashion Industry." Both documents utilize the words *textile, garment, apparel, fashion, textile, clothing,* and *fast fashion* as interchangeable throughout the documents, which justifies the inclusion of these terms in the general title search parameters.

The key term *apparel* appears 651 times across the text corpus. In general, the term is used consistently across the industry's literature. Although *apparel* appears to have peaked use in the reports "Pulse of the Fashion Industry 2019" and "Measuring the Fashion World 2018," which primarily focus on the trends and directions of retail and sales within the fashion industry, *apparel* often refers to categories of garments sold at mass-market, i.e., men's, women's, athletic, etc. After reviewing both figures from the visual text analysis, the terms selected for the keyword

title search in the empirical literature review are *apparel, clothing, fashion, fast fashion, garment, and textile.* The consistent use of these terms, as indicated by the H-index ranking, across the text corpus indicates that academic articles that contain these terms within the title are the most likely to be utilized within the fashion industry and among academics.

3.4.2 Secondary keyword selection

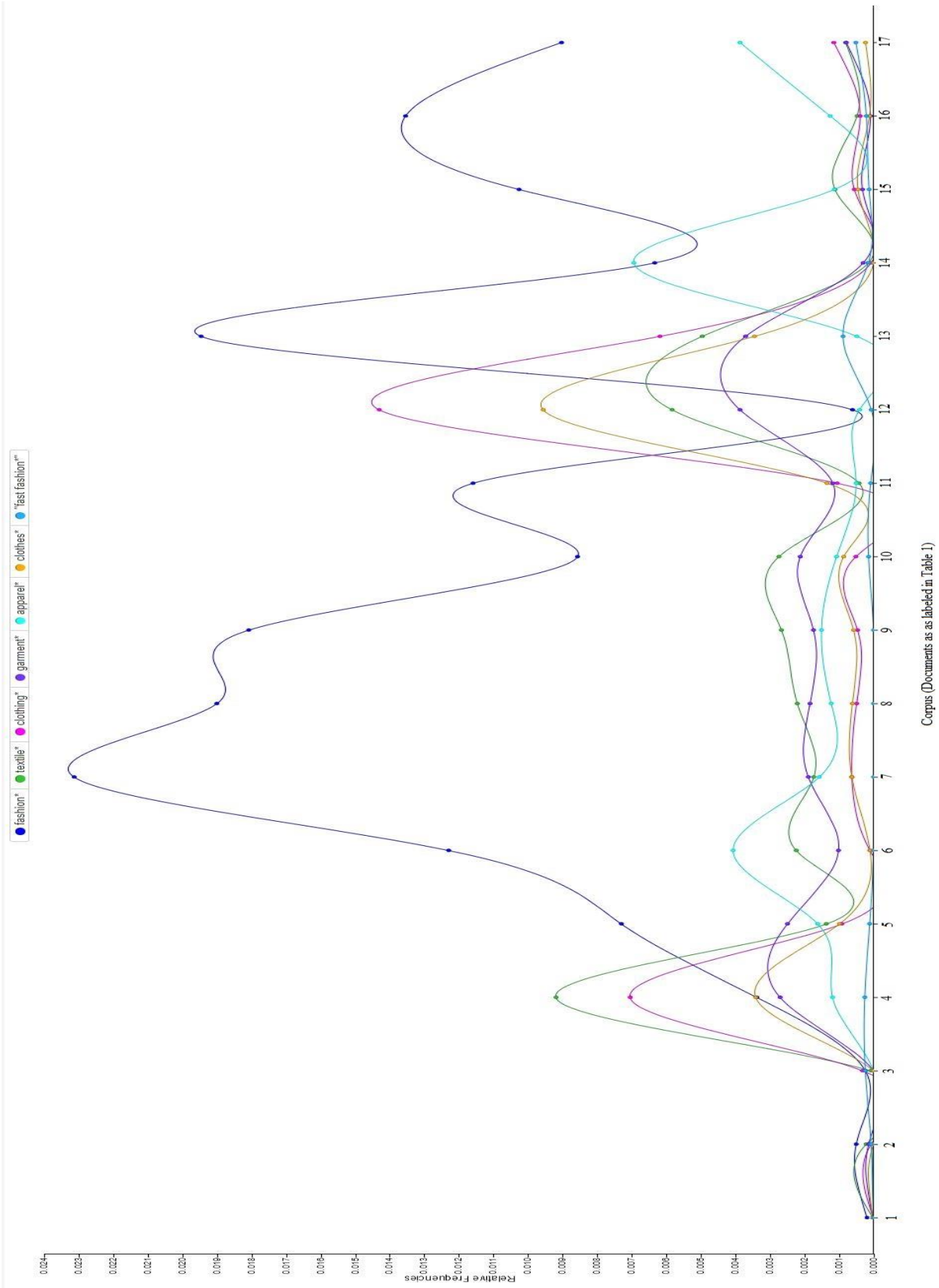
The secondary words assessed apply REoptions. The secondary title keywords are added to each of the six primary keywords and used to narrow the scope of the search. Forty-Seven keywords appear in Figure 1 of these words, and eleven were chosen as the most relevant to REoptions. The relevant terms are listed in Table 2. These terms *circular economy, environmental impact, recycling, reuse, sustainability,* and *waste* were selected as secondary title keywords and added to the empirical literature review search criteria.

The term *economic* is used broadly across the industry, i.e., economic impact, economic value, economic stimulus, which do not closely relate to REoptions. The term *circular* may have multiple meanings within the industry, as many knitting and construction practices are referred to as *circular*. Therefore, the terms *economic* and *circular* were combined into *circular economy* to narrow the search parameters. The term *impact* is overly broad and may refer to water, social, financial, or production impacts. Thus, *impact* was combined with *environmental* to refine the search parameters. The word *used* may be applied as a verb or adjective and describe a condition or action. To reduce opportunities for confusion, *used* was changed to *reuse* to align with REoptions. The terms *consumer* and *value* were considered to have an impact on all terms; as such, they are applied as tertiary keywords. As *sustainability* and *sustainable* are interchangeable throughout the literature and imply a use case for garments, the words will be used as tertiary keywords to help refine the search parameters.

Table 2 –Words descriptive of recycling behaviors

Recycling Words			
Circular	*environmental*	*sustainability*	*Value*
Consumer	*Impact*	*sustainable*	*Waste*
Economic	*Recycling*	*Used*	

Figure 2- Use of keywords throughout corpus



3.4.4 Tertiary keyword selection

The tertiary keywords used to narrow the search parameters for this systematic review ensures that the articles are relevant to REoptions in the fashion industry. The tertiary keywords may appear anywhere within the article and are applied individually to each primary and secondary title keyword combination. This additional filter limits literature assessed to reflect trends within REoptions research and identify opportunities for academics to contribute to industry knowledge on REoptions. The words chosen for tertiary keywords are listed in Table 3 and are classified by the purpose each word serves in narrowing the field. If a term is labeled as REoptions, the term directly reflects one of the REoptions pathways of interest to this chapter. If a word is labeled as use type, this indicates the keyword is added context to the way the garments are used and collected.

Table 3 – Tertiary keyword association

Tertiary Keyword	Purpose	Tertiary Keyword	Purpose
Collection	**REoptions**	*Consumer*	**Use Type**
Donation	**REoptions**	*Post-Consumer*	**Use Type**
Rental	**REoptions**	*Sustainability*	**Use Type**
Resale	**REoptions**	*Sustainable*	**Use Type**
Secondhand	**REoptions**	*Value Chain*	**Use Type**

3.5 Article search results

The purpose of identifying keywords from industry literature is to narrow the scope of applicable works that could be identified to inform REoption development within the fashion industry. Utilizing scientometric methods, this chapter examines the quantity of existing academic works, identifying opportunities for future research, and summarizing current trends within academic literature on REoption topics. Repanovici (2010), argues that the impact of academic research can be identified using the H-index, among other scientometric methods, and advocates for the importance of open access assessment tools to ensure the reliability of academic research. She writes, "scientometric analyses the quantitative aspects of generation, dissemination, and utilization of scientific information in order to contribute to the understanding of the mechanism of scientific research" (Repanovici, 2010, p. 2). The primary data of this analysis includes the authors, the article's citation average (h-index), the year of publication, and the average number of citations since the year of publication. In the case of literature on REoption for the fashion industry, the keywords identified through textual analysis paired with the results from scientometric analysis convey context, identify impactful works, and expose common themes in REoption research.

3.6 Methods for determining the popularity of academic literature

Utilizing the keywords selected through the visual text analysis tools, the author searched Google Scholar using the open-source software Publish or Perish by Hazing (https://harzing.com/resources/publish-or-perish) (Harzing, 2007). Developed by Dr. Anne Harzing of Melbourne University, Publish or Perish is an open-source software which has been justified for use in scientometric analysis and data mining to assess the impact of academic

research (Repanovici, 2010). The H-Index is assessed for each article pulled matching the selected keywords.

The H-index was developed to identify how commonly cited an author or article is as an indication of the impact of academic work over time (Hirsch & Buela-Casal, 2014). The H-Index differs from the number of citations as it examines the average number of citations over time compared to the authors' total number of cited articles (Hirsch, 2005). The H-index, therefore, helps determine the author's overall impact within the field (Repanovici, 2010). So long as the H-index is above ten, the H-index helps determine the importance of articles within the field (Hirsch, 2005). The H-index helped determine the prevalence of the terminology in the field for primary and secondary terms. The index will not, however, be used to assess the quality of academic articles when filtered by tertiary terms if the H-index for many of the terms is below ten.

3.7 Application of primary keywords to academic literature

When applied to the search utilizing Publish or Perish (Harzing, 2007), the primary title keywords; *apparel, clothing, garment, fashion, fast fashion,* and *textile;* yielded the results in Table 4. The search parameters with only primary title keywords produced over 7000 pieces that span 121 years. The H-index of *fast fashion* implies that the breadth of work produced in the field does not rely on or reference *fast fashion* as broadly as the other terms in the primary keyword set. Table 4 indicates that the breadth of academic literature containing the keywords begins at the turn of the twentieth century and spans until the modern-day. Therefore, the parameters utilizing only the primary keywords are too broad as the pace of fashion did not increase until the end of the 1970s, as indicated in chapter 2. This assumption is confirmed by the appearance of the term *fast fashion* in academic literature beginning in 1979.

