Sustainable Production and Design of Cycling Lifestyle Apparel for Women

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Abstract

The cycling industry as a whole has not done well at satisfying the needs of female riders and it has not kept pace with the greater athletic and outdoor industry's advances in sustainable manufacturing techniques or responsible business. This has led to a disconnect between consumers, who report a desire to make responsible purchasing decisions, and companies which are not supplying them with the knowledge the make those decisions. While a lack of sustainability planning is sometimes attributed to cost, in the long term, efficiencies in manufacturing and the benefits to brand reputation reaped through transparency can have a net financial benefit to companies.

Women ride at significantly lower rates than men and this can be attributed to a lack of comfortable infrastructure, inconvenience, lack of confidence on the bike, a dearth of consumer products, and difficultly finding communities to connect. Women's cycling apparel is hard to come by and often is ill-fitted for athletic women. Brands do not take advantage of the potential within the women's marketplace to build loyalty and community, or create apparel that can go beyond the bike. Additionally, new fabrics and technologies have made it possible to create apparel with a lower ecological footprint.

A survey was conducted to determine what features were most desired by female consumers in order to inform the design of cycling lifestyle garments for women. An evaluation and comparison of currently popular and newly developed fibers for athletic products was undertaken to understand which were most preferable from a performance and a sustainability standpoint. Life Cycle Analysis was used to examine these fibers, but also critiqued for its difficulties in successfully comparing fibers of various origins.

Two garments, a top and a pant for use both on and off the bike, were designed against the features requested in the consumer survey. Feedback from a body measurement survey was used to determine how best fit the unique bodies of female cyclists. Branding and positioning were developed for the garments under the brand name Beryl.

Next steps toward implementation of the project were examined. Although many infrastructure obstacles still exist in the way of truly sustainable apparel manufacturing, the resources are in place for it to come to fruition. All that is needed are the right people and forward-thinking businesses to implement change. Connections must be made between different suppliers in the chains of custody in order to reach a sufficient level of accountability and transparency. The trend is moving in the right direction, so there is cause for hope.

Introduction

The problem

The cycling industry has, for much of its existence, catered to traditionally male cyclists to the exclusion of women. In a stagnant business climate, evolutionary change to become more inclusive of women is necessary for growth (Edmondson). Meanwhile, the cycling retail segment has not kept pace with ecologically sound development in the greater athletic and outdoor retail group.

Sustainability in the athletic apparel industry

Overall situation in today's business climate

In the athletic and outdoor space, sustainable and responsible business practices have taken hold in recent years. Brands are increasingly capitalizing on their environmental records to reflect the values of their consumers. Individuals who are actively living their lives outdoors want to support brands that are working to protect the places they hold dear. Following in the footsteps of forerunners like Patagonia, which speaks extensively to consumers about its environmental record and is transparent about its supply chain decisions, outdoor companies are talking more and more about the value of the environment. In 2011, the Outdoor Industry Association added a Sustainable Apparel Coalition to its Sustainability Working Group to create an Eco Index as a basis for a common framework for working toward more responsible apparel production. Specialized Bicycles is the only cycling industry company that is a voting member of the working group, out of 52 outdoor industry companies (Outdoor Industry Association). Consumers who span other subcategories of the outdoor industry are used to hearing ecological messages. The cycling subgroup, however, has not joined this trend.

Lack of support within cycling subgroup

Even though cycling itself is a carbon-neutral behavior that some riders participate in because of its eco-friendly characteristics, there is currently not a single major cycling apparel company that produces environmentally responsible goods. In the present state of the industry, it is simply not part of the conversation.

This might be attributed partially to the increasingly low margins and tight operating budgets of many companies in the industry. Sales of bicycles and accessories have been largely stagnant in the United States for over a decade (Edmondson). Some businesses fear that implementing sustainability measures will cut into already slim profits. However, this is often a false assumption; many

times efficiency and sustainability programs actually result in financial benefit over the long term. Implementing efficiency initiatives can often save overhead and operating costs. Rising variable costs tied to scarcity of resources increases risk, which can be mitigated through efficiency programs. From a human resources perspective, sustainability programs have been shown to increase employee retention and improve a company's reputation as an employer. The marketing, brand reputation, and public relations reasons for sustainability may actually be overshadowed by the pure business case (Spector).

Fiber and fabric technology has advanced significantly as the apparel industry has sought ways to reduce its impact. Major human rights violation scandals in the 1990's caused the apparel industry, which is one of the highest impact industries on the planet, to examine itself and find ways to improve. The Danish Fashion Institute makes the claim that the fashion industry as a whole, which includes both footwear and apparel, is the second worst polluting industry globally, after petroleum production, and is the second worst polluter of clean water as well. Brands, led especially by Nike in the late 1990's with their organization of the Fair Labor Association (Nisen) in the athletic and outdoor marketplace, have lead the charge toward better practices, pushing factories to clean up and committing research and development dollars to finding lower-impact ways to manufacture garments. This culminated in the OIA Sustainability Working Group, established in 2007 (Outdoor Industry Association). In contrast, the cycling industry has focused more on performance improvements.

The cycling consumer's viewpoint

Lacking substantial recognition from within the cycling industry, the conversation about sustainability has been largely driven by consumers. Unfortunately, many consumers do not consider environmental impact in their purchasing decisions. A 2014 survey of 130 cyclists by the author of this report, determined that only 7% of frequent female cyclists consider the ecological footprint of cycling apparel products when making purchases (see appendix A).

Disconnect between consumer values and behavior

While many consumers report when asked that they take environmental and social responsibility seriously when making purchasing decisions, actual consumer behavior does not align with these statements. In fact, consumer concern about these issues has decreased in the past six years (Cotton, Inc.). Research has shown that in actuality, economic or financial benefits are the true drivers of behavior. 70% of consumers say they will choose to be environmentally friendly only if it saves them money, and 86% say that knowing features of a garment will save them money in the long term is "very influential" at the point of purchase. Since the great recession of 2007-2010, buying local has made inroads with consumers. 78% of Americans say they prefer to have a positive influence on the local economy. This in aggregate shows that

consumers do wish to see themselves as making responsible choices in their purchasing of products, but, in reality, they are often confused or under-informed about the true effects of the items they select (Cotton, Inc.). Tellingly, when it comes to environmental concerns, many consumers appear not to understand the word "sustainability." 51% of Americans believe it refers to the durability of a product, and only 22% associate the word with eco-friendliness (Cotton, Inc.). Clearly, there is ground to make up when it comes to identifying consumers' motivations and aligning behavior with values.

Lack of women who ride

Why don't women ride?

Historically, women have lagged behind their male counterparts when it comes to bicycle ridership in the United States. The latest data available, from 2009, showed that only 29% of bicycle trips are taken by women (Szczepanski). This gap between female and male ridership does not exist in other more cycling-oriented countries, such as The Netherlands (55%) and Germany (49%) (Szczepanski). If the lack of women riders is not inevitable, there must be reasons that might be pinpointed. Several studies have been undertaken in recent years to examine just that.

In 2013, the League of American Cyclists published an aggregate report which reduced the reasons that women ride at lower rates than men to five categories: Comfort, Convenience, Confidence, Consumer Products, and Community. Seeking to debunk the myth that women are not interested in cycling, the League suggested that by working on these five leverage points, women could be coaxed to join the ranks of everyday-cyclists at comparable rates to men.

Comfort is defined as an infrastructure problem. America's emphasis on the automobile in development of infrastructure has forced cyclists to adapt to motor-based roads, decreasing access to destinations for both cyclists and pedestrians. This creates a steep learning curve for new, less confident riders. Women have been shown to be more risk-adverse than men, on average, and are more affected by perceived lack of safety (Emond et al.). European countries with higher rates of women cyclists benefit from world-class cycling infrastructure, including separated bike lanes, bike paths between destinations, and traffic preference for bicycles over other vehicles, making beginner cyclists feel safe and secure on the roads.

Convenience addresses familial issues that affect women's preferences for travel. Women make twice as many trips as their male partners each day to deal with family responsibilities, such as picking up or dropping off kids, running errands, or purchasing groceries, even in households where both adults work full time (Czszepanski, Emond et al.). Each of these types of trips is made less complicated by using a vehicle. This is essentially a socially driven problem that is a result of social inequality in the home. Even so, half of all trips by car are

fewer than three miles: a distance that is easily traveled by bicycle, if the equipment and time constraints were to be removed. Indeed, according to the League of American Bicyclists, women cited “lack of time”, “inability to carry more stuff”, and “inability to carry passengers” as major barriers to cycling (Czszepanski). Women in pre-childbearing years are likely to participate in the activity at higher frequency level as their male peers (24 days per year). However, between ages 25-34, participation drops to 11 fewer days than men in the same group (Edmondson).

Confidence is defined by the League as “tools to ensure women feel secure in their skills.” This is a sticky problem. Women are more likely to ride frequently if their skill level on a bike is high, and skills are developed through riding. Frequent, highly-confident cyclists are likely to feel comfortable on most roads with a bike lane, but new riders prefer separate paths, which make up only 1% of cycling networks nationally (Dill). Sticking with an activity that makes one uncomfortable requires sufficient motivation, which must be provided to lower-skill level female cyclists.

Consumer Products centers around the lack of functional and/or fashionable products in the bicycle gear marketplace. In a 2010 Bikes Belong survey, only 1/3 of women who ride regularly reported that finding appropriate clothing for cycling was “no problem” (Czszepanski). This same survey discovered that 36% of women feel that clothing or grooming is a problem for them as a cyclist, and 44% said they limited trips by bike as a result of having to carry a change of clothing. This is a problem of consumer offerings failing to meet the needs of female cyclists. Women cyclists plan to spend $418 each on bike-related products annually (Princeton Survey Research Associates, national poll, September 27-30, 2012), so it does seem puzzling that brands are not attempting to fill this gap in the marketplace. The fact that 89% of bike shops are owned by men, 96% of whom are white, (Czszepanski) leads to the conclusion that shops simply aren’t fully aware of what their potential customers are looking for.

Community is a powerful driver of cycling activity. The 2010 Princeton Survey Research Associates poll of transportation behavior found that 42% of American women would ride more frequently if they had “people to bike with”. Unfortunately, the number of total cyclists has dropped nationwide over the past decade, with women specifically down 13% between 2000 and 2010 (Edmondson). While cycling has shrunk overall, the number of frequent cyclists has actually increased. 8% more women are riding at least 110 days per year than in 2000. This demonstrates a rift between cyclists and non-cyclists that is difficult to overcome. While cycling has shrunk as a recreational activity around the fringes, its core has hardened. Cyclists are now seen as a special-interest group, rather than participants in a recreational or transportation-focused activity. The rise of “bike culture” has transformed the activity into a way of life or an identity, which makes entry to the culture more difficult (Edmondson).

Creating a more welcoming, inclusive community of riders can encourage new participation at a lower entry point. Organizations and brands can help to create connections between women riders at different levels of interest, encouraging the social connections women seek.

Lack of women's cycling clothing options

A survey of the competitive landscape of women's cycling apparel reveals a lack of options overall. For serious riders or those spending longer periods of time on the bike, traditional bike performance apparel is easy to come by. This consists mainly of jerseys, bibs, and shorts made from spandex or polyester and containing a chamois, or seat pad. Sizing runs very small, ideal for the average petite endurance athlete. These staples of the cycling wardrobe are excellent for performance situations, but entirely inappropriate for recreational or transportation cyclists or for the body of the average American women, which, according to Women's Wear Daily, is a size 14.

In recent years, brands such as Giro, Levi's, Rapha, and others have introduced casual cycling apparel for the men's market. Jeans, tops, shorts, and outwear have incorporated functional touches such as reflective strips, hidden pockets, and articulated knees, while maintaining enough style and attractiveness to be worn after the ride is over. After testing the market with men's wear, Giro and Levi's both expanded their line to include women's apparel. The Giro offering focuses on layering, with small chamois undergarments that can be slipped under a pair of stylish basic shorts or khaki pants for comfort on the bike. Sizing, however, has been a major issue for both brands. In a 2014 survey conducted by the author, athletic women reported being unable to find anything within the Levi's line that can fit over well-developed quadriceps muscles, and plus-size women have been unable to find anything in the Giro line that works well for them.

Poor fit

Fit has been a consistent problem for women seeking cycling apparel for some time. In a survey undertaken by the author in 2014, women were asked to describe any problems with the fit of the apparel they used while riding their bikes. Responses were wide ranging, but several patterns emerged. Women found most tops to be too short, exposing the lower back while in the riding position, and too tight in the bust. Jeans and pants were perceived as too tight in the thighs and hips, while being too loose at the waist. The general solution is to purchase clothing that is too big, and adjust with belts, or simply accept a sloppy appearance if bike riding is required. Many women keep a full wardrobe of cycling clothing that is separate from their regular clothing, doubling the number of pieces purchased and requiring women to carry a change of clothes with them when they travel by bike. See appendix A for more details.