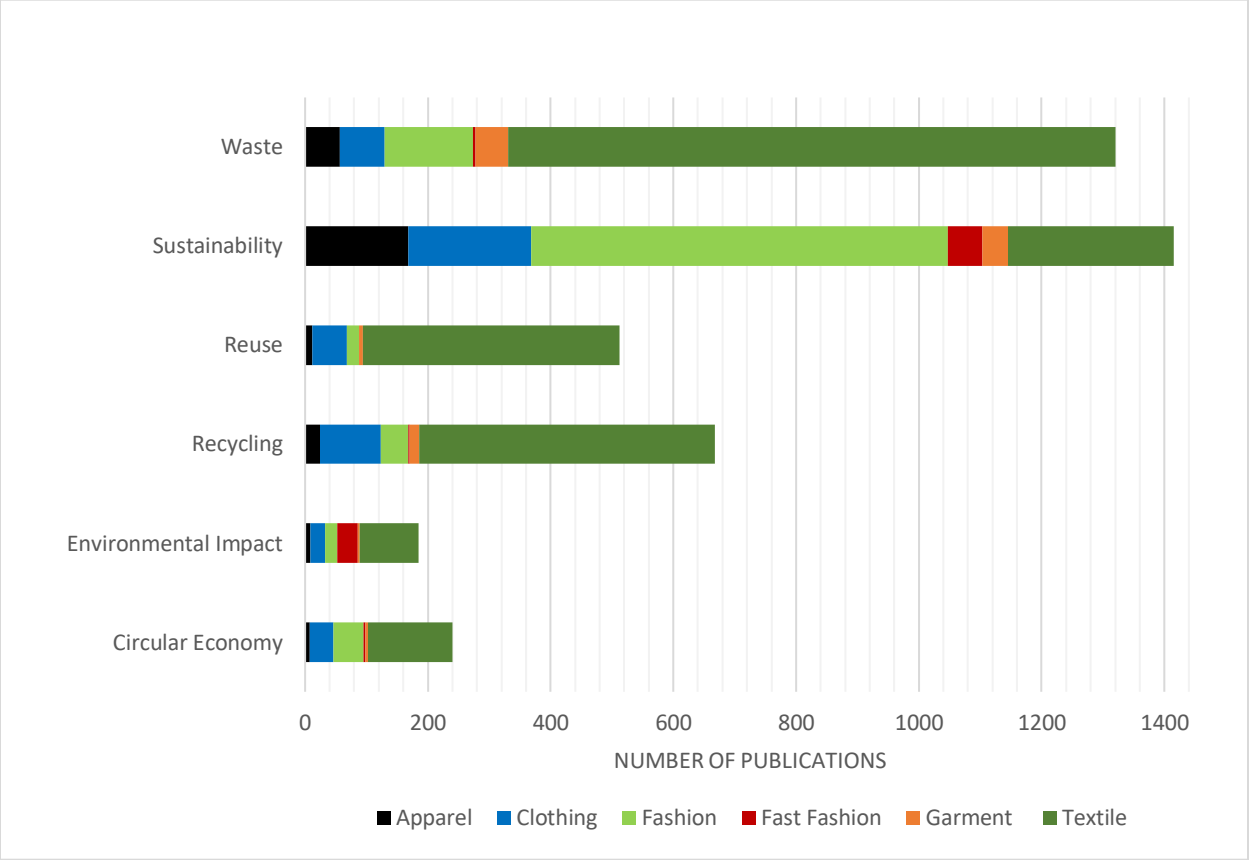
Table 4 – Results of primary keyword search

	Literature	Yrs.	H-index
Apparel	1000+	1899-2019	126
Clothing	1000+	1905-2020	155
Fashion	999	1893-2020	208
fast fashion	980	1979-2020	47
Garment	1000+	1909-2016	122
Textile	1000+	1904-2020	225

3.7.1 Application of secondary keywords to academic literature

The secondary keywords, *waste*, *sustainability*, *reuse*, *recycling*, *environmental impact*, and *circular economy*; were applied along with the primary keywords in the search parameters in order to narrow the results in Table 4 to be more reflective of REoptions in the fashion industry. Figure 3 reflects the number of total publications with the primary and secondary keywords sorted by correlation. The H-index for each search is not represented here as the results between searches are varied and most often below ten. Many of the academic publications found exist within the *textile waste* and *fashion sustainability* subtopics. The other significant categories are *textile reuse* and *textile recycling*. Unfortunately, these terms are overly broad and may imply changes to methods which forward current industry practices instead of assessing the alternative end of life options. To align the results with the REoptions proposed in this thesis, the tertiary keywords are applied to the literature.

Figure 3 – Academic Writing by Primary Keyword Title Topic



3.7.2 Application of tertiary keywords to academic literature

The tertiary keywords; *collection, consumer, donation, post-consumer, rental, resale, secondhand, sustainability, sustainable,* and *value chain* are essential to assessing the presence of REoptions in academic literature as they help determine both the use case and method of recycling discussed. Not only do the tertiary keywords pinpoint the occurrence of REoptions in the literature, but they differentiate themes in recycling conversations. Table 5 reflects the number of publications containing each of the keywords and their corresponding H-index, which implies both the presence of REoption conversation and the impact of associated articles. The average H-Index is variant throughout this chapter. While the H-index is not utilized in topic comparison, it does indicate that the most impactful literature exists within the subtopics of consumer use and sustainability initiatives.

Table 5 – Keyword Search Results

Primary Title Keywords					Secondary Tittle Keywords				Tertiary Keywords (subject matter)																											
									REception		Use Type		REception		REception		Use Type		REception		REception		Use Type		REception		Use Type		REception		Use Type		REception	
									Collection		Consumer		Donation		Post-Consumer		Rental		Resale		Secondhand		sustainability		Value Chain		sustainable		Value Chain		sustainable		Value Chain	
										h-index		h-index		h-index		h-index		h-index		h-index		h-index		h-index		h-index		h-index		h-index		h-index	
Apparel	126	1899-2019	1000+		Circular Economy	8	2016-2018	2	4	2	6	2	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Environmental Impact	9	2007-2019	3	3	1	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
					Recycling	24	1998-2019	5	10	4	16	5	6	2	0	0	2	1	1	1	0	0	0	0	11	4	15	5	0	0	0	0	0	0	0	0	0
					Reuse	12	2002-2018	3	6	3	6	3	3	1	1	1	4	3	1	1	0	0	0	0	1	1	5	3	3	2	1	5	5	3	2	1
					Sustainability	168	2006-2020	14	59	11	95	12	9	5	13	5	4	2	1	1	6	2	8	2	168	14	138	14	14	6	6	138	14	38	6	6	6
					Waste	57	1998-2000	6	27	6	34	6	3	0	21	5	0	0	26	5	1	0	1	0	22	4	27	5	5	2	2	27	5	5	2	2	2
Clothing	155	1905-2020	1000+		Circular Economy	38	1930-2019	4	10	1	8	1	0	1	4	1	3	1	1	1	4	1	3	1	9	1	10	1	1	1	10	1	3	1	1	1	1
					Environmental Impact	24	2007-2019	6	10	4	10	3	5	3	1	1	1	1	1	1	6	3	10	5	10	5	11	5	5	3	2	11	5	3	2	2	2
					Recycling	99	1976-2019	12	23	7	26	7	11	4	4	5	11	5	4	1	10	5	3	1	16	7	20	6	6	3	1	20	6	6	3	1	1
					Reuse	56	1975-2019	8	20	7	18	7	5	1	9	4	2	1	6	4	5	3	15	6	16	5	6	2	2	2	2	16	5	6	2	2	2
					Sustainability	200	1992-2020	14	53	9	75	13	10	5	16	6	4	2	4	1	11	4	139	14	92	13	15	3	3	1	1	92	13	15	3	3	3
					Waste	73	1921-2019	5	28	2	19	3	10	2	13	3	2	1	11	2	6	1	26	4	27	3	3	2	2	1	1	27	3	3	2	2	2
Fashion	208	1893-2020	999		Circular Economy	49	2013-2020	6	33	5	33	4	9	2	17	4	10	3	9	2	4	2	41	6	43	6	18	3	3	3	43	6	18	3	3	3
					Environmental Impact	19	1997-2019	7	6	3	9	4	1	1	1	1	0	0	0	0	1	0	8	5	9	5	0	0	0	0	0	9	5	0	0	0	0
					Recycling	45	1975-2020	6	15	4	17	3	6	1	7	1	0	0	6	1	0	0	14	3	18	3	3	1	1	1	1	18	3	3	1	1	1
					Reuse	20	1998-2020	3	11	3	16	3	7	1	2	1	1	0	2	1	6	1	10	2	15	2	4	1	1	1	1	15	2	4	1	1	1
					Sustainability	679	1994-2000	25	276	23	396	25	39	5	53	13	24	3	32	4	28	8	679	25	511	25	109	9	9	6	6	511	25	109	9	9	9
					Waste	143	1975-2020	10	47	8	51	8	8	3	25	6	1	0	5	3	2	1	61	8	73	9	6	2	2	2	2	73	9	6	2	2	2
Fast Fashion	47	1979-2020	980		Circular Economy	3	2015-2018	3	2	2	3	3	1	1	1	1	1	1	2	1	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
					Environmental Impact	34	2007-2019	6	14	4	22	5	1	0	0	0	2	1	1	0	2	2	12	4	15	4	4	3	3	3	3	15	4	4	3	3	3
					Recycling	2	2015-2018	1	2	1	2	1	1	0	0	0	0	0	0	0	0	0	2	1	2	1	0	0	0	0	0	2	1	0	0	0	0
					Reuse	0	N/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Sustainability	57	2008-2020	7	25	4	42	6	6	0	7	1	1	0	3	0	3	0	57	7	42	6	12	2	2	2	2	42	6	12	2	2	2
					Waste	5	2015-2019	2	2	1	2	1	0	0	1	1	0	0	0	0	0	0	2	1	3	1	0	0	0	0	0	3	1	0	0	0	0
Garment	122	1909-2016	1000+		Circular Economy	4	2009-2019	3	2	1	8	3	2	2	1	1	0	0	1	1	1	1	9	2	13	3	1	1	1	1	13	3	1	1	1	1	1
					Environmental Impact	3	2014-2014	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					Recycling	16	1975-2019	3	7	3	5	3	3	1	0	0	1	1	3	2	2	1	4	0	5	1	0	0	0	0	0	5	1	0	0	0	0	0
					Reuse	6	1998-2014	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0
					Sustainability	41	2001-2020	3	18	1	26	1	3	0	4	0	5	2	1	0	7	1	41	3	27	1	13	2	2	2	2	27	1	13	2	2	2
					Waste	53	1967-2019	10	22	6	8	3	2	2	1	1	0	0	1	1	3	2	0	0	0	0	1	1	1	1	1	0	0	1	1	1	1	1
Textile	225	1904-2020	1000+		Circular Economy	138	1974-2020	11	14	2	12	2	7	2	30	6	4	1	8	3	4	2	51	6	54	6	30	5	5	5	54	6	30	5	5	5	5
					Environmental Impact	96	1976-2020	11	20	4	19	6	11	4	4	2	0	0	0	0	2	0	20	5	29	7	3	1	1	1	1	29	7	3	1	1	1	1
					Recycling	482	1975-2020	27	137	21	123	21	53	13	0	0	7	3	36	11	76	15	96	14	139	18	22	5	5	5	5	139	18	22	5	5	5	5
					Reuse	418	1972-2020	48	84	18	51	10	15	6	20	7	7	3	7	3	21	7	48	12	89	17	4	7	7	7	7	89	17	4	7	7	7	7
					Sustainability	270	1992-2020	14	96	9	109	12	10	3	21	7	7	1	4	2	22	7	270	14	197	13	45	6	6	6	6	197	13	45	6	6	6	6
					Waste	990	1912-2020	56	314	24	232	21	42	10	119	15	18	4	29	7	73	11	177	16	365	25	28	5	5	5	5	365	25	28	5	5	5	5

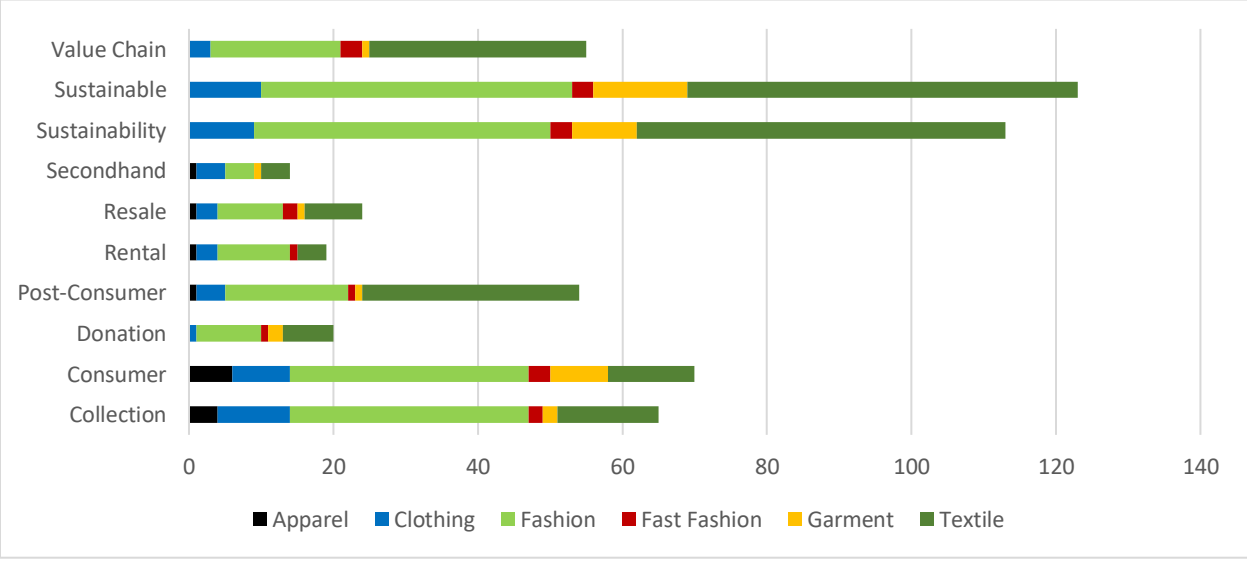
3.7.3 Keyword impact

Due to the variability in H-index and article population across all keyword categories, it is essential to break each keyword combination out into sets to assess overall impact and establish themes across available literature. The themes are broken into the secondary keyword categories to observe themes in writing across use and REoptions.