Branding

Outside of the cycling-specific athletic space, brands have found ways to overcome the challenge of creating apparel that works for both an athletic situation and a casual social situation. Such "crossover" apparel is common in the yoga and athletic outdoor marketplaces. Brands such as Athleta and Lululemon have succeeded in designing stylish garments made from performance fabrics. Branding for these companies targets women who make activity part of their lifestyles, going so far as to identify with these brands as representative of their philosophies toward life. These brands have brought fashion into the gym space, and made the "gym look" desirable in streetwear.

Currently, none of the brands in this space are attempting to market to cyclists specifically. Because of the polarization in the cyclist market discussed earlier, many cyclists do not identify themselves simply as active, outdoor-oriented people; they are bike enthusiasts. Therefore, if brands wish to appeal to this consumer segment, they must speak directly to them. This is currently lacking in the casual athletic apparel marketplace.

The Opportunity

Women's cycling is increasing within a stagnant market

For the past 15 years, the US cycling market has been largely stagnant (Edmondson). Growth has not kept pace with overall economic and population growth in the country at large. The US is becoming more diverse, as population growth is happening primarily among people of color. Yet the cycling industry has remained overwhelming dominated by white males, a population which is not expanding (Edmondson). Opportunity for market expansion is ripe if the industry can find a way to appeal to women, along with Hispanic, black, and Asian families.

Women have made up a large portion of those who have increased the frequency of their riding within the greater cycling community in recent years. A Gluskin-Townley Group study from 2011 discovered that while total ridership decreased by 1.3 million individuals during the years 2000-2010, an additional 100,000 women moved from the category of "infrequent" rider to the category of "enthusiast" (Edmondson). Women are continually embracing cycling as a frequent mode of transport and recreation.

Women have identified clothing as a need and are looking for solutions

As women point to a lack of clothing and gear options as a force preventing them from increasing their ridership, they continue their search for appropriately styled and fitted apparel. The author's 2014 survey of women's needs in cycling garments uncovered a great desire to find these solutions. Additionally, the socially-connected nature of the community of female cyclists indicates that awareness of successful products will spread quickly. 85% of women cyclists

have a Facebook account, and 28% keep a personal website or blog (Czszepanski). Brands who find a way to satisfy this niche will be rewarded.

New fabrics and techniques offer opportunities to improve sustainability in the industry

As technology continues to advance in the textile and material industry, opportunities for lower-impact, higher performance products will continue to increase. By embracing new fabrics and techniques, brands will be able to stay on the cutting edge of eco-effective and regenerative garments, giving the most innovative companies an edge on their competition. This advantage may be parleyed into lower costs, higher margins, and stronger brand loyalty, while likewise being ethical and responsible in practice.

Thesis statement

How might sustainability-focused design standards and processes be applied to cycling apparel for women in order to create a more responsible and more useful product for consumers?

Project Statement

This paper focuses on evaluating the existing fiber products and technologies in the market at this point in time. Using existing research, Life Cycle Analyses (LCA) are used a tool for evaluation, and limitations of LCA in agricultural application will be discussed. Additionally, desired performance characteristics are used as criteria for evaluation. Current popular fabrics in the athletic apparel space, PET / polyester, Lycra, and wool, are evaluated against new blends and fibers, CRAiLAR and the man-made cellulose based fibers Tencel and Modal, to make a recommendation for the lowest impact material with the strongest performance standards.

Furthermore, a thesis project is undertaken in conjunction with research of fibers and manufacturing impact. The project focuses on the design and development of a pair of pants and a top that are intended to be used as crossover garments for both cycling and casual use. This paper walks through the methodology and intention of the design solution that is the result of the project. Brand positioning, philosophy, and consumer communication strategies will be demonstrated with the goal of effectively conveying the sustainability message of the garments to an intended audience.

Finally, recommendations for future development in the sustainable textile marketplace and the athletic and outdoor apparel sector are made.

Design Process and Methodology

Evaluation of fibers and materials currently in the marketplace

Today's athletic and outdoor apparel market is dominated by a few highly-sought after materials that have excellent performance characteristics and great aesthetics. Particularly, polyester (PET) and its variants are ubiquitous. In the cycling performance market, spandex is the most common material found in gear. Many blends, finishes, and treatments are applied to achieve different performance and aesthetic goals, creating what appears to be a huge variety of fibers in the marketplace, but is in reality many variations of a single fiber.

Traditionally, wool was used as a primary fiber for cycling garments (as well as those for other sports) from the origin of the activity until the 1970's, when polyester and spandex blends gained popularity as more lightweight, aerodynamic alternatives. Wool has seen a renaissance of sorts in recent years as more companies have embraced it as a harkening to the glory days of the sport, while also recognizing the advancements made in wool production that have made it once again an excellent fabric for athletic use. Wool is a very breathable fiber with a high ability to transfer moisture. It also resists odors thanks to its antimicrobial properties. These properties were recognized by early sports apparel designers, making it a good choice in the past, and again now (WoolSports).

PET and spandex are both hydrocarbon-based products, and therefore are created using finite, non-renewable resources, causing abiotic depletion (defined as the depletion of resources which cannot be replenished). While they score as low-impact in production when compared to natural fibers on impact calculators such as Okala, there are many externalized costs and impacts that are not represented in these scores. The environmental impacts of petroleum can be mapped to extraction, transportation, refinement, use and disposal, including land, air and water pollution, human exploitation, and the existence of persistent chemicals. Natural fibers and synthetics that are made from natural resources, such as cellulosic fibers, are renewable, but relatively high impact as scored by Okala and others. The reasons for these discrepancies in impacts and benefits of both currently popular fibers and emerging fibers will be analyzed in a later section of this document.

Fit evaluation and methodology

To determine how to correctly size and fit the final designs, a second survey of 134 female cyclists was conducted in March and April of 2015. This survey was designed to collect key measurements of the bodies of female cyclists, along with some basic demographic information. Results were then used to find

standard fit dimensions. This survey, its results, and methodology will be discussed further in the Design Methodology section of this paper. Complete results are available in Appendix B.

Styling and design approach

In the consumer research, several features were requested repeatedly and rose to the top as key to success. Table 1 shows these top features.

Requested Feature	**Rank**
High waist for coverage while riding	1
Extra room in the thigh and/or calf	2
Articulation in the knees	3
Classic colors and patterns: refrain from pink	4
Appropriate sizing for a wider range of body types	5

Table 1: Most Requested Features

During the design discovery phase, these top requests were taken into account and weighed against the brand's positioning and values. Sustainability-oriented strategies were also considered in design. Pieces were designed to be long lasting, highly durable, and versatile enough to replace multiple pieces in a user's wardrobe. They were also designed to break down easily for end-of-life repurposing, recycling, or decomposition.

Fabric Evaluation

Overview

When garments are intended for use outdoors and in athletic situations, certain performance characteristics are vital for success of a product. Breathability is important, allowing moisture from sweat to move away from the skin when a person is in motion. Fabrics are developed to be moisture-wicking and/or water repellent, keeping rain and other precipitants away from the skin. This increases the comfort of a garment in the variable conditions that may occur outdoors. Comfort against the skin, often referred to as "hand-feel" or simply "hand," makes a garment more likely to be used often.

What is sustainable manufacturing?

The concept of sustainable apparel is frequently misunderstood. Consumers do not have a solid grasp on what the term "sustainable" means, as demonstrated by a recent Cotton, Inc survey focusing on consumer behavior (Cotton, Inc).

Only 22% of consumers surveyed associated the word with an item being eco-friendly. The majority of respondents (51%) thought of the word as meaning durable.

To further complicate the matter, the lack of consistent messaging around apparel sustainability efforts makes it difficult for even educated consumers to understand what is behind the manufacturing of their apparel. Few companies in any part of the apparel industry are fully or even partially transparent about their supply chains and the choices they make around fabrics and sourcing. Many companies consider their processes and chemical formulas to be proprietary, preventing outside agencies from evaluating their sustainability qualifications. The FTC requires "Labels containing fiber content, country of origin, the identification of the manufacturer, importer, or other dealer, and care instructions must be present at the time the end user takes possession of the good." (WeWear). No information is required concerning processes or chemical inputs.

Sustainability has been defined by the Environmental Protection Agency as "the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." (Environmental Protection Agency) The key to this equation is to use resources at a rate equivalent to or slower than the rate at which they can be replaced by nature. With the current state of technology, modern apparel can be created with methods that use resources at a slower rate, but not yet at a rate which could truly be considered sustainable by definition.

In the following discussion on specific fibers and blends, information presented is an aggregate of high-level data. Specific scores, numbers, and weightings are not presented; instead, conclusions based upon existing data are used to make recommendations.

Pros and cons of apparel Life Cycle Analysis

In most production sectors of the economy, LCA is a useful tool for evaluating the impact of products and materials. LCA can be used to discover areas from a product's life cycle that are high impact and track improvements over time. If boundaries are consistent across multiple materials (i.e., cradle to factory gate), comparisons in environmental impact can be made across materials. For instance, accurate impact comparisons can be made between polyester fabrics from virgin sources and polyester fabrics from recycled sources. Processes in different factories, locations, and countries are similar enough to ensure that comparisons are valid.

However, complications occur in agricultural applications which make LCA comparisons difficult. Ecological, biological, and geographic differences in farm or grazing locations can cause wildly different LCA measurements when the focus is brought down to the individual level. The common processes that

characterize synthetic production do not exist in agricultural production. Because of this, LCA analysis must rely on global or regional averages, and can often fail to tell the whole story of a product's impact (Henry).

In agricultural LCA, land use is often a large impact category, as many crops and materials require vast expanses of land for production. But the simple tonnage per acre formula does not take into account the opportunity cost of land use. For instance, in wool production, land is often used that is not suitable for food production. Multiple products may be produced from the same land, or secondary products may be created from the bi-products of a primary crop. Proper herd management can have a regenerative effect on marginal land, and have the added benefit of increased carbon sequestration. Poorly managed land can be equally disruptive and damaging, causing erosion, requiring chemical inputs, and polluting waterways.

Inconsistent boundaries can result in confusing LCA results. Only cradle to grave analyses, which are difficult to assess without making assumptions about the use phase, can accurately show a proper comparison between natural and synthetic garments. For instance, if a kilogram of wool is used as a functional unit, the analysis must define whether the wool is greasy (prior to washing) or cleaned. This could cause variance in water use and effluent run off (Henry).

As commonly conducted, LCA are most useful for agricultural products when used to baseline and track improvements within an individual supply chain, as opposed to use for cross-material comparisons. Global averages will not properly describe the impact of a given product in a way that can enable accurate improvement tracking. These examples illustrate the variability of agricultural land and products, and the potential for inaccurate generalities in LCA reporting. It is vital to bring the focus down to the level of individual properties in a supply chain to get a clear picture of the impact of an agricultural product (Henry). If LCA in agriculture is applied deep enough in the supply chain, it can be useful in cross-material comparisons.

In the comparisons made in this presentation, LCA boundaries are set at *cradle to factory gate*. Dyes and aging processes are not considered. There is variability in how each of the fibers discussed accepts dyes, and what secondary chemicals are required after raw materials are completed. For the purposes of the comparisons made here, these impacts are considered to be outside the boundary. However, scrutiny is applied to potential impact differences during the use phase of a garment's life cycle.

Petroleum Origin Fibers

Polyester

Description

Polyester, a manufactured fiber created from a by-product of crude oil refinement, is part of a group of fibers that makes up 50% of the apparel marketplace. Polyester absorbs dyes well and has strong color retention. It is resilient in both wet and dry states, and is highly durable. While not known for having a comfortable hand, defined as the way a textile "feels against the skin" (Kadolph 42), it is stable and highly elastic, making finished garments move well with the body.

Polyester lends itself particularly well to performance fabrics because of its ability to be tweaked and adjusted to achieve specific characteristics. It is very light weight, and can be formulated to incorporate moisture-wicking and wind-protection properties (Kadolph 123). Embedding nanofibers, those fibers with a diameter or less than 1,000 nanometers, can allow for highly effective evaporative cooling – beneficial for situations in which the wearer is exercising or sweating. One major drawback of polyester as a performance textile is its propensity to become odiferous after absorbing sweat. This characteristic can be mitigated by adding antibacterial or antimicrobial fibers which may inhibit bacterial growth to a blend during the spinning process. These chemical additives have been identified as triggering the development of resistant bacteria, and often require more frequent washings, making them a marginal-at-best solution to the problem of persistent smell (Kadolph 121).

Life Cycle Impacts

While polyester is a textile derived from fossil fuel extraction, a non-renewable resource with a finite supply, manufactured fibers as a whole account for only 1% of global fossil fuel consumption. Polyester is very efficient in manufacturing, as illustrated by the fact that one 300-acre facility can create as much fiber per year as 600,000 acres of cotton (Kadolph 113). Polyester uses very little water in production, sometimes actually using none at all, but energy inputs can be high (NRDC). The primary environmental impact areas of polyester fabrics are often global warming potential, abiotic depletion (the consumption of nonrenewable resources), and acidification of soil and water (Shen et al.).