Circular economy

According to the Ellen McArthur Foundation, the *circular economy* is the ideology of designing to eliminate waste, encourage continued use of materials, and regenerate natural systems (Ellen McArthur Foundation, 2017). In the fashion industry this means not only eliminating the waste and impacts created by textile production but also fundamentally reimagining the end of life for clothing after consumer use. However, Figure 4 demonstrates that alternative use pathways are the least discussed topics in academic literature across all primary keyword topics. While the concept of *circular economy* is linked to *sustainability*, *value chain*, and *consumer use*, there is a lack of literature in alternative end of life opportunities

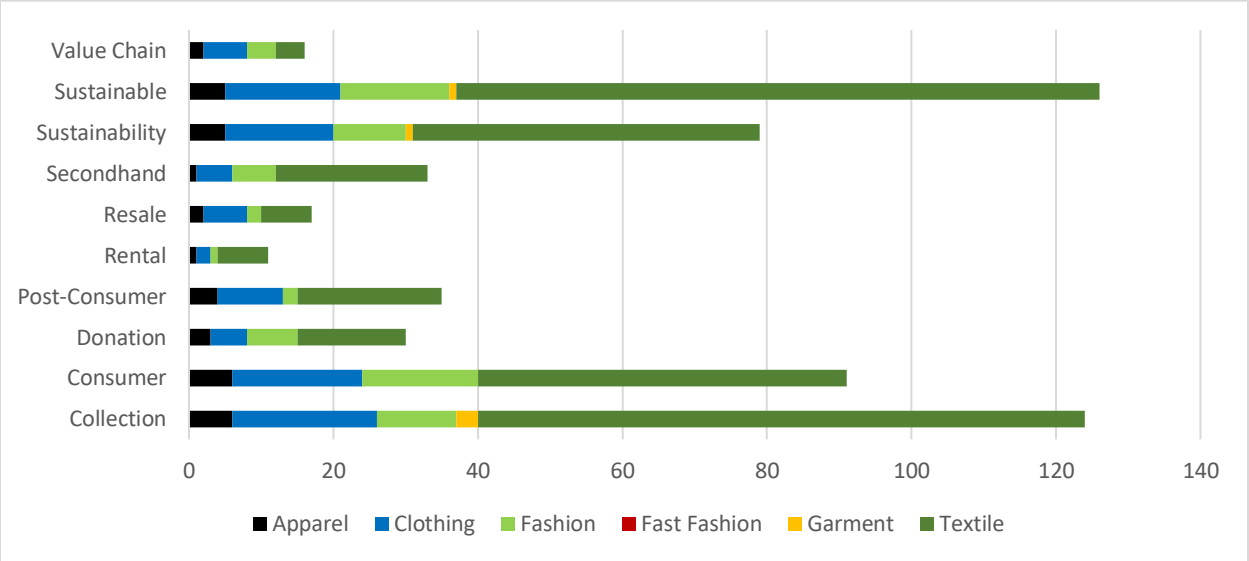
Figure 4: Circular Economy in Relation to Primary and Tertiary Terms



Reuse

The number of times a consumer wears a garment before replacing it has decreased by 36% in high-income countries in the last decade. In emerging economies, this number is as high as 70% (Ellen McArthur Foundation, 2017). Many of these garments rarely make it to the thirty wears modern garments can last, more commonly entering the disposal cycle anywhere between one and eight wears (Ellen McArthur Foundation, 2017; Fashion Revolution CIC, 2018). In Figure 5, it is evident that the majority of research on *reuse* pathways occurs in the literature regarding sustainable textiles and textile collection. There is a notable connection between the keyword clothing and alternative pathways. This connection may imply a theme in the research of *reuse* pathways for *consumer* and *post-consumer clothing*. There is also a notable connection between *fashion reuse* for *sustainability, consumers,* and *collection*. It will be essential to determine how these terms are connected to the general theme of *reuse* and whether they imply industry *reuse* or *consumer reuse*.

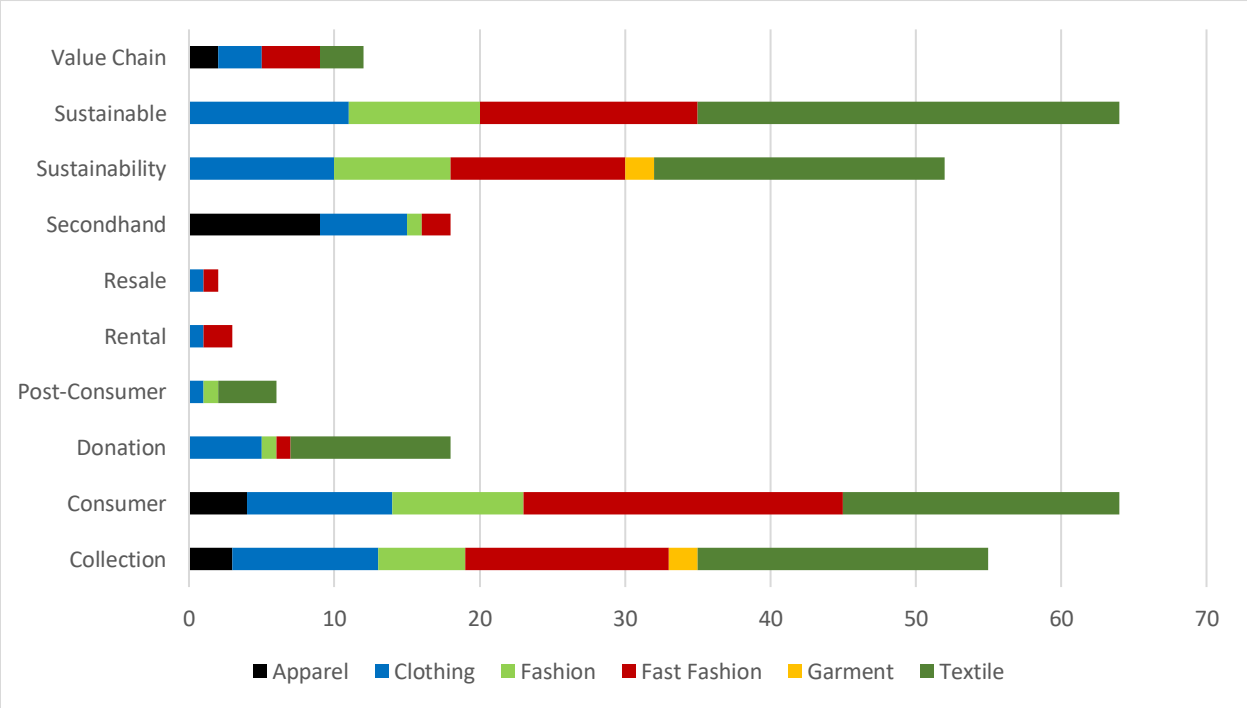
Figure 5: Reuse in relation to primary and tertiary terms



Environmental impact

Contrary to the common keywords in Figure 1, *environmental impact* appears as the most uncommon theme across the academic literature surveyed. As depicted in Figure 6, most literature on this theme discusses the *environmental impact* of *clothing, fashion, fast fashion*, and *textiles*. Interestingly, the topic of *fast fashion* occurs as a significant topic within the *environmental impact* theme. This trend is particularly interesting as, according to Table 4, *fast fashion* only appeared as a topic in literature for a little over a decade, therefore its significant to see *fast fashion* hold a high percentage of research within this theme. *Garment* does not appear among any of the subtopics on REoptions, although it does appear under distinct use cases. Although this breadth of literature is the least researched, it has the most commonality with the fashion industry literature. Such a link indicates a need for further and continued research from academics on this topic.

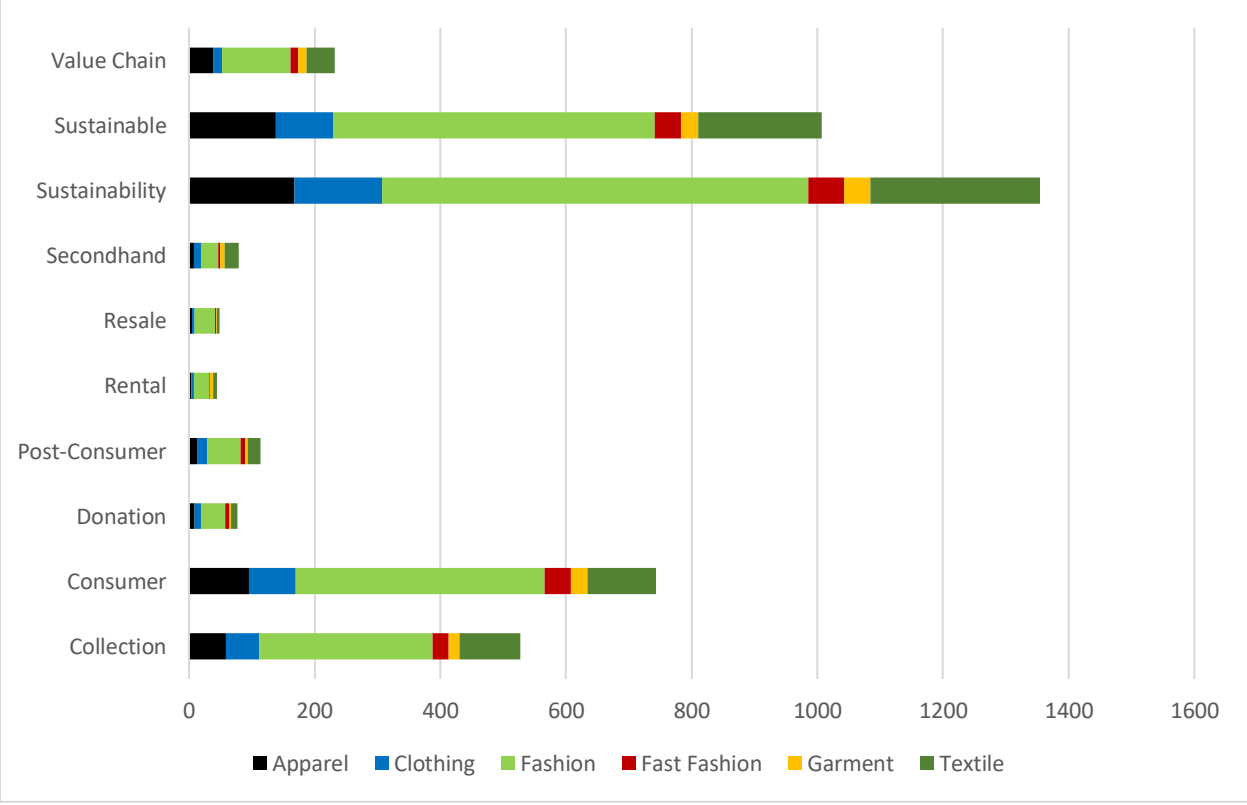
Figure 6: Environmental impact in relation to primary and tertiary terms



Sustainability

Sustainability is the theme with the highest rate of literature produced per year and has the most comprehensive selection of academic works. The theme *sustainability* is the most consistently published term in the literature survey, with an average rate of 10.30 articles per year. Interestingly, the REoption topics are the least written about within the theme of *sustainability*. The largest concentration of literature within this theme is in the topic of *fashion sustainability*, with over 600 pieces of academic literature written on the theme and subtopic. The presence of literature on this topic indicates interest among academic researchers to write about sustainability and the fashion industry in general. Further research is needed on the context of sustainability conversations within the fashion industry to understand the nature of academic suggestions on *fashion sustainability*.