Recycled polyester is an excellent substitute for virgin fibers that can greatly reduce the environmental impact of a polyester garment. Massive reductions in inputs can be achieved by utilizing items such as soda bottles, melted and put through the polyester spinning process again. Recycled feedstocks do not contribute to abiotic depletion. Air pollution from polyester production can be reduced by as much as 85%, and energy by 70%, when secondary sources are used (Kadolph 167; NRDC). *The Okala Practitioner* gives polyester a score of

between 2.8 and 3.1 (varying by rigidity), while PET from secondary sources is scored at 1.6, giving it a roughly 45% reduction in impact (44).

Spandex

Description

Spandex is a manufactured fiber containing long-chain synthetic fibers derived from at least 85% polyurethane. It was first produced in 1958 under the trade name Lycra, and is sometimes referred to as elastane. A combination of short and long-chain fibers resulted in a very useful material with incredible stretch and rebound that was intended to be used as a replacement for natural rubber. As a textile, Spandex is uncomfortable against the skin, so it is often blended to add stretch and rebound to other fiber blends.

As a performance fiber, Spandex has been used in cycling apparel since the late 1970's. The combination of extreme stretch and resilient rebound with high durability leads to a textile that has low air resistance, take dye superbly, and gives wearers the benefit of decreased muscle fatigue through compression (Romanowsky). These factors add up to an unsurpassed product for high-performance, athletic garment applications that require high elasticity and rebound.

In more casual applications, Spandex is often blended with more rigid fibers to create special blends with just the right amount of stretch for freer movement during active use. Many denim products contain 1-2% spandex in order to add stretch for both style and function. Even so, the activewear industry dominates spandex consumption, using 44% of US Spandex production (EPA).

Life Cycle Impacts

As a pure, unblended fiber, Spandex is similar in impact to polyester or other petroleum based manufactured fibers. While polyester fibers are melt spun, which avoids the use of certain solvents, Spandex requires either wet spinning, in a chemical bath, or dry spinning, both of which require the use and recovery or solvents. However, this added impact is a very small part of the total impact of the fiber in use (Kadolph 115).

Spandex is most often combined with other, more rigid fibers, which can cause end of life disposal issues. It is preferable from a sustainability perspective to restrict fiber blending to only natural fibers within a biological nutrient stream, or only manufactured fibers within a technological nutrient stream, as described by the Cradle to Cradle philosophy of sustainable design. Therefore, when Spandex is blended with natural fibers, it creates a "monstrous hybrid", or combination of two nutrient streams (McDonough). Recycling and reuse becomes difficult, because the biological and the technical nutrients are not easily separated and must be processed differently. For this reason, it is ecologically beneficial to avoid combining Spandex with natural fibers. One

increasingly common application of Spandex outside the athletics market is as a stretch-additive in denim products. Combining biological cotton with technical Spandex creates a material that is difficult to break down for recycling, making "down-cycling," often as insulation material, the best option outside of landfill or incineration for end of life disposal.

Summary: Synthetics

Synthetic fibers offer a nearly unlimited array of possibilities for development of performance characteristics and unique new fibers. They are generally low impact in comparison to simple LCA analysis of natural fibers, and this impact can be reduced even further through the use of secondary feedstocks. There is a very good reason why these materials have become so dominant in the athletic apparel industry.

However, it is important to keep in mind the origin of most manufactured fibers. The petroleum industry has massive impacts on the environment, and although textiles account for only 1% of global oil use, they still play a roll in an oil-based economy (Kadolph). Additionally, the tendency of manufacturers to take the best of manufactured fibers and combine them with natural fibers, which consumers find more desirable, creates a great dilemma for end of life disposal. Recycling of polyester garments has become more common in recent years (owing greatly to Patagonia's encouragement of the practice through their product take-back program), but biological-technical blends cannot be recycled in this way (Patagonia). Natural fibers can be composted and synthetic fibers can sometimes be recycled, but blends are difficult to separate sufficiently enough to enable both processes to occur with any degree of efficiency. The energy required to separate the two types of fibers is prohibitive of the benefits (Kaye). Therefore, while synthetic fibers carry great potential in the athletic apparel industry, they must be used with care and thoughtfulness, and consideration must be given to the externalized costs associated with the fossil fuel industry upon which these products rely.

Natural Origin Fibers

Wool

Description

Wool as a fiber source has been in use for millennia. It was one of the first true fibers ever used by ancient civilizations for clothing. The Babylonians began to weave wool into fabrics as early as 4000BC (Pepper). In the Middle Ages and beyond, Northern Europe and Britain became hubs for high-quality wool production. Today's wool industry is centered in the Southern Hemisphere, with Australia, New Zealand, and Argentina leading in production (although China has recently overtaken Australia as the world's top producer, with the majority of its production being for domestic use) (Henry). The profitability of wool is highly

variable. In order to demand a good price for wool, farmers must insure that it is very high quality. This means that efficiency in sustainable grazing, an abundance of native grasses, and a resistance to climate variations can benefit the long-term success of a farm – good practices in herd and land management leads to greater profits (Henry).

For athletic apparel use, merino wool is vastly preferred over other varieties of sheep. Merino is special in its softness, as the fleece of the merino sheep has exceptionally long and fine fibers. Fine fibers are not only more comfortable against the skin; they also wick moisture more efficiently and absorb less water than courser fibers. These properties allow a garment to insulate even when wet, a helpful characteristic for cycling during the winter season (Chaudhari et al.).

Most wool production globally occurs on mixed-use farms. Sheep are used for meat, lanolin (wool oil), hide and wool production throughout their life cycles. While different varieties of sheep are optimized for different products, most still are used for all to some degree. Fleeces can be harvested at least yearly without harming the sheep. Fleece removal helps cut down on mites and parasites, keeping sheep healthier (Henry).

Life Cycle Impacts

At face value, wool scores as a very high impact product. Land use, water use, effluent run off, and greenhouse gas emissions (GHG) are all considered high impact in comparison with other athletic fibers. However, when taken at a local scale, these impacts can be mitigated or even reversed, depending upon management and production practices (Henry).

Land use is particularly high for wool when looked at as a function of acres consumed per kilogram of product. However, much land that is in use for sheep herding is not able to be utilized for other types of agriculture. Often herding land is marginal or of poor topography for other types of farming. Additionally, scoring land use as a negative assumes that land is damaged in the process of herding. While this is often the case, it does not have to be. Holistic land management techniques can actually have a beneficial effect on grasslands. Native grasses can be restored, and carbon sinks can be expanded, reducing or even off-setting the effects of methane production from the digestive systems of ruminants (Savory). All ruminants, including sheep, emit methane, a greenhouse gas 20 times more potent than CO2, during digestion. Today, soils capture approximately 10% of methane in the atmosphere. Proper management of soils and lands may increase that percentage (Savory Institute). Therefore, while land use and GHG production are both counted as high-impact categories for wool in traditional LCAs, on an individual farm level, there is a capacity to reverse these effects. With 70% of the world's grasslands in a state of decline or damage, regeneration of these habitats will be useful for capturing atmospheric greenhouse gasses (Savory).

When the fleece is removed from the sheep, it contains large amounts of debris, oil, and other materials that must be removed through a process called scouring in order for the fleece to be spun into yarn. This requires large amounts of water, and often harmful chemicals. Lanolin, which is removed from the fleece, can be captured and used as a separate product, while the rest of the debris is flushed away, contributing to effluent contamination (Henry). This is another instance where material origin location makes a large difference. Chinese woolen mills often are higher impact than Australian or American mills, due to their poor wastewater treatment systems (Henry).

Finally, wool is often a catalyst for high amounts of chemical pesticides during the agricultural phase. Sheep that are managed poorly are subject to mites and other insects and infections, and are “dipped” in harsh pesticides in order to be rid of the pests. These chemicals are often harmful to both humans and animals. Avoidance of these chemicals is sometimes achieved through better land management practices, and by shearing sheep with enough regularity to prevent overgrowth of the fleece (Henry).

The use phase of any garment can be attributed with up to 60% of the total water usage of the product, mainly from laundering (Siegel). Therefore, if laundering can be minimized or reduced, the total water consumption of a garment could be greatly improved. Because wool is naturally antibacterial, it has the ability to resist body order from bacterial growth attributed to sweating. If a garment does not emit a bad odor, consumers may be likely to wash it less. While this does require several assumptions, it is worth taking into consideration that stink-free garments may require less water consumption in the use phase (Kviseth).

In short, wool is a fiber that is often scored poorly in comparison with synthetics and even other natural fibers. Much of this is due to the use of global or regional averages, and can be mitigated through corrected management and production processes. For this reason, it is still a valid sustainable fiber, but it must be considered on a case-by-case basis to ensure its validity.

CRAiLAR

Description

CRAiLAR was introduced in Vancouver, British Columbia in 1998 by Jason Finnis and Larisa Harrison (CRAiLAR). The technology utilizes bast fibers, such as flax and hemp, to create materials for fabric production. The raw material inputs are designed to be low impact, resulting in what is professed to be an “environmentally friendly” product. The primary fiber currently used in CRAiLAR production is flax.

Flax fiber has been used by humans for over 6,000 years, and was commercialized for use in garments and sails for sailing ships in the Middle Ages. Industrialization of linen production in the 19th Century caused

handcrafted garments to fall out of favor, although they are seeing a resurgence today. Much of the world's flax production (80%) is in Northern Europe, with France accounting for the majority. Flax in its various forms represents only 1% of textile fiber consumption worldwide (Le Lin et al.). Flax requires a damp ocean climate to thrive, and needs no irrigation and only very minimal fertilizer input. Because of the ancient nature of flax production, regionally integrated systems that preserve local knowledge are common (Le Lin et al.).

The majority of agricultural flax supports the seed oil and linen industries. Fields are rested from flax production for seven years, requiring diversified agricultural systems (Die Leinenweber). Pesticides and fertilizers are used only rarely, and no chemicals are required for the separation of fibers in linen production. Raw flax can be steamed or retted (allowed to rot naturally) in order to separate fibers for material development (Die Leinenweber).

CRAiLAR is a specific technological process that uses the byproducts of linen and seed oil production to create a new fabric from the waste. Linen requires long fibers for spinning, but CRAiLAR can be woven from the short fibers that are discarded in production. It boasts several excellent performance features which can be applied to athletic apparel use. The resulting fibers are moisture wicking, have high tensile strength, and are shrink resistant. Dye uptake is strong, meaning comparatively less dye is needed for bright coloration. Bast fibers, including flax, are generally stiff and scratchy, but in the CRAiLAR process, pectin is removed, giving the fabric a soft hand-feel similar to that of cotton (CRAiLAR, Borromeo). Natural antibiotic properties of the fiber make it "stink-free" and able to be worn multiple times without requiring a wash – an excellent characteristic for athletic materials (Nalbach).

Life Cycle Impacts

CRAiLAR has been touted as a major breakthrough in fiber technology, using waste products (short flax fibers) to create high-performance materials. Made-By, a European benchmarking standard that measures greenhouse gas emissions, human toxicity, energy, water and land use, categorizes CRAiLAR as a Class B fiber, the second best score available. This puts it in a similar impact category as chemically recycled polyester, organic cotton, and Tencel (Made-By). CRAiLAR has a very low water impact because flax does not require irrigation. This water impact can be lessened even more by reduction in washing during the use phase: if consumers understand the antibacterial and antimicrobial properties of the fiber, they may be inclined to wash the finished garments less. Less frequent washing could reduce water and energy use by a great degree, since the use phase of a garment's life cycle is by far the highest impact.

It is preferable for flax feed stock to be processed with natural retting, rather than chemical baths, in order to cut down on toxicity inherent in the production phase. Pectin removal, which gives CRAiLAR its soft hand feel, is achieved

through an enzymatic process, which, according to the company, is “natural” and non-toxic (Borromeo). CRAiLAR production utilizes existing cotton spinning machines, meaning spinners do not have to purchase or produce new machines, further lessening the initial impact of startup production (Borromeo).

To date, CRAiLAR fibers are not certified organic and are not manufactured with closed-loop methods. However, the company is moving toward sustainability and hopes to implement whatever standards its customers request (Nalbach, Borromeo). At this point in time, CRAiLAR is a good fiber; in the future, it may be a great fiber. Because CRAiLAR is a byproduct of the production of other materials, much of its impact should be allocated to primary and secondary products, reducing the true impact of the fiber considerably.

Lenzing Fibers: Viscose, Modal, and Lyocell

Description

Cellulose fibers are man-made synthetic polymers made from wood pulp and cotton linters. Natural materials are converted into polymers through a Viscose or Lyocell process that breaks the fibers down completely and spins them into a new raw material that behaves similar to, and is in fact nearly molecularly identical to, polyester. The global leader in ecologically efficient cellulose fibers is the Lenzing Group of Austria. In total, Lenzing Manufactures five products: Lenzing Viscose Asia, Lenzing Viscose Austria, Lenzing Modal, Tencel Austria (Lyocell), and Tencel 2012 (Lyocell).