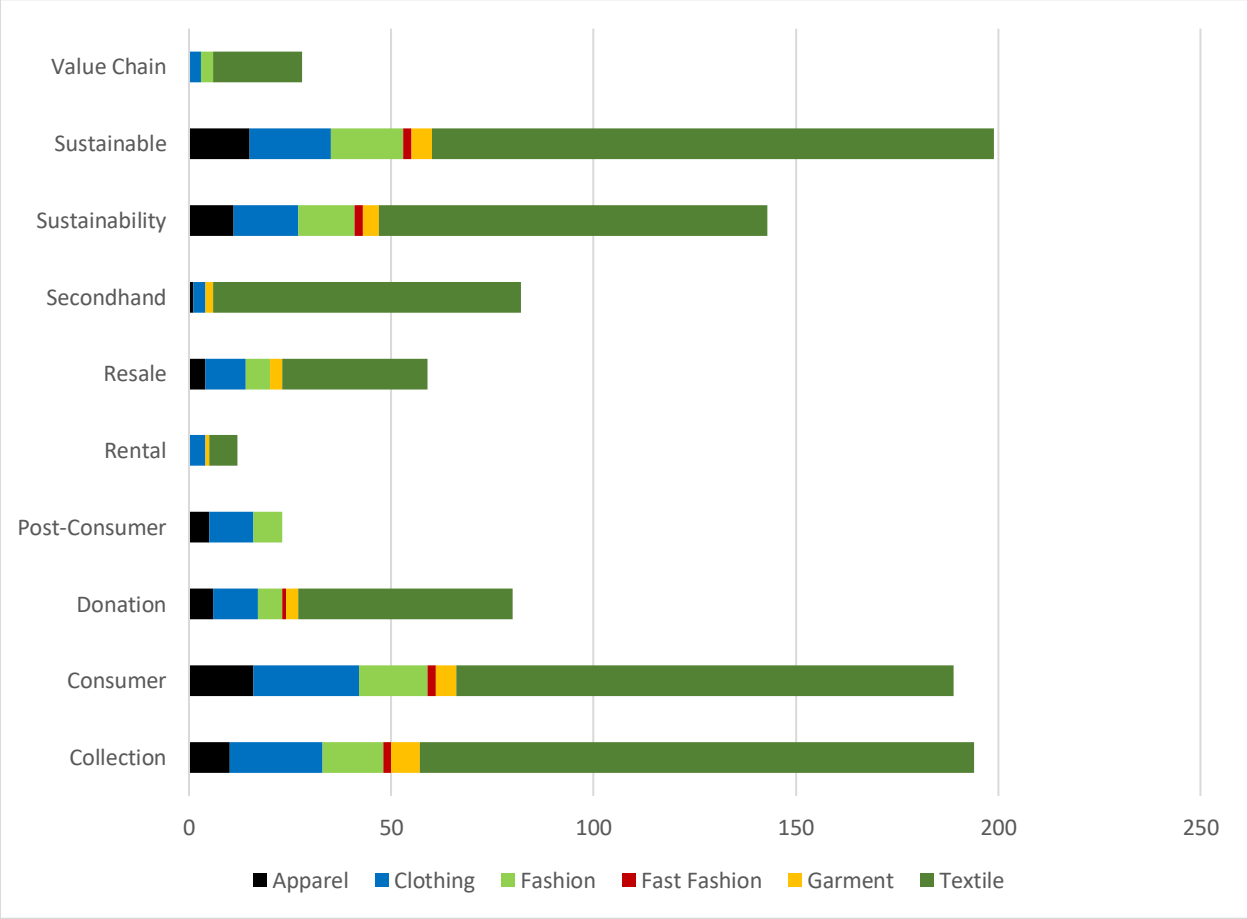
Figure 7: Sustainability in relation to primary and tertiary terms



Recycling

The most common literature on the theme *recycling* exists within the *textile* category. There is no literature on the topic of *textile reuse* with the context of *post-consumer*. This trend may indicate that most literature written in the topic is written about *textile recycling* within the production process rather than utilizing post-consumer garments as an alternative feedstock. Further research is needed to confirm the context of the surveyed literature. Notably, there is also a trend between the themes *reuse* and *clothing*. This occurrence may indicate an emergence of literature about post-consumer recycling methods. Further research such as a context analysis of REoptions in the surveyed literature is needed to confirm this hypothesis.

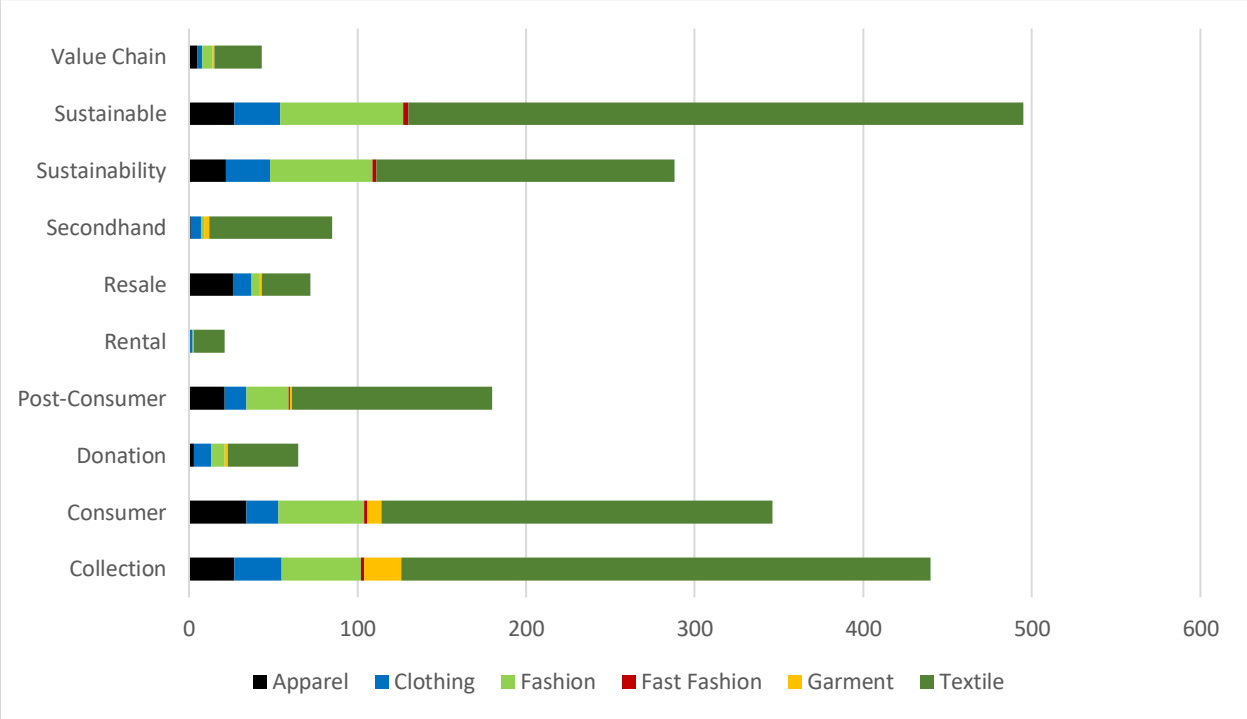
Figure 8: Recycling in relation to primary and tertiary terms



Waste

The theme *waste* is the second most common theme within the surveyed literature. The theme *waste* produces an average of 2.95 articles per year since its first publication date and an average of seven articles per year during the major years of publication. This rate of published work implies that *fashion waste* is a well-researched topic in the academic literature on the *fashion industry*. The most researched topic within the genre is *textile waste*. Further research is needed to confer context on the manner of use and waste generation associated with *textile waste*. There is increasing literature within the field of *post-consumer textile waste*, which implies that research into the post-use collection, take-back schemes, and secondhand garments are emerging trends within the literature.

Figure 8: Waste in relation to primary and tertiary terms



3.8 Limitations of REoptions and future research

. Quantitative analysis of sustainability assessments not only allow the industry to test alternative REoptions but also test their viability within the market. Havas (2014) suggests that further research into innovation and post-consumer actions involving greater responsibility and culpability by fashion industry actors will incentivize companies to invest in furthering reclamation, reuse, and recycling programs. Identifying crucial linkages between industry and academic literature identifies the prevalence and occurrence of such calculation systems within the industry. Chapter 4 conducts a critical review of methodologies within the literature bank created through this systematic review. However, further research is needed to assess the quality of industry calculations that are not published or publicly available to assure such calculations are genuinely comparable.

3.9 Conclusions

While this method of systematic review offers insight into the quantity and impact of literature on REoptions, it does not shed much light on the context in which REoptions are discussed, evaluated, or measured. Therefore, it is essential to assess how the discovered articles measure the sustainability impact of REoptions. Textile waste is an unmatched environmental impact produced by the fashion industry that needs to be addressed. With emissions at a rate of 1.2 billion tonnes annually, the effects of textile waste cannot be ignored. This systematic review demonstrates a clear pattern of the industry considering sustainability impacts, alternative material, and alternative REoptions. The linkage between the keywords identified and the industry literature demonstrates the increase in research and interest in quantifying and measuring the potential impacts of alternative materials and REoptions. However, further research in measures such as recycling, fibre reclamation, extended use, and closed-loop textile

innovation will progress the industry allowing regimes and actors to reduce waste production, minimize emissions, and negate fast fashion. Success in these innovations and research will allow regimes to achieve a measure of social, environmental, and economic balance within the industry.

Chapter 4- Sustainability impact measurements in the literature

The textile industry produces approximately 62 million tons of textiles per year (Knowledge Transfer Network, 2020). These textiles use agricultural space, non-renewable resources, water, global labor, and fuel for transportation. They create emissions, economic impacts, and generate social concerns on a global scale through the industry's productions, logistical, and retail operations (Press, 2018). Fast fashion garments also contribute to a significant waste crisis (Fashion Revolution CIC, 2019). With the industry's accountability ending at consumer purchase, garments' impacts are then unaccounted for during care and wear as well as at the end of life. This lack of accountability, combined with the trends of fast fashion, leads to an accumulation of textile waste, which could instead be utilized as an alternative feedstock within the fashion industry, stimulating the circular economy.

Life Cycle Assessment (LCA) allows producers and manufacturers in the textile industry the opportunity to assess the environmental and economic impacts of their practices as well as explore the economic and social advantages of alternative end of life methods (Watson & Wiedemann, 2019). The most effective method to assess the impacts of textile waste, consumer use, and the potential benefits of alternative end of life is through LCA. The textile industry currently utilizes LCA as a design aide and decision-making tool (Karaosman, et al., 2017). While companies may use LCA to inform their material selection, it is also vital to understand the parameters, methodology, quality, and quantity of LCAs that exist within the academic body of fashion industry research.

Therefore, this chapter investigates the application of LCA to the fashion industry to consider the environmental impacts of REoptions through a methodological review. The primary goal of this review is to assess the standards for LCAs on textiles, identifying similar functional

units, modeling methods, preferred calculations, and inconsistencies across the literature. This chapter will then answer three questions: (1) How is consumer use considered and assessed across these studies? (2) How are REoptions assessed across these studies? and (3) What should report standards for textile LCAs be? Chapter 4 builds on the systematic review in chapter 3, utilizing the literature bank created through data mining and distance reading of industry literature. Chapter 4 expands upon these methods by applying additional keywords to narrow the breadth of academic literature and locate only the most relevant sustainability impact calculations. This chapter concludes with a series of propositions regarding standardized reporting methods for considering REoptions and consumer use in textile LCAs. Such LCAs will create comparable sustainable impact calculations which will help guide the fashion industry towards a more sustainable future

4.1 Methodological review

To determine the economic, environmental, and social impacts of REoptions in the textile industry, it is paramount to assess the impacts utilizing a standard calculation method. To fill this calculation need, the author chose to use LCA. Torres et al. find that LCA streamlines the identification and assessment of all processes that contribute to the life cycle of a product through calculating impacts as quantifiable, comparable data (Torres, et al., 2019). LCA also provides insight into environmental, economic, and social metrics across the lifecycle of a product (Jia & Jiang, 2018). In their analysis of the structuration, creation, and reproduction, for sustainable sourcing, Jia and Jiang, identify five common modeling themes in supply chain literature. Among the five themes, they identify LCA as a useful tool in guiding decision making for “green supplier selection” and modeling the potential environmental impacts of alternative suppliers (Jia & Jiang, 2018). Shin et al. explore the limitations of these calculations due to the

generalization of referential data and its failure to accurately represent individual manufacturing processes (Shin, et al., 2017). Shin et al. (2017) explain that this practice of using referential data is common as primary data gathering is often labor and time-intensive hampering timely decision making. However, this data can cause differentiation in weighting, normalization, and geographical representativeness making data generated in these studies both nonrepresentative of reality and incomparable between studies (Shin, et al., 2017).

While the ISO 14044 guidelines provide a measure of standardization for LCAs by providing baseline reporting parameters, modeling structuration, critical review, and reproducibility, the guidelines are vague and leave much to interpretation (European Commission, 2005-2012). The Joint Research Center has attempted to further standardize LCA through the International Reference Life Cycle Data System (ILCD) and Product Category Rules (PCRs) through the European Platform on Life Cycle Assessment. However, there is still measurable debate and variation in data collection, modeling, and reporting methods (European Comission, 2019). PCRs and Environmental Product Declarations (EPDs) are standardized rules intended to help guide the environmental sustainability statements a company makes about a product in Europe (Watson & Wiedemann, 2019). In the United States, these are found as less stringent statements under the Federal Trade Commission guidelines. While PCRs currently exist to quantify the impacts of virgin textiles, they do not necessarily cover modeling for REoptions.

Such variation is an essential caveat in selecting LCA as the source of analysis across the literature. Gaps in LCA literature within a specific field may include inconsistencies among functional units, system boundaries, data selection, impact indicator selection, and overall quality (Santero, et al., 2010; Salas, et al., 2016; Petti, et al., 2018; Lemming, et al., 2010; Allesch & Brunner, 2014). Once considered these limitations and variations will demonstrate how the

fashion industry represents consumer use phases and alternative end of life in their life cycle and sustainability decision making.

4.1.1 Methodological parameters

Literature reviews of LCA are a popular method for academics to assess the methodology of LCAs when applied to a specific product or standard. These reviews evaluate the quality of decision making from these studies. This assessment is useful in assessing the potential benefits of REoptions as alternative feedstocks. Dixit reviews the embodied energy analysis of parameters for residential buildings through the scope of Life Cycle Analysis and Energy Analysis (Manish, 2017). Shin et al. utilize a review of LCA literature to propose a new methodological framework to stimulate improvements in environmental performance in manufacturing (Shin, et al., 2017). Jegannathan and Nielsen propose enzyme use in industrial manufacturing by reviewing the positive impacts of enzyme integration across a variety of systems through LCA (Jegannathan & Nielsen, 2013). Chastas et al. asses LCA literature in order to establish a reliable method for calculating residential buildings' embodied energy and net-zero capability (Chastas, et al., 2016). Lemming et al. conduct a literature review to assess the quality of soil and groundwater technology through the lens of LCA. The authors find that the quantified impacts are largely incompatible; they recommend the incorporation of more rigorous characterization factors and impact categories (Lemming, et al., 2010). Petti et al. evaluate LCA literature containing social impact modeling to advocate for the consolidation of methodology and define the role of social impacts in LCA (Petti, et al., 2018). Salas et al. analyze the methodology of LCAs for cement production and manufacture and asses the presence of environmental impact improvement through alternative materials and end of life scenarios (Salas, et al., 2016). Allesch and Burner asses the breadth of literature focused on

reducing the environmental impact in solid waste management through LCA, finding that the majority of LCAs conducted in this field fail to consider the five primary methods for waste diversion as recommended by the EU. The authors utilize the literature review for recommending a narrowing of practitioner assumptions through the use of a proposed framework to standardize LCA methodology in the field of solid waste management with the EU Waste diversion hierarchy (Allesch & Brunner, 2014). These articles provide the methodology for conducting an empirical literature review of LCAs within a specific sector in order to identify modeling methodology, make recommendations for standardization, identify patterns in alternative scenario assessment, and use of the literature to improve industry impacts.

4.2 Literature selection

Employing the literature bank developed in chapter 3, this chapter refine the articles discovered in the systematic review by adding the keywords *life cycle analysis* and *life cycle assessment* to the keyword parameters for both the secondary and tertiary groups. *Life cycle assessment* and *life cycle analysis* are occasionally used interchangeably in the literature, although they fundamentally separate the modeling and reporting processes of LCA. By adding both words to tertiary and secondary title keywords groups, the database is narrowed to the LCAs most relevant to REoptions. The keywords are applied in combinations of three with the [title] and "+" Boolean operations. The literature is narrowed by limiting the date range to 2007-2020. This narrowing of dates ensures compliance with the ISO 14044 guidelines, which were initially published in 2006 (International Organization for Standardization, 2006).

4.2.1 Literature selection results

To discover existing literature relevant to the field of LCA, the words *life cycle analysis* and *life cycle assessment* are applied to the secondary keyword group utilizing the distance

reading method outlined in chapter 3. The tertiary keyword group from chapter 3 is applied to the initial results, narrowing the literature to 60 results. Each piece was then reviewed to verify content and sorted by literature type. The literature contained twenty-seven articles, two books, five book chapters, six conference papers, and sixteen theses. It is crucial to note the number of theses conducted within this scope, as such a trend indicates a growing interest in the relationship of LCA to fashion sustainability. Each of the articles was then read to ensure relevancy to the research questions. This process narrowed the relevant literature to twenty-seven articles, of which eighteen conducted an LCA, two conducted a literature review, and seven were methodological reviews of LCA practices in the field of textiles.

When applied as a tertiary term to the parameters outlined in chapter three after eliminating duplicates from the individual search groups, the distance reading method identified 342 possible matches. The literature was then reviewed to confirm digital accessibility, which eliminated 31 articles, and two books from the results. The breadth of discovered literature was reviewed to assess content type. Of the 321 pieces reviewed, there are 145 articles, six books, 36 book chapters, nineteen conference papers, eight conference proceedings, two posters, six reports, and 99 theses. For this review, only the published journal articles are used. The group of remaining 145 articles were submitted to an intext word search to establish relevance and context. Using the terms *life cycle analysis*, *life cycle assessment*, *LCA*, *functional unit*, and *14044*. These terms are vital to conducting a complaint LCA; therefore, if an article only mentioned LCA as an available tool, in a brief list of methods, or the term only appeared in references, the article was eliminated from the group. This review identified nineteen pieces conducted an LCA, eight pieces explored methodological recommendations for conducting LCA's in the fashion industry, four pieces conducted a literature review of existing LCAs, three

pieces utilized LCAs to conduct supply chain assessments, and one piece compared existing LCA results.

Once combined, the amendments to the search parameters of chapter 3 yield a total breadth of 62 articles of which ten conduct LCAs of textile fibers in products other than garments (such as tires and cement), twenty-seven are textile LCAs, fifteen are methodological recommendations, six are literature reviews, three are supply chain analyses, and one is an LCA comparison. Table 6 shows the range of research in these articles. Each LCA was then read and assessed for relevancy. LCA's which focused on utilizing textile waste to manufacture other products (i.e., tires concrete, etc.) and LCAs that analyzed wastewater or sludge recycling were removed from the group. While these LCAs do include recycling alternatives, they do not contribute to creating new garments and therefore do not meet the criteria of the three research questions.

Table 6 - Breadth of textile LCA literature in peer-reviewed academic journals

REFERENCES	GOAL	FUNCTIONAL UNIT	SYSTEM BOUNDARY	CALCULATOR
(Barnes, et al., 2015)	EI SELF-ASSESSMENT	1000 KG OF COTTON FIBRE	CRADLE TO GRAVE [D]	CML-BASELINE
(La Rosa & Grammatikos, 2019)	EI OF ALTERNATIVES TO COTTON	1 KG OF FIBER & 1 KG OF TEXTILE	CRADLE TO GATE [K]	CML-BASELINE
(Zhang, et al., 2018)	EI OF POLYESTER-COTTON PRODUCTION	2 TONS OF POLYESTER/COTTON FIBRE	CRADLE TO GATE [G]	CML-BASELINE
(Moazzem, et al., 2018)	EI OF CC FOR 3 TYPES OF APPAREL IN AUSTRALIA	1KG APPAREL/LIFE	CRADLE TO GATE [F]	CML-BASELINE
(Morita & Ravagnani, 2011)	EI OF 3 TYPES OF	370 G SOCKS	CRADLE TO GATE [G]	EI99

	SUPPORTIVE SOCKS			
(Yacout & Hassouna, 2016)	EI OF CURRENT WASTE STREAMS	1000 KG ACRYLIC FIBER	GATE TO GRAVE [F]	EI99
(Prabowo, 2019)	EI OF PRODUCTION AND FINISHING OF COTTON	50 M B/L OF COTTON FIBRE	CRADLE TO GATE [H]	EI99
(Baydar, et al., 2015)	EI OF CONVENTIONAL COTTON AND 3 TYPES OF ECO COTTON T SHIRTS	200 KG COTTON TSHIRTS/3 YRS/50 WASHES	CRADLE TO GRAVE [F]	EDIP 2003
(Clarke-Sather & Cobb, 2019)	EI OF WOMEN'S ATHLETIC PRODUCTS "MADE IN THE USA"	1512 WOMEN'S LEGGINGS	CRADLE TO GRAVE [F]	PRODUCT SOCIAL IMPACT ASSESSMENT
(Zamani, et al., 2017)	EI OF DIFFERENT CLOTHING LIBRARY SETUPS	1 USE/DAY	CRADLE TO GRAVE [E]	GWP100, IPCC 2013, USETOX, SWISS ECOSCARCITY, EUTREND
(Muthu, et al., 2012)	CC BENEFITS OF RECYCLING MATERIAL	1 KG COTTON FABRIC	PRODUCTION TO GRAVE[L]	IPCC 2007
(Nørup, et al., 2019)	EC OF TEXTILE SORTING	1 KG OF COLLECTED TEXTILES	GATE TO GATE [NR]	LCC
(Roos, et al., 2016)	ARE PROPOSED INTERVENTIONS ENOUGH TO ACHIEVE SUSTAINABILITY?	$6.7 B GARMENTS/YR	SECTOR SCALE [NR]	PLANETARY BOUNDARIES
(Muthukumarana, et al., 2018)	EI OF ENERGY IN GARMENT PRODUCTION	1 BLOUSE	GATE TO GATE [H]	RECIPE

(Zamani, et al., 2014)	EI OF VARIOUS TEXTILE RECYCLING METHODS	1 TON HOUSEHOLD TEXTILE WASTE	WASTE TO TREATMENT [C]	RECIPE
(Roos, et al., 2015)	EI OF UNBLEACHED VS BLEACHED GARMENTS	337 G NIGHTGOWN & 496 G CARDIGAN	CRADLE-DISTRIBUTION[G]	RECIPE, CML, USETOX, SCORE SYSTEM
(Lenzo, et al., 2018)	EI OF KNITTING A GARMENT	1 KNITTED GARMENT	CRADLE TO GATE [H]	RECIPE
(Zamani, et al., 2018)	SI OF TEXTILE PRODUCTION FOR CONSUMPTION IN SWEDEN	$1 OF SWEDISH CONSUMPTION	CRADLE TO GATE [H]	SHDB
(Lenzo, et al., 2017)	SI OF ITALIAN TEXTILE PRODUCTION	495 CAPES	CRADLE TO GATE [H]	SHDB
(Fatarella, et al., 2015)	EI OF UNIFORM FOR 3 DIFFERENT END OF LIFE OPTIONS	2.5 M2 COMPOSITE FABRIC	CRADLE TO GRAVE [F]	RECIPE
(Esteve-Turrillas & de la Guardia, 2017)	EI OF COTTON YARN FROM RECOVERED FIBERS	1 KG OF COLOURED COTTON YARN & 1 100% COTTON T-SHIRT	RECOLLECTION /CRADLE- TO GATE [B]	ND
(Yousef, et al., 2020)	CF OF TEXTILE RECYCLING	10 G WASTE JEANS	2ND CRADLE TO PRODUCTION [C]	ND
(Yasin & Sun, 2019)	EI OF EOL FOR TECHNICAL TEXTILES	10 YRS CURTAIN USAGE	GATE TO GRAVE [F]	ND

4.3 Textile LCA application to REoptions in the academic literature

4.3.1 Goal definition

The goal definition is the portion of an LCA that introduces the application of the study and broadly outlines the focuses, concerns, and priorities of the researcher. According to both the

ISO 14044 guidelines (2006) and the ILCD Handbook (2012), the goal definition allows the researcher to state their research question, make predictions or hypotheses about the outcomes of the LCA, as well as outline the intended application of the results. In Table 6, the column labeled "Goal Definition" outlines the goals for each of the articles reviewed. Eighteen of the articles address the environmental impacts (EI) of textile sustainability, two articles address the social sustainability impacts (SI) of textile sustainability, one article assesses the Economic Costs (EC) of textile sustainability, one article addresses the Climate Change (CC) effects of textile sustainability, and one article explores the Carbon Footprint (CF) of textile sustainability. Most studies assessed focus on the EI of textile sustainability, which helps ensure similar parameters across studies.