In the Viscose process, pulp is alkalized with caustic soda, depolymerized, reacted with carbon disulphide, dissolved in caustic soda again, filtered, degassed, aged, and then spun in a precipitation bath with sulpheric acid, sodium sulphate, and zinc sulphate. While most chemicals and byproducts are captured and reused, the inputs are quite dangerous. The newer Lyocell process improves upon the Viscose polymerization process by instead using NMMO (N-methylmorphine-N-oxide) to dissolve the raw pulp materials. This is a closed solvent cycle that avoids the use of carbon disulphide while reducing steps involved and total chemical use (Shen et al.).

Life Cycle Impacts

Each of the five Lenzing products, although similar in final structure, carries with it differences in embedded energy, resource use, and environmental impacts. Origin of feedstocks, which are primarily beech wood and eucalyptus, as well as factory design and municipal infrastructure have a large impact on the finished fiber’s environmental footprint. In most measured categories, including global warming potential, nonrenewable energy use, cumulative energy demand, and ecotoxicity, Lenzing Viscose Asia ranks at the bottom of the five fabrics (Shen et al.).

Because of the improvements to the Lyocell process used in the manufacturing of Tencel and Tencel 2012, toxicity impacts, especially from caustic soda, are lower in Tencel than in Modal or either Lenzing Viscose product. The primary toxicity impacts from Tencel instead are attributed to the factory's use of municipal solid waste incineration (MSWI) for power generation. Land use impact is low for Tencel and Tencel 2012. This is because the forests used are well established and do not have high land transformation costs. Tencel and Tencel 2012 require low amounts of energy in production, and get a high percentage of energy from MSWI, which is considered a renewable energy source (Shen et al.).

Lenzing Viscose and Modal, while of higher impact in land use and toxicity, have advantages in their potential to impact global warming. In fact, Lenzing Viscose Austria is a net carbon sequesterer in manufacturing. Much of this can be attributed to the integrated production systems incorporated in the factories. These facilities have been optimized for efficiency, and energy is recovered and put back into the system when possible (Shen et al.).

Based on this information, it is determined that Tencel 2012 is the preferable choice of all the five Lenzing cellulose fibers. Lenzing Viscose Asia should not be considered a sustainable fiber, as it is in fact on par with conventional cotton in its impacts. Even without the advantages of integrated production and recaptured energy, Tencel 2012's lower ecotoxicity score, a benefit of lowered chemical inputs, and use of renewable energy make it a preferable fiber to any of the other four cellulose fibers or PET / polyester.

Summary: Natural Origin Fibers

Natural fibers are difficult to compare to synthetic fibers. Variations in production methods and agricultural standards cause difficulty in establishing norms or averages. Instead, trends may be extrapolated in order to determine whether the trajectory of a fiber is moving toward improvement. Naturally-derived fibers have many advantages over synthetics. Consumers view natural fibers as more favorable than synthetics (Cotton, Inc.), whether or not they are actually lower-impact. This creates a challenge for synthetic fibers to communicate the sustainability benefits to consumers. Natural fibers are inherently renewable. They do not rely on the perpetuation of petroleum industries, or the recycling of fossil fuel-derived products. However, using today's benchmarking standards, all natural fibers fall short of polyester in most LCA. *Okala Practitioner 2014* scores polyester from recycled bottles at 1.7 impact factor points, as opposed to wool's 15 and linen's 3.1 (White et al.). These numbers rely on global averages and should be considered short-hand for an in-depth LCA evaluation.

If natural fibers are to be used in sustainable textile production, it is essential that individual sources and site specific data be used to hone in on the lowest possible impacts. It cannot be assumed that natural fibers are completely non-

reliant on fossil fuels. Indeed, heavy equipment required to plant, harvest, and process natural feedstocks relies almost entirely on traditional sources of gasoline or diesel. However, natural fibers have the capacity to be positive impact. By completely maximizing efficiency and taking care to use holistic management that is constantly monitored for impact, otherwise damaged land can be improved through grazing and other agricultural activities. Farming implements and mass transportation vehicles could be redesigned to use fuels other than diesel. The end result of many years of effort may be the creation of carbon sinks and improved habitat, not simply less impactful products.

Conclusion: Fiber choice

It is deduced that the best possible fiber at present day for use in athletic apparel is a blend of 25% CRAiLAR and 75% Tencel 2012. Both of these materials are naturally derived and do not rely on petroleum, and as such do not contribute to abiotic depletion. The agricultural and forest feedstocks of both fibers do not require irrigation or contribute significantly to effluent runoff or freshwater consumption. CRAiLAR contributes antibacterial properties, indicating that finished garments may be worn multiple times before washing is required. This cuts down on the total water, energy, and chemical consumption of garments. Comfort and breathability is sufficient for athletic-wear standards. Figures 1-4 illustrate the specific impacts of the chosen blend, as compared to PET, Tencel 2012, and CRAiLAR. Because CRAiLAR does not release public data about their environmental impacts, estimates are used.

CRAiLAR is estimated to increase the impact in the production phase of the garment's life slightly over pure Tencel. This impact is outweighed by the benefits offered by the potential savings of water and energy during the use phase. The antibacterial properties of CRAiLAR may incentivize users to wear a garment more than once before washing. Figure 5 shows the energy use of a garment using hot or cold water and different amounts of time in the dryer, illustrating the potential for energy savings.

In the future, if the trajectory continues toward better, less impactful, fossil fuel-free natural fibers, wool will become an excellent fiber for athletic apparel use. The trend is positive in that direction currently, so the likelihood is that this will be the case in a short time. There are still barriers to overcome at present day, such as determining origins and tracking the product's supply chain. If gains continue to be made toward impact reduction, wool can become an ideal future fiber for athletic and casual garments.