While there are benefits to some variation in goal definition, such as unique methodological approaches and modeling approaches, the general similarity in goal definition indicates the reviewed literature has a measure of consistency across study parameters. Both consistency and inconsistency are essential in moving the field of sustainability forward. For example, the two studies exploring sustainable impacts utilized a growing methodology that addressees a known shortcoming of LCA, which is the perceived inability to model social and labor impacts. Growing research in this field helps the industry expand its understanding of previously undocumented supply chains and guides decision-makers in critical sourcing choices. Likewise, consistency across the goal definition phase helps ensure compatibility across literature, providing decision-makers with similarly delivered literature.

While the general intention of the goal definitions is similar, it is vital to note the variety of parameters the goals set for determining the environmental impact of the textile industry. For example, the types of materials and breadth of the process can vary significantly between LCAs.

These small differences are a warning of significant variance during the scope definition phase and should flag decision-makers to check system boundaries and functional units before comparing results directly. Furthermore, the variance in goal application reflects the different REoptions assessed in the literature. Table 7 outlines the textiles assessed, and the type of REoptions covered in the goal definition for each piece. Notice the variety in textile content, use case, and finishing methods considered across Table 7.

Figure 9 demonstrates the variety in recycling options addressed and exemplifies the inconsistencies in modeling across the group of LCAs. Notice that 44% of the LCAs examine traditional disposal or reuse; 5% examine process improvement, and 13% of the LCAs either do not address (NA) or do not disclose (ND) any REoptions. This occurrence means that only 28% (a little over 1/4) of academic, peer reviewed LCAs consider the alternative end of life options. Figure 10 demonstrates the textile types examined in each LCA. It is interesting to observe the fibre content of materials examined as this helps determine the general interest in LCA for decision making, particularly the environmental impact of cotton textiles. These trends across goal definitions in textile LCAs indicates a need for more consistent goal setting to develop a larger breadth of reliable LCAs for both the fashion industry in general and to assess REoptions for garments, clothing, and textiles.

Figure 9- REoption range from goal definition phase

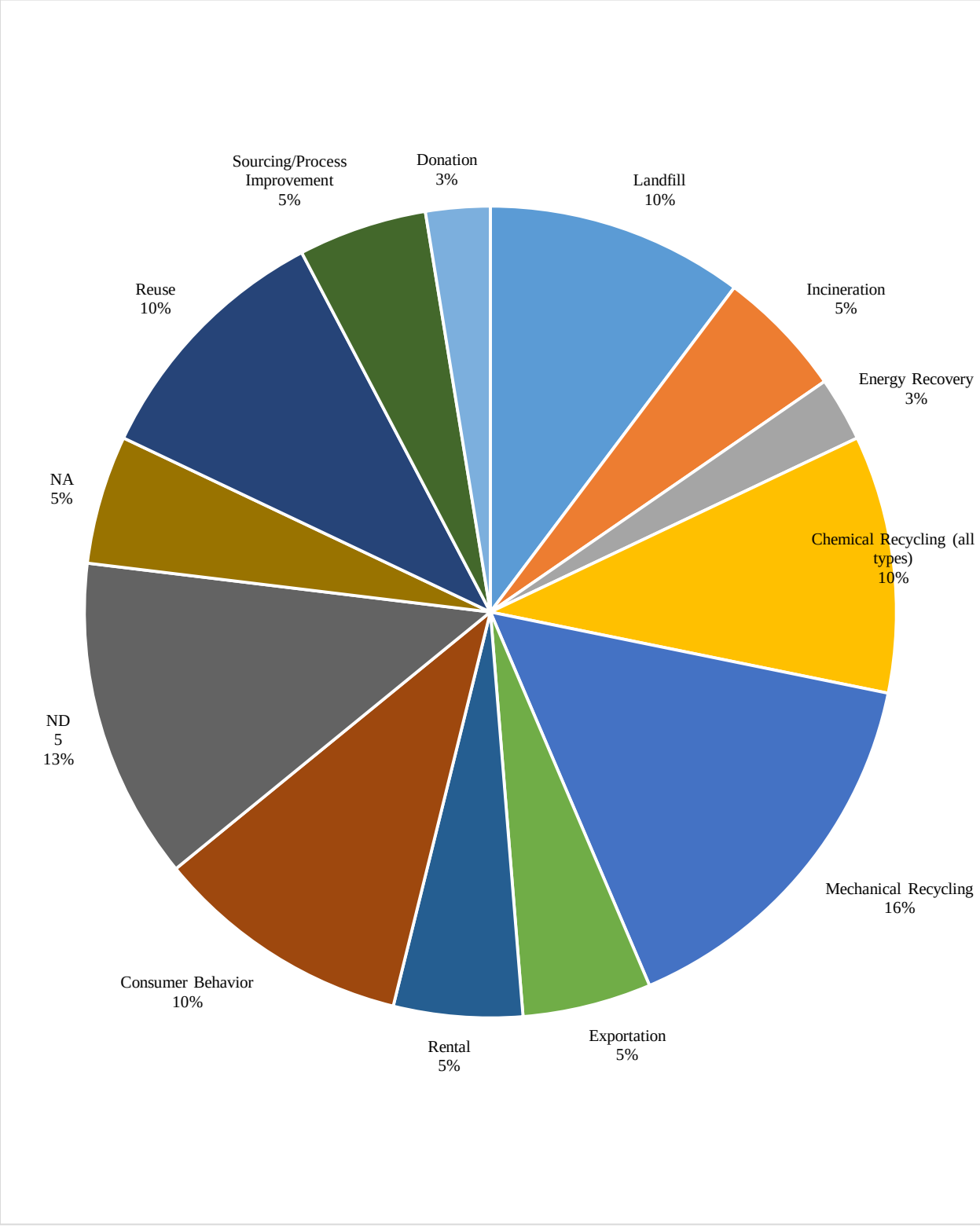
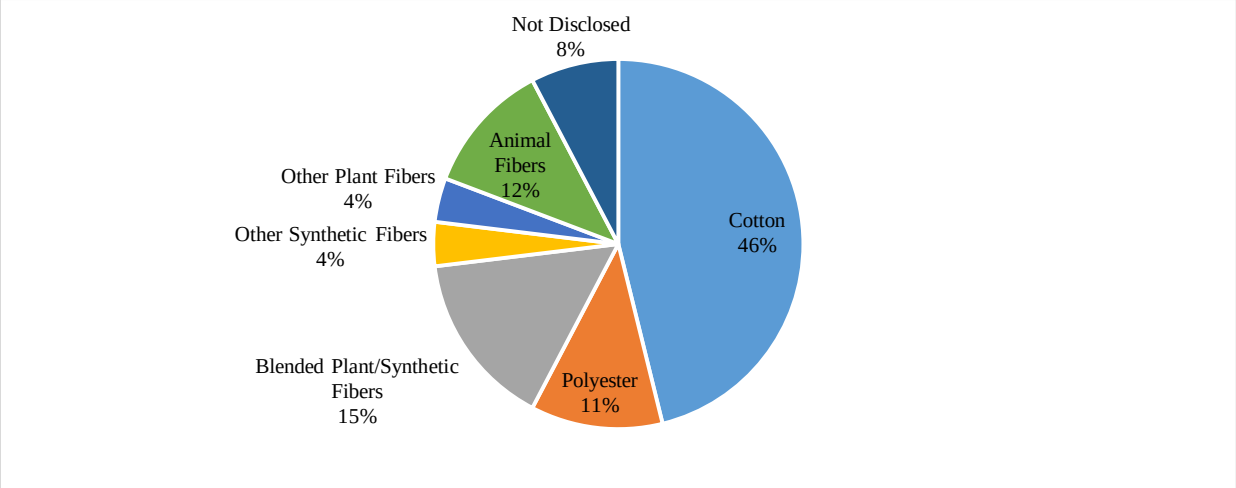


Table 7- Goal definition examination of textile content, finishing, and REoption inclusion

REFERENCES	GARMENT TYPE	REOPTIONS CONSIDERED
(Barnes, et al., 2015)	COTTON FIBRE	SHORT FIBER/CUTTING WASTE RECYCLING
(La Rosa & Grammatikos, 2019)	COTTON FABRIC KNEAF FABRIC JUTE FABRIC	ND
(Zhang, et al., 2018)	POLYESTER/COTTON FIBRE	USE OF RECYCLED FIBERS
(Moazzem, et al., 2018)	COTTON KNIT SHIRT POLYESTER KNIT SHIRT WOOL SWEATER	LANDFILL, DONATION, EXPORTATION
(Morita & Ravagnani, 2011)	COTTON/POLYMIDE/ELASTANE SOCKS	ND
(Yacout & Hassouna, 2016)	ACRYLIC FIBER	LANDFILL/ INCINERATION
(Prabowo, 2019)	50 M B/L OF COTTON FIBRE	PROCESS IMPROVEMENT
(Baydar, et al., 2015)	COTTON T SHIRTS	NA
(Clarke-Sather & Cobb, 2019)	COTTON/SPANDEX MIX LEGGINGS	SUSTAINABLE SOURCING
(Zamani, et al., 2017)	COTTON T SHIRT COTTON JEANS POLYESTER DRESS	GARMENT REUSE
(Muthu, et al., 2012)	COTTON FABRIC	CONSUMER BEHAVIOR, CUTTING SCRAPES, MECHANICAL RECYCLING, BLENDED RECYCLING
(Nørup, et al., 2019)	COLLECTED GARMENTS	GARMENT COLLECTION AND SORTING FOR REOPTIONS
(Roos, et al., 2016)	1 T SHIRT 1 PAIR OF JEANS 1 DRESS 1 JACKET 1 HOSPITAL UNIFORM	CLOTHING LIBRARIES, CHEMICAL RECYCLING, MECHANICAL RECYCLING, CELLULOSE RECYCLING, TENCEL, EXTENDED USE, CONSUMER BEHAVIOR
(Muthukumarana, et al., 2018)	COTTON BLOUSE	ND
(Zamani, et al., 2014)	COTTON/POLYESTER FIBER	REUSE, CHEMICAL RECYCLING, CELLULOSE RECYCLING
(Roos, et al., 2015)	COTTON NIGHTGOWN & COTTON CARDIGAN	ND

(Lenzo, et al., 2018)	COTTON/POLYESTER BLEND JEANS	NA
(Zamani, et al., 2018)	ND	ND
(Lenzo, et al., 2017)	WOOL/CASHMERE CAPE	ND
(Fatarella, et al., 2015)	SAFETY UNIFORM	INCINERATION, LANDFILL, RECYCLING
(Esteve-Turrillas & de la Guardia, 2017)	COTTON YARN	MECHANICAL RECYCLING OF GARMENTS
(Yousef, et al., 2020)	COTTON & POLYESTER FIBERS	CHEMICAL RECYCLING
(Yasin & Sun, 2019)	WOOL CURTAIN & POLYESTER CURTAIN	ENERGY RECOVER, INCINERATION, LANDFILL

Figure 10- Percent of textile content fibres studied as functional units



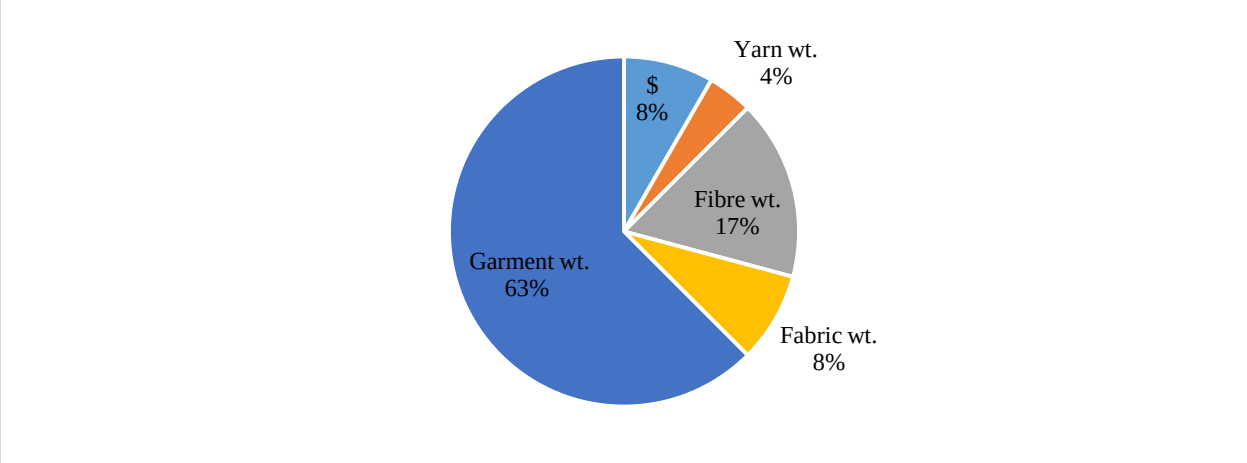
4.3.2 Scope Definition

Inconsistencies in modeling within the reviewed literature mainly occur during the scope definition. According to the ILCD Handbook, the scope definition phase should set the methodological, reporting, and quality standards for the LCA (European Commission, 2005-2012). Primarily the scope definition determines the functional unit (FU), system boundary (SB), and the reproducibility of the LCA. These parameters help guide compatibility between LCAs.

Comparability is significant as it establishes if the results of an LCA can be compared. As LCAs are often highly labor-intensive, the ability to compare the results allows industry decision-makers to make an informed choice between materials or processes without having to conduct or commission internal LCAs for every product.

The functional unit is the precise unit by which the LCA is measured (European Commission, 2005-2012; International Organization for Standardization, 2006). For example, a functional unit could be 1 kg of yarn, one garment, or a monetary denomination. Figure 10 demonstrates the range of functional units in the reviewed literature. Figure 11 illustrates the percentage of units of measurements used across the functional unit, 63% of the studies assessed utilized the weight (wt.) of finished garments in the functional unit. In Table 6, notice the variety of weights assessed in each functional unit. Differences in weight are critical to note before studies can be compared as the results need to be correctly converted before the comparison of results.

Figure 11- Percent of common units of measurement used in functional units



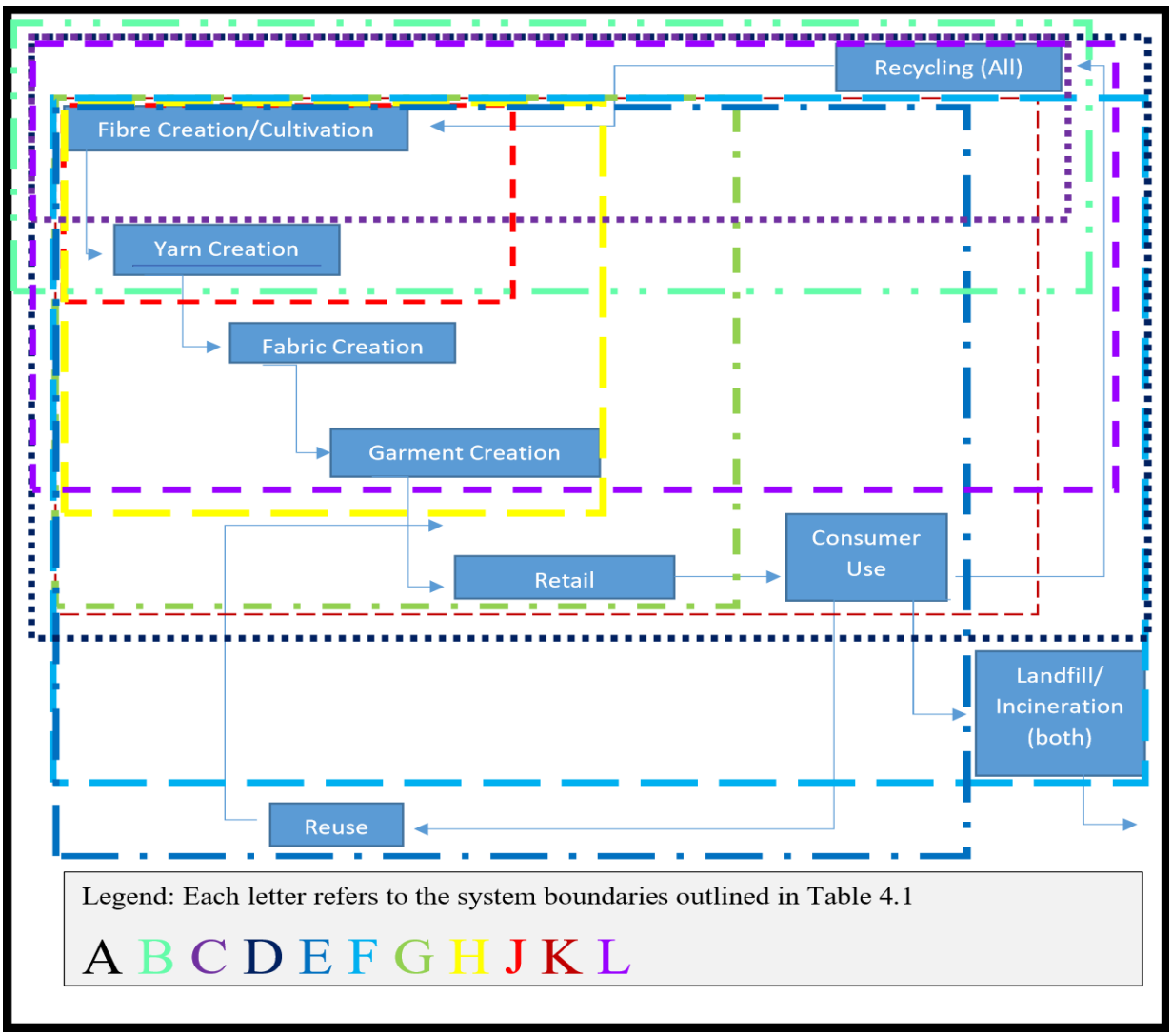
The system boundary is the definition of the parameters by which the LCA will include inputs, outputs, technical flows, and processes in the LCA. The system boundary should indicate

which materials are in the foreground and background of the study as well as which materials inputs are derived from or emitted into either the Techno or Eco spheres[5] (European Commission, 2005-2012). Figure 12 demonstrates the common system boundary considered across the reviewed literature. The letter legend in the figure corresponds with Table 6. The various dashed boxes indicate the variety of system boundaries utilized across the literature and the inconsistency in the modeling parameters. LCAs with dissimilar system boundaries cannot be compared unless individual processes are represented in the results, as this would lead to incompatible process considerations (European Commission, 2005-2012).

The inconsistencies across system boundaries and functional units in the literature are problematic because any LCA conducted with either a different functional unity or system boundary cannot be compared from the literature. However, if the study is reproducible, a researcher or LCA professional may be able to use the literature to perform an ISO 14044 compliant comparative LCA (International Organization for Standardization, 2006). Reproducibility should be indicated during the scope definition along with publication intention. To be considered ISO 14044 compliant, an LCA must be both publicly available and reproducible (International Organization for Standardization, 2006; European Commission, 2005-2012). While this literature is all academically reviewed, it does not mean the studies themselves are fully ISO Compliant. ISO compliance was not assessed for the literature review to ensure a dynamic selection of literature.

[5] Ecosphere is system where raw materials are extracted and emissions from processes are output. Technosphere is the part of a system boundary that exists after raw materials of resources have been processed by humans. Materials in the Technosphere can still sever as input or outputs to the system boundary. (European Comission, 2005-2012)

Figure 12 – System Boundary Allocation across Literature



4.3.3 Life Cycle Inventory

The Life Cycle Inventory (LCI) is the portion of an LCA where reproducibility, consistency, and quality of the data is ensured. Often the LCA establishes the elementary, product, and waste flows considered within the LCA (European Commission, 2005-2012). The LCIs represented in the reviewed literature are not complete. Therefore, as this is not a critical review, and the authors were not contacted to review full LCI data sets. LCI was not considered in this analysis.

4.3.4 Impact Assessment

Life Cycle Impact Assessment (LCIA) is the phase in LCA where the data, LCI, is input into a calculator to determine social, environmental, and economic results. To compare LCIA results, studies must utilize consistent calculators and impact indicators. There are thirteen recommended impact indicators for use in LCA, but calculators vary based on impact assessed (Hauschild, et al., 2013). As a response to advocates for more standardized data in the textile industry (de Saxcé, et al., 2011), some PCRs and EDP have been updated to require LCA studies to utilize specific calculators or assess certain impact indicators to make studies comparable. However, these requirements vary within the textile industry and are not always observed (Watson & Wiedemann, 2019). In this review, the calculation methods are highly variant. While LCIA is not meant to be wholly inclusive and is not intended to account for all impacts, consistency in modeling helps establish a baseline of assessment (International Organization for Standardization, 2006). Table 6 demonstrates the variety in calculator use across studies. Of the studies reviewed, five utilized CML-baseline, three utilized EI-99, three utilized Social calculators, two utilized IPCC, four utilized ReCiPe, three studies used specialized calculators, and three did not indicate which calculation method was utilized. This inconsistency, when combined with the variety of functional units and system boundaries across the literature, implies that more consistent replicable models are needed to create comparable LCAs for the textile industry.

4.4 Discussion

After reviewing the literature for methodology and structure, the studies were then applied to the three research questions. (1) How is consumer use considered and assessed across the literature? (2) How are REoptions assessed across these studies? and (3) Should reporting

standards for textile LCAs be reevaluated? This chapter answers each of these questions with observations from the literature and methodology review. It presents a series of propositions developed after careful reflection of this literature review intended to guide research and help move the industry closer to achieving global sustainability.

4.4.1 Consumer use across the selected studies

While the importance of consumer use as a significant and relatively unknown environmental impact is reported or referenced briefly in almost every article reviewed, it is rarely modeled. Only four of the ten common system boundary structures consider consumer interaction with textiles, and these SBs are included in only seven of the twenty-three articles. Following the outline for REoptions in Chapter 3, common REoptions for consumers include reuse, rental, and resell. In this literature review, the end of life pathways that best fit these options, as shown in Figure 9 are donation, exportation, reuse, consumer behavior, and rental, making up 33% of all end of life options explored across the literature. Rental, Reuse, and donation were among the least assessed pathways. Further research is needed to determine the environmental impact, environmental cost, and social impact of these and other REoptions to engage consumers.