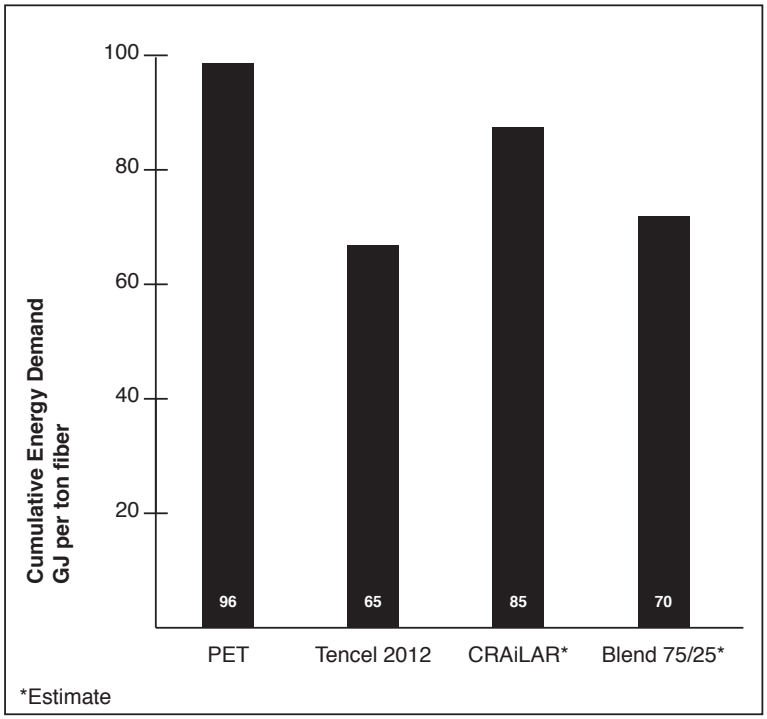


Figure 1: Cumulative Energy Demand

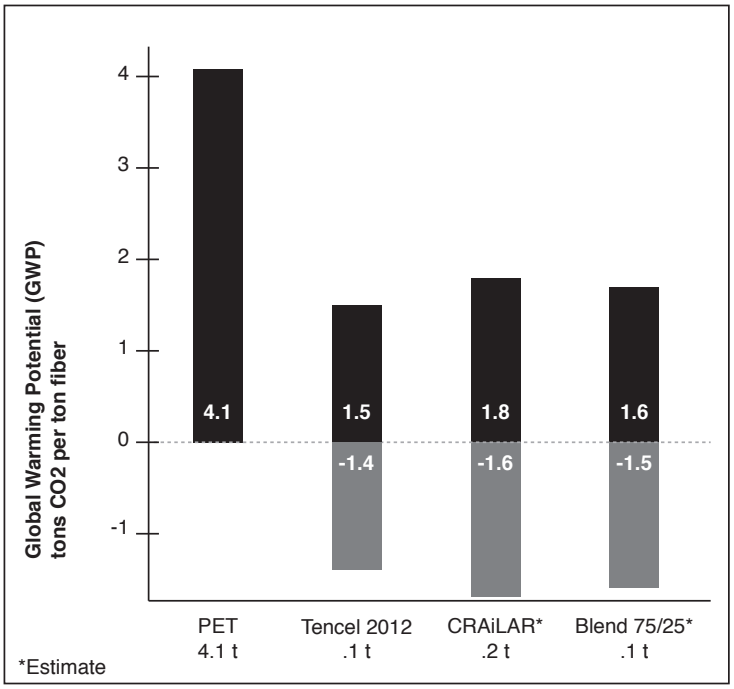


Figure 2: Global Warming Potential

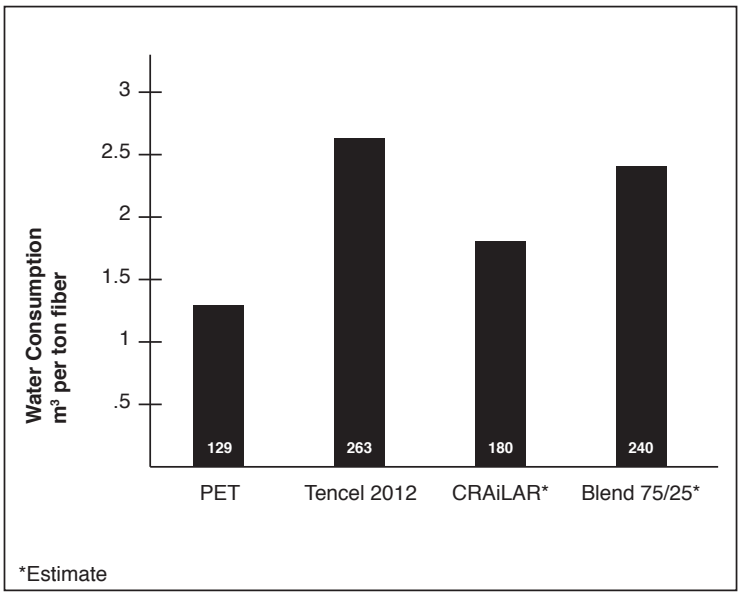


Figure 3:Water Consumption

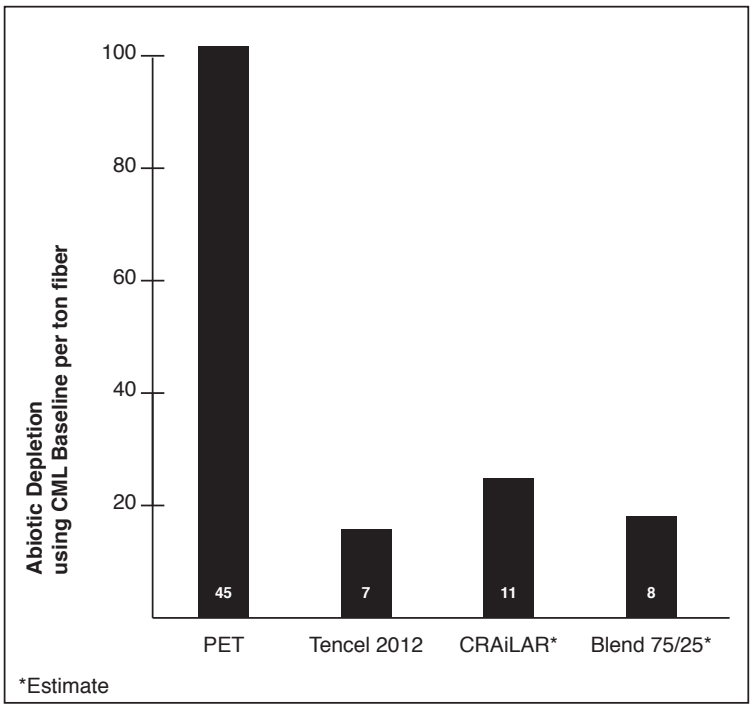


Figure 4: Abiotic Depletion

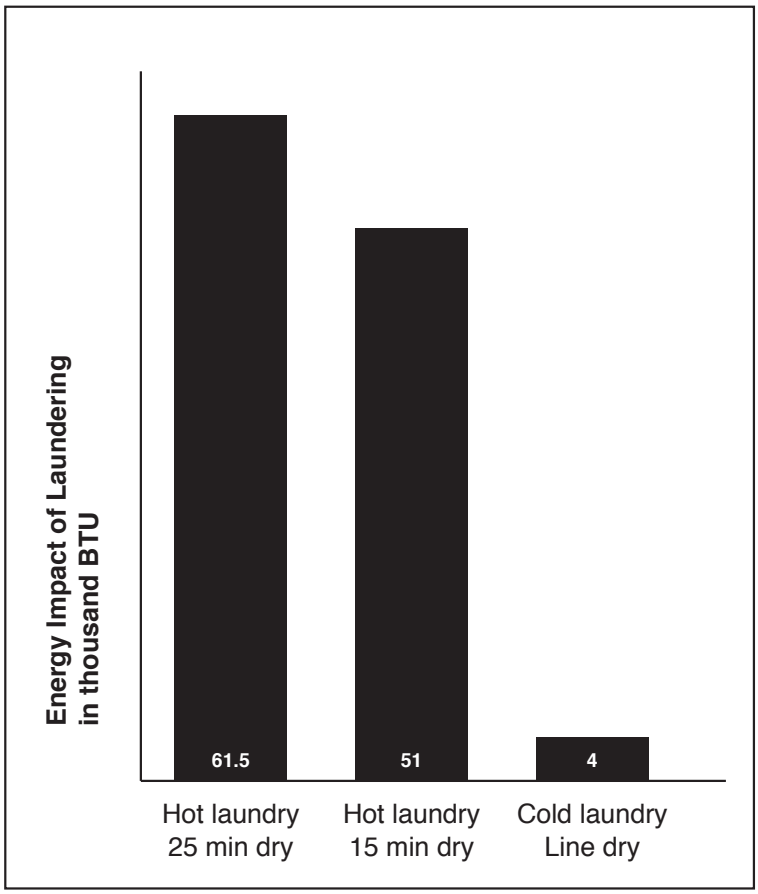


Figure 5: Impact of Laundering

Third party standards and materials tracking for agriculture

In general, aggregate LCA is difficult to use effectively as a tool for comparing the eco-effectiveness of natural fibers. Raw material site differences, land use policies, and other variables make global or even regional generalizations or averaging of impacts inaccurate. This problem has been solved for an analogous industry, wood products, by the introduction of a tool like the Forest Sustainability Coalition (FSC) system for complete supply chain certification. Implementing a similar system for wool products would be an effective way to ensure supplier compliance with best known practices for herd management, ethical treatment of flocks, chemical- and water-use efficiency, low-impact spinning and dyeing, and even fossil-fuel free transportation between facilities.

The FSC standard provides an excellent model to follow, in that all suppliers within the chain of custody must be compliant before an end-product can be certified. In an agricultural situation, efficacy would be ensured by third party oversight, with regular inspections. The seal of approval would provide a way for consumers to seek out products carrying the certification, and give compliant

brands a way to speak to consumers about their sustainability efforts without risking misleading their audience.

The concept of supply chain tracking and certification need not be limited to wool production. In fact, issues abound with LCA accuracy across most natural fiber production, and many textiles could benefit from increased accountability and transparency in manufacturing. It is strongly recommended that such an effort for complete supply chain compliance be undertaken to solve the problems of natural textile supply chain opacity.

Style and Design

While the problem of women being underrepresented in ridership is complex and can be approached in many ways, apparel is one factor that can have significant impact. The design of athletic crossover apparel developed specifically for women riders was the course of action for the purposes of this project. By coupling the consumer products that are the outcome of the design exercise with community-based outreach, this project focuses specifically on the final two of the “Five C’s” defined by the League of American Cyclists: Consumer Products and Community. Sustainability and ecological efficiency have been given equal consideration to functionality.

Methodology

What design problems will be solved?

One of the goals of this project has been to create garments that work both on and off the bike. Crossing over between these two spaces requires certain design and construction considerations.

The act of cycling is especially hard on the crotch of a pair of pants. Pedaling causes the inner thigh to rub against the saddle of the bike, often wearing it out before the pant would normally reach its end of usable life. Reinforcement of the area in a way that maintains comfort and prevents chaffing is mandatory. Cycling specific (not crossover) apparel solves this with specialized padding, but pads are not an acceptable solution for off-bike wear. The question of how to solve this in a casual wear situation has been addressed during the design phase of the project.

The particular movement of pedaling requires articulation in the hips and knees that would not be necessary in traditional athletic apparel. Creative solutions for making movement natural and comfortable, while not being overwhelming in appearance, will facilitate the transition from bike to office.

Cyclists have a need for safety while operating in an area dominated by motor vehicles – the American roadway. Reflective, bright colored touches, and integrated lighting can make a cyclist more visible to those driving cars and also increase the comfort felt by the bicycle operator.

Figure 6: Cumulative Energy Demand

Poor fit has been identified as an issue for athletic women in multiple surveys and discussions (see appendix B). The added complication of the cycling body position amplifies these issues. If the waist and hips of a pair of pants are not ideal, bending over to ride intensifies the affect of poor fit. The most common specific problems are exposure of the lower back, tightness at the waist, and tightness in the thighs. An in-depth fit survey was undertaken to collect measurements of women in the target market in order to determine optimal sizing.

Survey from 2014 – results and methodology

In Spring 2014, the author conducted a survey of 130 female cyclists in order to collect data about what was missing and what was being asked for in the women's cycling marketplace. Responses were submitted via online form, and participants were solicited via Facebook, Twitter, and email lists. While the majority of the respondents were residents of the Pacific Northwest, responses were collected from all around the US, as the survey was shared through personal online networks. The survey was left open for approximately one month. Participants were asked to share the survey with friends in order to increase the reach.

The primary intention of the survey was to gather information on what features and design elements were most sought after by women already participating in a cycling-oriented lifestyle. Several design directives rose to the top as they were repeated several times.

1. Tops must have longer lengths in order to protect the lower back from exposure when riders bend down to reach the handlebars. Short torso lengths of existing clothing was identified by at least 15 individuals as an issue in need of a solution.
2. Pants must be reinforced in the saddle area. Consumers tire of wearing out the crotches of jeans long before the garments should realistically need to be replaced.
3. Frequent riders have trouble finding pants with enough room in the thigh and hips and also a small enough waist to prevent the pants from falling down or exposing the lower back while riding.
4. Classic, tailored style is the look that is most desired. Consumers would like to see basic colors and silhouettes that will last through several seasons and are not trend-driven. Most options currently on the market are designed with bright pastel colors or floral patterns, failing to meet this need.

Survey from 2015 – results and methodology

Following up on the results of the 2014 survey, a second online-form survey was conducted to gather specific data on the measurements of women who frequently ride bikes for sport, recreation, or transportation. With the input of

seamstress Elizabeth Guise, ideal areas for measurements were chosen and described in detail, with focus on pants fitting. The survey was pushed online via Google Forms in February 2015, and ran through March 30th, 2015. A partnership was undertaken with Reid Miller, a cycling crossover apparel designer in Raleigh, North Carolina, in order to extend the reach of the audience. In total, 134 responses were gathered, 91 of which contained fully usable data.

Following the gathering of responses, the data was sorted by size range and divided into realistic sizing groups. Averages were taken in each identified group, providing an optimal fit range for each size.

Design process

The design phase of the project was approached from a problem / solution standpoint. Once problems with existing apparel options were pinpointed, each issue was addressed and led to experimentation in sketching and prototyping.

A seamstress was employed to assist with fitting and construction of prototyping, and assisted in design as well. A basic shape was developed and refined through fit sessions and by checking against the measurements that were self-reported by female cyclists. Once the basic pant and shirt forms were developed, embellishments, improvements, and specific design treatments were added as the pieces moved toward finished garments.

Throughout the process, the wearer's experience was kept at the forefront. This user-centric approach was taken in order to ensure that the final garments would be highly satisfactory to the audience, and be worn for many years. Throw away, fast fashion, or trend-centric design was considered to work against the sustainability goals of the project. Additionally, fabric considerations, including drape (how the garment lies against the body) and hand (how the garment feels against the skin), were taken into account to best maximize the characteristics of the chosen fibers.

Summary

The collaborative process between designer, seamstress, and user (through suggestions and input) was rewarding and fruitful in its outcome. Rapid prototyping to generate and test ideas was integral to the success of the process. Cycles of fitting, adding features, and testing against the needs expressed by potential consumers were an excellent way to reach a satisfactory design solution.

Design Solution

The outcome of the design process was a pair of gusseted riding pants and a versatile hooded riding top with hidden pockets. Both garments incorporate lighting for increased safety while riding.

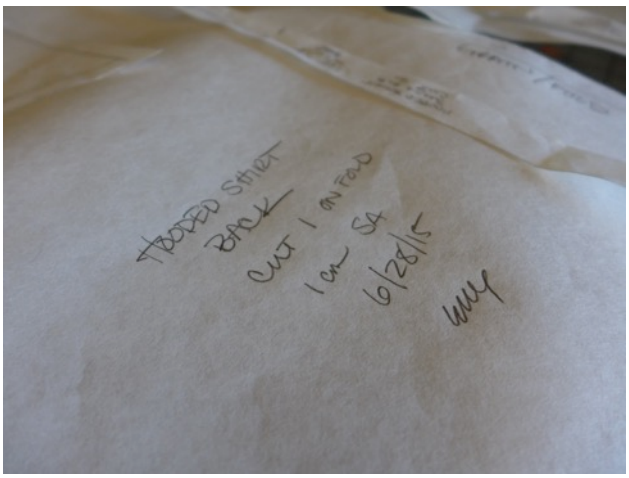
Highlights of pants design

The pant design is a well-fitted, tapered leg, woven pant made from lightweight merino wool. It features hidden reinforcement, high-denier (thicker weave) fabric and gusseting in the crotch to increase durability in this high-friction area. Intentional patterning allows for a mix of fabric weights, with the highest weights in the crotch and front of the thigh for wind resistance, and lightest weights on the side and in the knee gusseting for flexibility and ease of movement.

The pant features a relaxed fit ankle that can be zipped up to decrease its circumference and keep the cuff out of the chain of the bike. The rear waistband of the pant is higher than the front, increasing the coverage of the lower back. This increase in waistband width offers a strategic zippered pocket for small items such as a phone or wallet. Design cues for patterning were taken from jodhpurs and motorcycle pants, and tweaked to create a look that was not specifically identified with any one activity. Seams are hidden as best as possible to make the pant versatile and not simply a pant for cycling, but a pant for every day living.

Inconspicuous vertical mesh pockets on both pant legs provide the option for LED lights to be slipped in during night riding. The intention is that these lights will be sold as a separate accessory in the line and will compatible with several garments. By law, no side-facing lights are required to be used by cyclists, but “t-bone” or side-swiping collisions are a danger often faced by people on bikes. This lighting solution can increase visibility from an angle that is frequently a challenge.

For detailed illustrations of the pant design, see Appendix C.



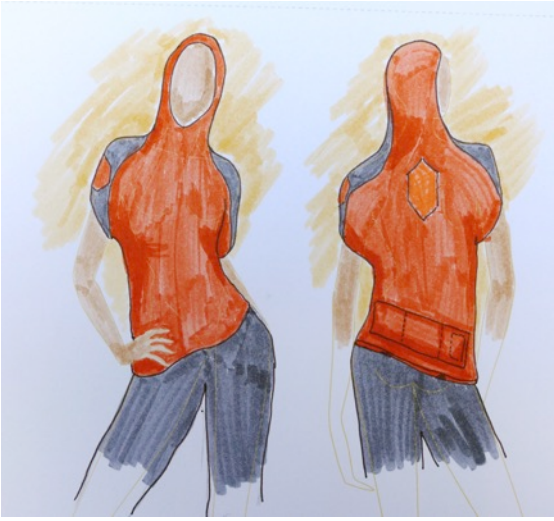
Highlights of top design

The lightweight top design is intended to be as useful as possible in a variety of weather situations. The blend of CRAiLAR and Tencel fibers provides sufficient stretch and rebound, great color retention, and resistance to body odor after sweating.

The design began with a basic raglan tee, with a hood was added for coverage in misty weather or light rain. The hood integrates with the back of the garment, creating a seamless line up the back. The close fitting of the hood to the contours of the head allows it to be worn under a helmet for protection while in motion. Extra length was added for complete coverage of the lower back while riding bent over in road bike position. Raglan seams moved fabric bunching away from the top of the shoulders, to make wearing a backpack more comfortable.

Pockets were integrated into the side seams and are pin-tucked toward the back of the garment. This prevents the effect of heavier objects pulling down on a shirt while bent forward. Pockets zip shut to keep their contents from falling out during rides.

Because safety was a top concern, lighting options were integrated into the shirt for extra visibility. A mesh pocket on the back is designed to hold a rear red blinking light. Often these lights don't attach well to garments or fall off while riding; this pocket provides a stable location and allows light to shine out. Vertical mesh pockets are also present on each sleeve, and fit the same set of LED light accessory as the pant, creating a second option for side lighting.



For detailed illustrations of the top design, see Appendix D.

Branding

Branding of a product is an important factor in how it is received and perceived by potential consumers. Branding forms the foundation of a product's identity,

and in many ways can be even more essential to a product's acceptance by consumers than the features of the product itself. Based upon the research conducted herein, it is concluded that there are several ways a brand might position itself while encouraging more women to ride with greater frequency. Brands can serve as a meeting place or connection point between women with similar interests.

Emphasizing community in marketing can be a powerful motivator of loyalty (Lee). When a consumer comes to see herself in a brand, she feels that the brand is something of an extension of herself and her own ideals. By remaining close to the consumer in this way, brands can retain authenticity. A women's specific, lifestyle-oriented brand for cyclists needs to be rooted in the community and the activity, or risk being one of many brands that simply "dabble" in the market and don't truly satisfy the needs of consumers. In the running space, Oiselle has proved this to be true. By building brand identity and, inevitably, loyalty through emotional connections with its consumers, Oiselle has managed to change the way women runners see themselves (Becker). When they align with Oiselle, they become part of a tribe. A similar position may be equally successful for a cycling lifestyle brand.

Beryl Cycling Apparel

While brands such as Oiselle have succeeded in activating consumers and creating community within the larger athletic and outdoors marketplace, there is still an opening and an opportunity for a similar strategy to be employed in the female cycling marketplace.

To position and market the garments designed for this project, a brand was developed specifically following the principles outlined above. Named Beryl, this brand is meant to become a rallying point for women cyclists to use to build community and explore their own identities and personal connections built through the cycling lifestyle.

Positioning

A successful brand in this marketplace needs to be lifestyle oriented. Beryl will be marketed on the benefits that the products can bring to one's life, not solely on the features of the products themselves. Crossover cycling garments enable women to spend more time enjoying themselves on the bike, being more mobile, and less restricted to vehicle travel. They make a car-free lifestyle more simple and appealing. They have the capacity to connect women to each other in a community of riders, and spread a sense of pride in ridership. Finally, they allow women to purchase fewer, better garments and make more responsible choices in clothing purchases. These are the benefits of the product that marketing will speak about in consumer communications.

Consumer Profile

Beryl's primary customers are professional women in their early to mid adult years with more than a passing interest in cycling.

Primary Customer: Active Adventurer

The primary consumer for Beryl is a woman dubbed Active Adventurer. She is in her late 20's to mid 40's, the most active time in her adult life. She has some college education and earns between $50 and $75k per year, putting her in a comfortable financial situation, but she is still well aware of her spending. Active Adventurer likes how she feels when she rides, but she's not in it for the endorphins. She sees cycling as an expression of her active lifestyle. For her, the bike is not a political statement. She is likely to have a small family, including one or perhaps two children. She limits her spending, but is willing to pay more for something that will last. Cycling is an outward reflection of who she is and what she stands for. She loves the outdoors, is very social, and wants to keep moving throughout her life.

Values

Three values have been identified as powerful statements for the women's crossover apparel brand Beryl. These are the ideals that are not compromised and are the pillars that marketing activity and positioning are oriented.

Women actively travelling

Reducing women's disproportionately high reliance on motor vehicles in comparison to men by removing barriers to active transportation and building communities of women who participate in bike-centered living at any level.

Future-focused living

Embrace positive change in the long term, rather than sacrificing values for short-term profit. Consumers are willing to invest in fewer, better things. The theory of infinite growth should be rejected as a business strategy, and growth must happen at the same rate as natural replenishment of resources.

Beauty in utility

Classic style and coloring coupled with functional, human-centered design leads to objects that stay in the wardrobe for years. Beloved, well-constructed pieces encourage long-term use and discourage unnecessary consumption of goods.

Identity and Execution

A logo and identity system was designed in an effort to develop a visual identity to align the garments with the market positioning. The goal was to expound visually upon the positioning and values outlined above. The visual style is fun yet classic, using enduring, mature colors. An emphasis is placed on the women

highlighted in photography and text: real female ambassadors for cycling and the brand.

Ride. Roam. Thrive.

The tagline "Ride. Roam. Thrive." was developed as a way to distill the values and messaging of the brand into a simple, memorable statement. These three words encourage actively moving, using a bike, and exploring new places. The "thrive" aspect of the tagline hints at both personal development, through community interaction and connection, and environmental regeneration. It gives the brand a starting point from which to talk to consumers about its environmental standards. It is important to refrain from delivering the environmental message too early, as consumers do not respond positively in large numbers to this type of messaging until they have adopted a brand (Cotton, Inc). This tagline is strong because it is open to interpretation.

Logo development began with an exploration of the meanings and connotations of the name, Beryl. Beryl is a mineral (aluminium cyclosilicate) that frequently forms hexagonal crystals, most commonly green in color, but sometimes blue, pink, or gold (Minerals.net). Beryl is also the name of a famous female bike racer from the 1950's and 60's who first discovered bikes through her daily commute to work (Pidd). These facts informed the coloration and visual characteristics. Angular lines, toughness, and strong femininity were paired with softer blue-green hues and a hit of deep red to convey the attributes of the brand and its consumer. Figure 1 shows the logo in its primary use, while Figure 2 shows the simplified logotype version, with the stone integrated subtly with the type.

For the complete visual identity, see Appendix E.

Packaging

Packaging used for shipping and labeling and identification at retail can have a large impact on the environment. Commonly, garments are packaged individually in LDPE plastic bags (#4), a material which is recycled at a rate of only 1% (Jedlicka 236). These bags are

lightweight, durable, and technically recyclable. However, in actuality, they are recycled at very low rates. In 2013, China imposed a so-called “green wall” against importing low-quality plastics for recycling, pulling the rug out from under the market. It should be noted that these regulations were put in place to stop an out-of-control, unregulated plastics recycling industry that caused severe health problems, including pulmonary issues and strokes, in workers exposed to fumes (Minter). It should be assumed that these bags will not be recycled, or, if they are, are still environmentally damaging, and should therefore be replaced. The purpose they serve is to keep garments clean and easily stuffed into larger multipacks for mass distribution. Therefore, if garments are finished in a location in close proximity to distribution, these plastic bags are not necessary.

For the development of Beryl, localized production and small-scale distribution are assumed. Garments are shipped direct to consumers via a package delivery service, avoiding the trip to distribution and retail centers. An excellent alternative to individual packaging is an FSC-certified paper shipping bag, such as the Pregis Pad-Kraft all-paper mailer (mocked up below) , which uses shredded recycled paper to cushion packages in shipment. Figure 7 illustrates a concept for a shipping bag design and garment label. The label includes a prompt to explore the origin of a product via the Beryl website.

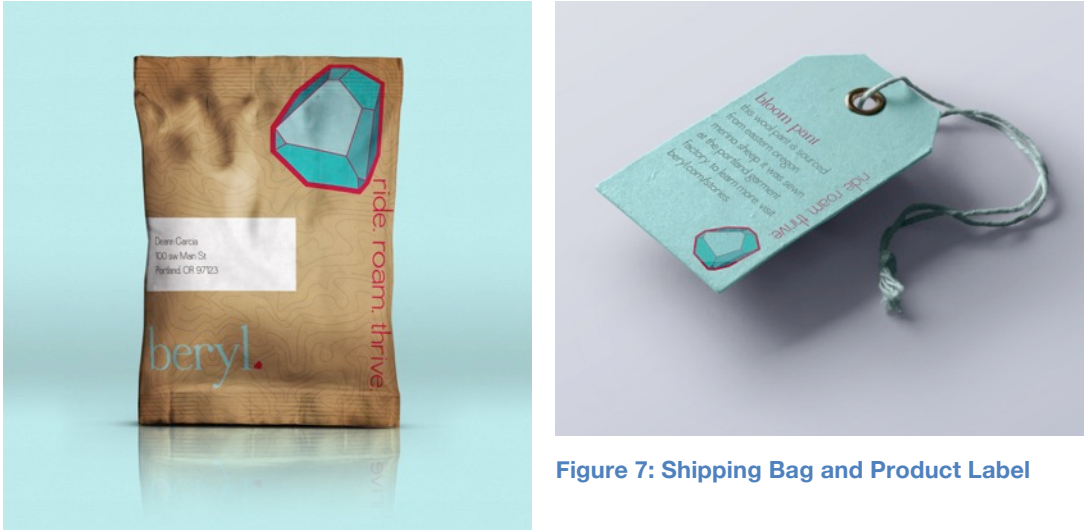


Figure 7: Shipping Bag and Product Label

Beryl branding execution would use FSC-certified papers with high post-consumer content and water-based inks for all labeling, which will be minimal by choice. Because garments are purchased online, the need for printed marketing materials is low. Examples of Beryl packaging design can be found in the supporting documentation in appendix E.

Conclusion

This project had distinct goals both for sustainability in design and manufacturing, and for consumer solutions. Each category is evaluated for its level of success.

Sustainability

The top and pant showed sustainability gains over existing marketplace options for several stages of the product life cycles. In the materials production stage, using blends of CRAiLAR provides the benefit of utilizing a waste product from another product stream as an input. The flax-based material reduces pesticides and herbicides use, and requires no irrigation input during growth.

Recent improvements to the Tencel process reduce the need for caustic soda and other toxic chemicals during processing. Using fibers from European mills, as opposed to Asian mills, reduces fossil fuel inputs during manufacturing.

Packaging, labeling and material reduction decisions reduce the impact of non-textile inputs in the product stream. Avoiding plastic bags increases the likelihood of packages being recycled by the consumer, as paper shipping bags are more widely recycled than plastic bags.

The antibacterial properties of CRAiLAR have the potential to reduce the impact of washing and drying during the use phase, if these properties are properly communicated or demonstrated to the consumer. Design decisions which are meant to make the garments useful for several different activities, including bike riding, have the potential to reduce the consumer's overall need for garment ownership. If, in the past, four garments were required for a day of bicycle commuting and office working, today only two might be needed. This could reduce the overall consumption of consumer goods in the apparel space.

With the infrastructure in place today, apparel has still not yet reached the point of being neutral in overall impact, let alone regenerative. The technology does exist for natural materials to have positive ecological benefit in production. Unfortunately, there is a lack of connection, transparency, and implementation of available technology to get apparel to this point. With enough resources committed to sustainability, the apparel industry could transition from being one of the most harmful industries to a model for other industries to follow.

Consumer Needs

Consumer research at the start of the project indicated that female cyclists were seeking apparel that was durable, provided sufficient coverage of the lower back, allowed for movement while riding, and accommodated the muscular body type of a cyclist. These criteria were met with varying degrees of success in the design of the final garments.

Durability was designed into the garment through reinforcements in high-frictions areas. It can be assumed that these design choices were helpful in creating long-lasting garments; however, this cannot be verified unless the finished garments are wear-tested for long periods of time and use.

Coverage of the lower back was achieved in both the top, through longer back panels, and the pant, with a high waist that rises in the back. These features keep the lower back covered in any position, included bent over in a tradition road bike-riding posture. The garments were successful at providing lower back coverage when used in tandem and when paired with other garments.

Allowing for sufficient movement while riding turned out to be a difficult problem to overcome. Excessive gusseting in the knee created a puffy look when standing, so a delicate balance had to be struck. Movement could easily be accommodated with oversized, baggy pants, but with a goal of designing stylish, professional clothing that could be worn in the office, style had to be considered. In the end, the design was a success, but the exercise highlighted the restrictions placed upon apparel design when style, movement, and materials all present constraints.

Fitting of the cyclist's body is a difficult proposition because there proved to be so much variety in body types. There was indeed a trend toward oversized thighs and quads, and comparatively slim waists. In order to truly satisfy the needs of the audience, an extensive size range will need to be developed. Ideally, the best possible product would be customizable, with the ability to be tailored to the body of the specific user.

Next Steps: Consumer Evaluation

Because the design of the garments was undertaken with consumer experience in mind, effectively evaluating the success of the designs requires talking directly to consumers to discover if the designs effectively addressed their needs. At a later date, a focus group session will be held. Participants will be asked to self-identify their own level of participation in cycling, and consideration will be given to those on the fringes who may be influenced to get more involved given the right conditions. Three groups of cyclists will be evaluated for reactions: occasional riders, frequent commuters, and dedicated cyclists.

Each participant will be given time to examine sample garments and write down feedback in a written survey. After surveys have been completed, a group discussion will take place. A moderator will lead the discussion, taking notes and getting a feel for the general reaction of the group. Finally, a single number score will be assigned to each garment by the participants. This will be compared to the written surveys. The purpose will be to evaluate both how the garments satisfy the conditions requested by the consumers in earlier surveys, and how the group dynamic influences reactions. Because community

connection will be an important part of the brand's platform, this group dynamic is important to measure.