4.4.2 REoptions across these selected studies

REoptions are a classification developed by the author to include all alternative end of life scenarios for textiles recycling, reuse, resale, and rental. The literature mostly considered some form of REoptions, although no more than one-third engaged the consumer. As illustrated in Table 7, only five of the articles reviewed either did not disclose (N) or did not account (NA) for some type of REoption. The majority of REoptions addresses were largely production-based initiatives for cotton, Figure 9 & 10. This indicates that more research is needed into the

alternative end of life scenarios beyond production-based initiatives for REoptions for materials beyond cotton.

It is important to note that individual PCRs and EPDs were not assessed in this study. PCRs and EPDs are continuing to grow and change every year as public, corporate, and government interest in sustainability for the textile industry continues to grow (European Comission, 2019). However, it is worth noting that in a recent assessment of the inconsistency across standards for the textile industry, ten sets of guidelines were identified as governing methodology for LCAS within the textile industry (Watson & Wiedemann, 2019). The authors address the inconsistency across these guidelines and demonstrate how industry LCAs may even outright dismiss the standards adopting and adapting their own systems, such as the Higgs Index (Watson & Wiedemann, 2019). This sort of inconsistency is confirmed by this literature review as the inconsistencies in goal definition, scope definition, and life cycle impact assessment are highly variant across the literature. Such variance may indicate a lack of knowledge about the standards, inconsistency across standards in methodology, or an inability to comply with the existing standards. Any of these reasons warrant a reassessment by the standardization bodies and a reassessment of standards.

4.5 Proposition 1:

The fashion industry and academics should collaborate to establish a clear and representative guideline on modeling the "Scope Definition" phase of LCA.

The fashion industry and academics should establish parameters outlining how to model and account for consumer use, alternative end of life pathways, and REoption loops to begin standardizing the breadth of work conducted in the field. The industry and academics should also establish a clear parameters for functional units including valuation, content, and weight for

garments, as such clarity will allow for LCAs to be comparable without requiring an individual to back-calculate or reproduce multiple studies.

4.6 Proposition 2:

The fashion industry and academics would benefit from standardizing impact assessment guidelines by requiring the use of relevant and reliable calculator and impact indicators.

As LCIA should not be wholly inclusive in decision making, such clarification should include parameters for economic impacts (LCC), geographic scope, environmental impacts (LCA, CC, CF, etc.), and social impacts. This proposition is particularly relevant as sustainability advocates continue to demand a more transparent supply chain, and full representative calculations will be paramount in making sustainability recommendations.

4.7 Proposition 3:

Academics should create an open-source database with primary textile data to build future LCAs upon.

Due to the inconsistent functional units, system boundaries, goal definitions, and content selections in the literature reviewed, an open-source database is an evident and apparent solution to implementing propositions 1 and 2. In order to ensure compliance with updated standards, the researcher must have reliable, consistent, and geographically representative data. An open-source library is the most efficient and effective way to ensure both access and reliability of LCAS going forward. Building blocks are essential to the success of any endeavor, and the ability to populate LCAs using consistent data will not only help yield more comparable results but will also allow for comparison across process sets within the supply chain. Meaning, if a system boundary is incorrectly structured or a functional unit is unusual in one study, another researcher

can quickly go back through the LCI and replicate the results to match a comparable system boundary or functional unit.

4.8 Conclusion

While the LCAs assessed in this literature review are academic, they represent a trend in sustainability tendencies within the fashion industry. By utilizing the systematic review in Chapter 3, this literature review in Chapter 4 mined surveyed academic literature for the keywords and topics vital to the industry at present. Through combining those words with a method to calculate environmental impact, the uniqueness of the LCA, this literature review was able to assess the quantity, quality, and consistency of peer-reviewed academic literature relevant to the growth of sustainability within the fashion industry. The literature revealed an overwhelming interest by graduate and doctoral students about researching and quantifying alternative ends of life for the fashion industry. The literature chosen for assessment did not include these works, but the sheer number may indicate an influx of peer-reviewed, published academic future in the years ahead. The literature assessed consisted of twenty-three LCAs which addressed sustainability and reuse across the textiles industry.

The literature reviewed demonstrated inconsistency in methodology for LCA modeling within this field. From REoptions to modeling methodology, these studies revealed the need for consistency textile LCAs to produce comparative literature, which will inform decision-makers and move the needle of the industry forward. After carefully reading and analyzing each of these documents, three propositions for moving LCA methodology in the fashion industry forward become clear. These are: (1) the fashion industry should establish clear and representative guidelines on modeling the scope definition phase of textile LCAs; (2) the fashion industry would benefit from standardizing impact assessment guidelines through requiring the use of a

relevant and reliable calculator and impact indicators; and (3) academics need to assemble an open-source database with primary textile data to build future LCAs upon. These propositions will be expanded upon in future research.

Chapter 5 – Is global sustainability possible in the fashion industry?

This thesis began by asking if global sustainability is possible for the fashion industry? This thesis asserts that current industry methods fall within the realm of weak sustainability as they are focused on consumer behavior change, continued growth, and technological advancements. Through an exploration of the effectiveness of current sustainable impact measurements, methods to improve the applicability of sustainability impact calculators in driving sustainability transitions within the fashion industry are proposed.

Chapter 2 outlines the evolution of the fashion industry, mapping the increased production, decreased costs, and arrival of fast fashion and mass retailers to the global market. This thesis illustrates the potential benefits of comparative measurements in guiding the industry towards an environmental, social, and economic balance utilizing the history of fast fashion.

Chapter 3 creates a literature bank using data mining and distance reading to inform a systematic review of academic literature along with core industry themes and sustainability interests. Chapter 3 argues that through understanding and accepting the vernacular of the industry, academics can align nonbiased research with industry motives, helping inform key decision-makers throughout the fashion industry.

Expanding upon the methods and literature bank developed in chapter 3, chapter 4 investigates the applicability and quality of current sustainable impact measurements within the fashion industry through a critical literature review of textile life cycle analysis. By assessing the modeling inconsistencies, gaps in data, and trends in LCA goals, chapter 4 concludes in three propositions to move the industry towards comparative sustainability impact calculations to inform decision making. These propositions are (1) the fashion industry should establish clear and representative guidelines on modeling the scope definition phase of textile LCAs; (2) the

fashion industry would benefit from standardizing impact assessment guidelines through requiring the use of a relevant and reliable calculator and impact indicators; and (3) the assembly of an open-source database with primary textile data would allow academics and key decision-makers the opportunity to build accurate and comparative models of strong sustainable pathways.

How then are corporations and brands convinced to undertake the scrupulous task of accurately measuring and assessing their impacts? If the fashion industry continues to perpetuate fast fashion, encourage consumption habits, and relies on changes in consumer behavior to impact their emission, it is predicted that the industry will be producing nearly 92 million tons of waste and CO2 per year by 2030 (Kerr & Landry, 2018). The industry's current sustainability methods echo weak sustainability patterns and will continue to fall short of impactful change unless something radically changes. The propositions presented in chapter 4 help guide the industry towards a more economically viable and manageable future. By creating open-access LCA databases populated with comparable sustainable impact data, the industry can make informed choices about the future. LCA allows the industry to test alternative material selection, sourcing routes, and labor sources. LCA also offers the industry the opportunity to test and evaluate the economic, social, and environmental benefits and impacts of embracing alternative use opportunities such as the REoptions. These options would allow the industry to make second and third returns on existing garments and utilize their waste as an alternative feedstock. Utilizing materials the industry has already produced, cuts down on labor and virgin material expenditure as well as enables growth and economic prosperity from new markets. Accurate, comparable LCAS would allow companies and designers to explore these new pathways and

make informed decisions about their environmental, social, and economic impacts without the level of risk associated with unguided, or blind growth.

5.1 Limitations

REoptions reduce the production burden of virgin derived materials and may also reduce the impacts of additional treatments throughout the lifecycle (Sadin & Peters, 2018). However, Domina and Koch found that the most substantial barrier to consumer behavior is the inconvenience associated with existing REoptions schemes. They found a positive correlation between consumer behavior, environmental initiatives, and education from companies supporting REoptions (Domina & Koch, 1999). However, the statistics surrounding consumer recycling and reuse practices indicate that there is a need to raise awareness of REoptions among consumers and fashion industry stakeholders alike (Gibson, 2006). The challenge the fashion industry will meet as they begin to incorporate REoptions into their business models is the level of convenience and education the industry provides to stimulate consumer participation in these new avenues. LCA can enable the industry to predict their impacts, but it will take a top-down buy-in for the industry to see real success in developing both the industry and consumer behaviors essential to REoption value chains. The inability to conveniently participate in REoptions or the continued availability of clearance and bargain items at increasing rates will likely hamper consumer participation in recycling practices and may result in undesirable recycling and reuse rates for fast fashion items (Daneshvary, et al., 1998). The effects of this skepticism and mistrust appear in the consumer's current utilization of existing REoptions. Such skepticism indicates that innovation is needed to actively and effectively divert textile waste from landfill in a more efficient manner Options to encourage participation include establishing

government facilitated textile collections programs that collect textiles along with traditional single stream recycling (Daneshvary, et al., 1998).

Additionally, consumers have been told by the industry that they must pay an exorbitant price to participate in REoptions, which in turn decreases participation. In a recent survey of consumer beliefs regarding textile sustainability, respondents indicated that they believe the only way to have access to sustainable, or preferred materials is through purchasing clothing at a premium (Chan & Wong, 2012). Understandably, consumers are hesitant to engage with brands seeking REoptions when the prices are much higher than that of fast fashion, and there is little education regarding the significance or capability of the company's sustainability measures beyond the marketing, which indicates sustainable textiles as luxury or premium items. Consideration of this concern will require regimes to vet their sustainability improvements vigorously and adequately educate their consumers on the value and impacts of these changes. The fashion industry cannot merely tell consumers that they must reduce waste, but must provide viable, convenient, economical, and verified REoptions in order to encourage participation, ensure buy-in to their sustainability endeavors, and counter the years of consumer culture and fast fashion marketing. LCA can provide the data, but the industry will need a culture shift and genuine buy-in from industry stakeholders to achieve sustainability.

5. 3 Further research opportunities in industry literature trends.

The most substantial drawback to recycling and reuse in the industry is that there is not currently an established way to eliminate textile waste without environmental degradation, or loss of viability from reclamation. The loss of viability during the recycling process is "Down Cycling" (Zamani, et al., 2014). Down Cycling presents a problem as the produced material is of a lower quality than the original (Sadin & Peters, 2018). However, Saladin and Peters (2018)

believe that the downcycling process is not always a deterrent to recycling. They conclude that downcycling is not necessarily a deterrent to mechanical recycling as it can enable multiple life cycles and uses.

Despite the need for further research and innovation, extending garment lifetimes through reuse, processing textiles through recycling is the most effective option regimes have in addressing post-consumer waste. Zamani et al. (2014) believe that instituting an integrated reuse and recycling approach will reduce approximately 10 tonnes of CO2-eq per 1 ton of textile material integrated into the multi-tier system. Sadin and Peters suggest the industry explore how multiple types of REoptions can be combined to extend lifecycles, yield economic value, and reduce environmental impacts (Sadin & Peters, 2018). Traditionally resource reuse is considered to be a 1:1 ratio, however, due to downcycling in current reclamation efforts it would be amiss for regimes, actors, and researches to regard reclaimed textiles as equal because there will be increased limits to functionality and a continuous decrease in variability until the discovery of more innovative methods (Sadin & Peters, 2018). The fashion industry will benefit from employing methods to calculate and quantify the efficiency and effectiveness of reclamation and reuse systems if they are to successfully navigate sustainability goals regarding post-consumer waste and responsibility for produced products.

The availability of LCA is also a topic that must be researched and expanded by academics, consultants, private research firms, and fashion industry stakeholders in tandem. So long as data is limited, incomparable, and unstandardized, LCAs will continue to be most effective for internal calculations and not to plan sustainability transitions. The fashion industry needs an open-source databank of standard materials and use pathways to begin stimulating the use of sustainable impact calculations. I believe that as access to this data increases, knowledge

and research will expand in turn. With more data sets, the fashion industry can encourage transparency, thoughtfully plan and design, making informed choices to reduce impacts, and perpetuate circular production and reuse systems.

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