Discussion / Commentary

Upon completion of this project, I was able to reflect upon the challenges and obstacles in the path toward truly sustainable apparel production. This is a large, deeply entrenched industry that is difficult to turn around. It is ruled by extremely large players and by consumer demands for cheap goods. The garments designed for this project will not fit into the low-budget price points that many consumers have come to expect. Major changes need to happen from a structural and supply chain transparency point of view, but perhaps the re-education of the consumer will be the largest obstacle to overcome.

I estimate that the two garments I designed in this project would realistically cost between $100 and $200 each in the retail marketplace, a price that puts them out of reach of many consumers who have come to expect $20-$40 price points on apparel. Reaching prices this low would require foregoing supply chain accountability and using subsidized fibers, such as cotton, which are sold at artificially low prices. Consumers do not see the hidden costs they incur through government subsidies of these fibers, which, according to the non-profit Oxfam, artificially lower the global price of the cotton commodity by 3 to 30% (Alston et al.). Competing against artificially low fiber costs creates an unfair marketplace, where brands must compete on platform instead of price. While price point is not something that I have approached in this project, it is definitely something that will affect the implementation of the project if I choose to commercialize the garments at a later date.

The path to true sustainability in apparel manufacturing has been clearly defined, and the resources are in place for it to come to fruition. All that is needed are the right people and businesses to implement change. Connections must be made between different suppliers in the chains of custody in order to reach a sufficient level of accountability and transparency. The trend is moving in the right direction, so there is cause for hope.

Works Cited

Alston, Julian M., Daniel A. Sumner, and Henrich Brunke. "Impacts of Reductions in US Cotton Subsidies on West African Cotton Producers." *Oxfam* (2007): n. pag. *Oxfam America*. Oxfam, 2007. Web. 6 July 2015. <http://www.oxfamamerica.org/static/media/files/paying-the-price.pdf>.

Becker, Braden. "How Oiselle Proves Audience Targeting Can Create Its Own Demand." The Content Standard by Skyword How Oiselle Proves Audience Targeting Can Create Its Own Demand Comments. Content Standard, 02 Feb. 2015. Web. 04 May 2015. <http://www.skyword.com/contentstandard/for-storytellers/how-oiselle-proves-audience-targeting-can-create-its-own-demand>.

Borromeo, Leah. "Technology Could Allow Hemp and Flax to Break Cotton's Global Hold on Textiles." The Guardian Online. The Guardian, 17 Apr. 2014. Web. 28 Apr. 2015. <http://www.theguardian.com/sustainable-business/hemp-flax-bast-cotton-crailar>.

Chaudhari, Sanjay S.,Chitnis, Rupali S., Ramkrishnan, Rekha. Waterproof Breathable Active Sports Wear Fabrics. The Synthetic and Art Silk Mills Research Association. 2006. Web. 04 May 2015. <http://www.sasmira.org/sportwear.pdf>.

Cotton, Inc. “Consumer Perspectives on “Green” Apparel.” Consumer Perspectives on “Green” Apparel - Cotton Incorporated. Cotton Incorporated, 2013. Web. 17 Mar. 2015. <http://www.cottoninc.com/corporate/Market-Data/SupplyChainInsights/consumer-perspectives-on-green-apparel>.

CRAiLAR. “CRAiLAR Fibers Create Sustainable, Better-performing, Products.” Your Product. CRAiLAR, 2015. Web. 08 Mar. 2015. <http://www.crailar.com/product>.

Die Leinenweber. “A Short Cultural History of Linen ...” Die Leinenweber. Die Leinenweber, 2007. Web. 08 Mar. 2015. <http://www.die-leinenweber.de/linen-cultural-history-en_10.html>.

Dill, Jennifer. “Transportation.” Journal of Public Health Policy 30 (2008): S95-110. Journal of Public Health Policy. Portland State University. Web. 10 Mar. 2015. <http://www.palgrave-journals.com/jphp/journal/v30/nS1/abs/jphp200856a.html>.

Edmondson, Brad. The US Bicycle Market: A Trend Overview. Publication. N.p.: Gluskin Townley Group, 2011. Print.

Emond, Catherine, Wei Tang, and Susan Handy. Explaining Gender Differences in Bicycle Behavior. Rep. N.p.: Active Living Research, 2009. Print.

Environmental Protection Agency "Sustainability Information." EPA. Environmental Protection Agency, n.d. Web. 02 Mar. 2015. <http://www.epa.gov/sustainability/basicinfo.htm>.

Hegde, Beth. Organic Cotton is Proven to Cause Less Environmental Damage than Conventional Cotton, New Study Shows.

Henry, Beverley. Understanding the Environmental Impacts of Wool: A Review of Lifecycle Assessment Studies. Rep. Australian Wool Innovation & International Wool Textile Organisation, Oct. 2011. Web. Mar. 2015. <http://www.iwto.org/uploaded/publications/Understanding_Wool_LCA2_20120513.pdf>.

Jedlicka, Wendy. Packaging Sustainability: Tools, Systems, and Strategies for Innovative Package Design. Hoboken, NJ: John Wiley & Sons, 2009. Print.

Kadolph, Sara J. Textiles: Basics. Eleventh ed. Boston: Prentice Hall, 2013. Print.

Kaye, Leon. "Textile Recycling Innovation Challenges Clothing Industry." The Guardian. The Guardian Online, 23 June 2011. Web. 01 July 2015. < http://www.theguardian.com/sustainable-business/textile-recycling-challenges-industry>.

Kviseth, Kjersti. Wool in Life Cycle Assessments and Design Tools. Rep. Statens Institutt For Forbruksforskning, May 2011. Web. Mar. 3. <http://www.sifo.no/files/file77634_wool_in_life_cycle_assessments_and_design_tools.pdf>.

Lee, Lara. "The Power Of Community In Marketing." Forbes. Forbes Magazine, 6 Apr. 2009. Web. 04 May 2015. <http://www.forbes.com/2009/04/06/lara-lee-community-branding-leadership-cmo-network-marketing.html>.

Made-By. "Environmental Benchmark for Fibres." MADE-BY. Made-By, 2014. Web. 28 Apr. 2015. <http://www.made-by.org/consultancy/tools/environmental>.

Masters of Linen. "Le Lin Et Le Chanvre Européen." Masters of Linen. European Linen and Hemp, 2010. Web. 08 Mar. 2015. <http://www.mastersoflinen.com/eng/lin/1-la-filiere-de-proximite>.

McDonough, William, and Michael Braungart. Cradle to Cradle: Remaking the Way We Make Things. New York: North Point, 2002. Print.

Minerals.net. "The Mineral Beryl." *Beryl: The Mineral Beryl Info & Pictures*. Minerals.net, n.d. Web. 08 June 2015. <http://www.minerals.net/mineral/beryl.aspx>.

Minter, Adam. "Plastic, Poverty and Pollution in China's Recycling Dead Zone." The Guardian Online. The Guardian, 16 July 2014. Web. 4 May 2015. <http://www.theguardian.com/lifeandstyle/2014/jul/16/plastic-poverty-pollution-china-recycling-dead-zone>.

Nalbach, Jay. Interview.12 February 2015. Beaverton, OR.

Nisen, Max. "How Nike Solved Its Sweatshop Problem." *Business Insider*. Business Insider, Inc, 09 May 2013. Web. 20 June 2015. <http://www.businessinsider.com/how-nike-solved-its-sweatshop-problem-2013-5>.

NRDC. "Clean By Design." Polyester Is a Synthetic, Non-Renewable Fiber, With Some Surprising Redeemable Qualities (2011): n. pag. Aug. 2011. Web. 22 Apr. 2015. <http://www.nrdc.org/international/cleanbydesign/files/CBD_FiberFacts_Polyester.pdf>.

Outdoor Industry Association. "Sustainability Working Group Members." *Outdoor Industry Association*. OIA, 2015. Web. 20 June 2015. <http://dev.outdoorindustry.org/responsibility/swg/members.php>.

Patagonia. Patagonia's Common Threads Garment Recycling Program: A Detailed Analysis (n.d.): n. pag. Patagonia Customer Service. Patagonia. Web. 12 Mar. 2015. <https://www.patagonia.com/pdf/en_US/common_threads_whitepaper.pdf>.

Pepper, Dan. "How Products Are Made." How Wool Is Made. MadeHow, n.d. Web. 31 Mar. 2015. <http://www.madehow.com/Volume-1/Wool.html>.

Pidd, Helen. "Beryl Burton: The Greatest British Female Cyclist of All Time." *The Guardian Online*. The Guardian, 13 June 2014. Web. 7 June 2015. <http%3A%2F%2Fwww.theguardian.com%2Fstage%2F2014%2Fjun%2F13%2Ftour-de-france-beryl-burton>.

Romanowski, Perry. "How Products Are Made." How Spandex Is Made. MadeHow, n.d. Web. 23 Apr. 2015. <http://www.madehow.com/Volume-4/Spandex.html>.

Savory, Allen. "An Overview of Holistic Management and Holistic Decision Making." (2011): n. pag. Savory Institute Online. Savory Institute, 2011. Web. 4 May 2015. <http://savory.global/assets/docs/evidence-papers/brief-overview.pdf>.

Savory Institute. "An Exploration of Methane and Properly Managed Livestock through Holistic Management." (n.d.): n. pag. Savory Institute Online. Savory Institute, 2013. Web. 4 May 2015. <http://savory.global/assets/docs/evidence-papers/exploration-of-methane.pdf>.

Siegel, RP. "Levi Strauss Brings Water Recycling to the Apparel Industry." Triple Pundit People Planet Profit. Triple Pundit, 19 Mar. 2014. Web. 05 May 2015. <http://www.triplepundit.com/special/sustainable-fashion-2014/levis-brings-water-recycling-industry>.

Shen, Li, and Martin K. Patel. “LIFE CYCLE ASSESSMENT OF MAN-MADE CELLULOSE FIBRES.” Lenzinger Berichte 88 (2010): 1-59. Copernicus Institute, Utrecht University, 2010. Web. 12 Mar. 2015. <http://www.lenzing.com/fileadmin/template/pdf/konzern/lenzinger_berichte/ausgabe_88_2010/LB_88_2010_paper_1.pdf>.

Spector, Dina. "10 More Reasons Companies Should Care About Sustainability." *Business Insider*. Business Insider, Inc, 01 Mar. 2012. Web. 07 June 2015. <http://www.businessinsider.com/the-top-10-benefits-of-convincing-your-company-to-care-about-sustainability-2012-3>.

Szczepanksi, Carolyn. Women on a Roll. August 6, 2013. Rep. N.p.: League of American Cyclists, n.d. Print.

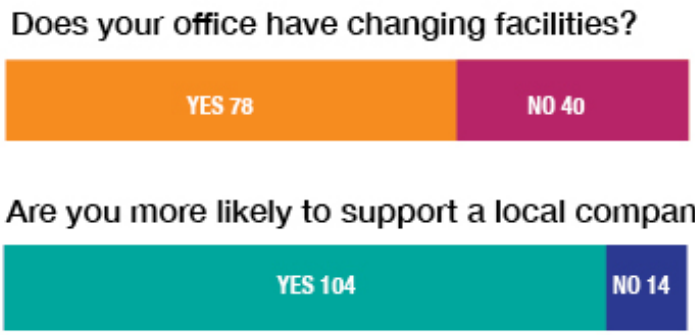
WeWear. "Frequently Asked Questions - Labeling - Labeling | American Apparel & Footwear Association." Frequently Asked Questions. WeWear.org, n.d. Web. 26 Mar. 2015. <https://www.wewear.org/industry-resources/frequently-asked-questions-labeling/#2>.

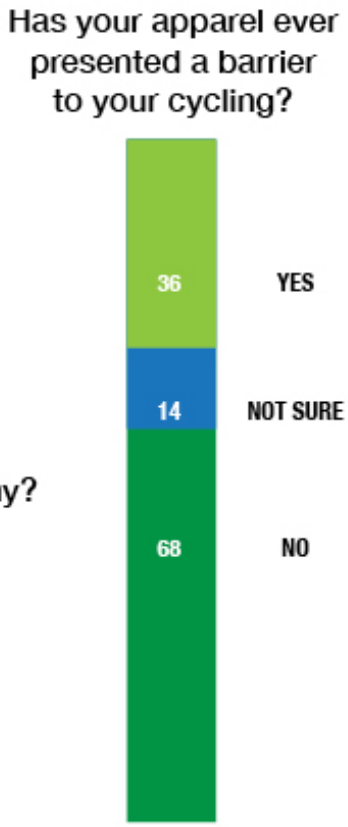
WoolSports. "Benefits of Wool." *WoolSports Clothing USA Merino Wool Clothing for Every Element of Your Life RSS*. WoolSports, 30 Aug. 2011. Web. 03 July 2015. <http://www.woolsports.com/wool-info/benefits-of-wool/>.

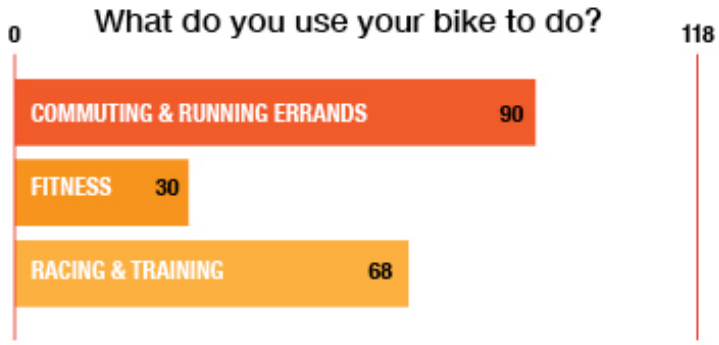
White, Philip, Louise St. Pierre, and Steve Belletire. Okala Practitioner: Integrating Ecological Design. N.p., 2013. Print.

Appendices

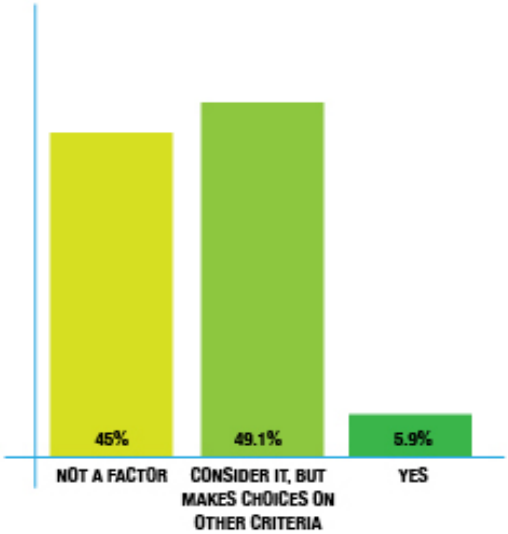
Appendix A: March 2014 Survey Results



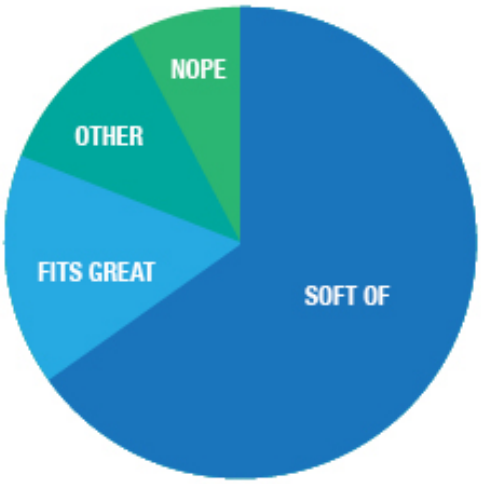




Do you consider the environmental impact of your choices when buying cycling apparel?



Are you happy with the fit of your cycling apparel?



How often is your cycling apparel appropriate for your destination?

Appendix B: March 2015 Survey Results

What one piece of cycling clothing do you wish for?	Shirt Size	Pant Size	Calf	Thigh	Hips	Waist	Height	Leg Length	Where do you live?	Age
A better shirt or top	S	4-6	14"	19.25"	35"	29"	5'9"	40"	Portland, OR	35
A better shirt or top	L	12-14	11"	14"	34	32	5'8"	32	annapolis md	58
A better shirt or top	L	12-14	14.5"	19"	41"	35"	5'7"	33"	Portland, OR	48
A better shirt or top	XL	12-14	10"	17"	40	38	5'4"		idaho falls, id	59
A better shirt or top	M	8-10	15"	21"	42	31	5'5.5"	33.5	indianapolis, indiana	54
A better shirt or top	S	4-6	13.5 “	20 “	37.5	28.5	5'5"	30	Portland, OR	41
A better shirt or top	L	8-10	15	21	41	34	5'8	32	Hillsboro OR	40
A better shirt or top	L	12-14	14.5"	23"	41.5	37	5"9"	36	Austin, TX	50
A better shirt or top	S	4-6	14.5 in	19 in	37 in	28.5 in	5'6"	37 in	Austin, TX	32
A better shirt or top	L	36-38	17.5	27.5	48	41	5'2"	28	Detroit Michigan	42
A better shirt or top	XL	16-18	19	23	40	36	5'3		Florida	30
A better shirt or top	XL	16	16.5"	22"	44"	35"	5'5	31"	Apple Valley, CA	46
A better shirt or top	L	8-10	14	21	38 1/2	30 in	5'6"	37 in	chino, ca	46
A better shirt or top	L	12-14	15"	20"	42"	32"	5'5.5"	32"	Minneapolis, MN	34
A better shirt or top	L	12-14	16.5"	20.5"	41.125	34.5	5'10	36.5	Raleigh, NC	56
A better shirt or top	S	4-6	14"	22"	39"	27"	5'5"	28"	Burlington, VT	23

A better shirt or top	S	0-2	13 1/4"	17"	32 1/2"	26"	5' 2 1/2"	32 1/2"	Manhattan, NY	50
A better shirt or top	XL	18-20	18"	28"	52"	38"	5' 6"	31"	Alpena Michigan	61
A better shirt or top	XL	18	18	26	44	36	5'2"	29	Fort Washington Maryland	53
A dress or skirt for cycilng	L	12-14	12"	17"	37"	32"	5'6"	30"	Portland,OR	39
A dress or skirt for cycilng	L	12-14	12"	17"	37"	32"	5'6"	30"	Portland,OR	39
A dress or skirt for cycilng	S	8-10	39 cm	41 cm	90 cm	70 cm	165 cm	95 cm	stockholm sweden	55
A dress or skirt for cycilng	M	12-14	14 7/8"	20 3/8"	41 5/8"	33 1/4"	5' 8"	38"	Portland	57
A dress or skirt for cycilng	L	12-14	14.5in	22in	25in	32in	5'6"	37in	Atlanta, GA	29
A dress or skirt for cycilng	S	4-6	13 1/4"	19 1/4"	36"	27 1/4"	5'4"	30 1/2"	New York, NY	48
A dress or skirt for cycilng	M	10-12	15"	20"	39"	30"	5'9"	36.5"	Kila, Montana	57
A dress or skirt for cycilng		18/20	18	26.5	52	47.5	5'7"	36	Washington, DC	44
A dress or skirt for cycilng	L	12-14	17.5	23	45	35	5'9	40	Oakland, CA	31
A dress or skirt for cycilng	S	4-6	15"	20"	42"	28				
A dress or skirt for cycilng	S	4-6	15"	20"	42"	28"	5'6"	33"	Carrboro, NC	30
A dress or skirt for cycilng	M	8-10	14.5	19 in	38	32 in	5'9''	40'	Alexandria	27
A dress or skirt for cycilng	XL	12-14	14.75	24.25	46	33	5'6	34	Carrboro, North Carolina	29
A dress or skirt for cycilng	XS	0-2	13"	16"	33"	26"	5'4.5"	36"	Portland, OR	40
A dress or skirt for cycilng	S	4-6	15.5"	21"	38"	27"	5'7"	42"	Raleigh, NC	26
A good winter commuter coat	M	8-10	14 in	19.5	38	29	5'5"	32	Carrboro, NC	59

with a lightweight insulation and a rollup hod.										
A rain jacket that isn't ugly	S	4-6	13 “	17.5 “	38 “	28 “	5'2"	30	Portland Oregon	35
an awesome lightweight jacket	XS	0-2	13 “	19 “	35 “	25 “	5'4''	31 “	Fairfax, CA	37
Better jeans	S	4-6	14"	18.5"	39"	28.5"	5'2"	30"	Pittsburgh, PA	30
Better pants	M	8-10	14.5"	18"	24"	32"	5'7"			
Better pants	S	4-6	17 1/2	23 1/2	52 “	36 “	5'7"	48 “	Portland, Oregon	29
Better pants	XL	12-14	16	21	39	39	5'4"	33	Townsend MA	50
Better pants	S	8-10	14.5 inches	21.5 inches	38.5	29	5'7"	36	Portland, Oregon	30
Better pants	M	4-6	13	23	38	29	5'3"	37	Portland	35
Better pants	M	8-10	14	18.5	40	28	5'4"	29	Salt Lake City, UT	25
Better pants	S	4-6	14"	22"	40"	30"	5"6"	34"	philadelphia , pa	34
Better pants	S	4-6	13"	18"	37"	26"	5'7"	34"	Portland, OR	31
Better pants	M	8-10	37.5cm	52.5cm	96.5cm	70.5cm	5'9"	95.5cm	Portland, OR	30
Better pants	S	4-6	38 cm	20 “	37 “	29 “	5'3"	34	PORTLAND, OR	31
Better pants	S	8-10	15"	19" & 19.5"	40"	30"	5'8"	35"	Federal Way, WA	42
Better pants	M	8-10	390 mm	530 mm	930 mm	900 mm	5' 6"	1060 mm	Portland, OR	38
Better pants	S	4-6	14.5"	25"	36"					
Better pants	S	4-6	14.5"	25"	36"	29.5"	5'8"	36"	Portland, OR	32
Better pants	M	12-14	15.75 “	22 “	42	34	5' 2"	34	Portland, Oregon	66
Better pants	XS	0-2	14"	18"	35"	26"	5'8"	32"	Wenatchee	35

									, WA	
Better pants	L	8-10	15 3/8"	21 1/4"	42"	30 1/2"	5'4	31"	Portland, OR	37
Better pants	M	8-10	16"	21"	43"	33"	5'2"	29"	Chicago, IL	25
Better pants	M	10-12	9"	16"	19"	33"	5'8"	38"	Somerville, MA	29
Better pants	M	8-10	13.5	14	37	27	5'3"	36	York PA	44
Better pants	M	8-10	14.5 “	23”	40 “	33.5 “	5'1	36 “	columbia, MD	34
Better pants	M	4-6	14 “	19.5 “	23.5 “	28 “	5'5"	30 “	Nashville, TN	31
Better pants	XS	4-6	15	19	40	26	5'7"	33	San Francisco	27
Better pants	M	16	15"	24.5"	46"	34"	5'7"	32"	Tolleson, AZ	51
Better pants	XS	0-2	13 in	19.5 in	36.5 in	27 in	5'4"	31 in	WA	36
Better pants	XL	16”	14.5	25	45.5	34	5'4"	31.5	Oakland, CA	36
Better pants	L	12-14	16"	22"	43"	34"	5'7"	34"	Seattle, WA	33
Better pants	M	6-8	14"	19"	39"	32"	5'6"	34"	Silver Spring, MD	36
Better pants	M	8-10	15.5"	22	39	29	5'10"	40"	Arlington, VA	42
Better pants	M	8-10	14”	20.5“	40”	28.5 “	5'4"	36”	Durham, NC	28
Better pants	S	0-2	14 “	21 “	37 “	28.5 “	5'0''	31 “	NC	28
Better pants	XL	16-18	18.5"	25"	45"	42"	5'8"	41"	Seattle	32
Better pants	M	8-10	14.5 “	23 “	42.5 “	31 “	5'9''	34 “	DC	29
Better pants	S	8-10	14"	18"	39"	31"	5'7"	35"	Durham, NC	30
Better shorts	M	8-10	12	32	29	28	5 5	48	Arlington, tx	47
Better shorts	M	8-10	15"	20"	38.5"	32"	5'9"	36"	Portland, OR	33
Better shorts	XL	12-	15"	16"	41"	32"	5'3.5"	33"	Nederland,	41

		14							CO	
Better shorts	M	6-8	40cm	50cm	101	27	5'9	89	portland, or	28
Better shorts	S	4-6	14.5 “	20.5 “	36.5 “	27.5 “	5'7"	34 “	Tempe, AZ	30
Better shorts	M	0-2	14 “	19 “	35 “	27 “	5'4"	33 “	Killeen Texas	52
Better shorts	M	4-6	36cm	55cm	102cm	89cm	5'3"	98cm	Fort Collins, CO	36
Better shorts	XL	22	14"	18"	43"	41"	5'2"	34"	New York, NY	51
Better shorts	S	4-6	14"	18.5"	38"	28"	5'' 5.5"	35"	Batavia, IL	45
Better shorts	XL	16-18	17	29	45	39	5'7	33	Allentown, PA	45
Better shorts	L	14-16	20	26	49.5	31	5'3''	35	Chicago, IL	31
Better shorts	M	12	13.5	25	43	36	5'1"	31	Los Angeles CA	56
Better shorts	M	8-10	14 in	19"	25 1/2"	34"	5' 4 &3/4"	32"	WS, NC	45
Better shorts	XL	12-14	37cm	52cm	38"	38"	6'4"	37"	Peoria, il	37
Better shorts	L	12-14	17	28	47	31	5'4"	31	Hayward, CA	48
Better shorts	M	8-10	14.5"	22"	44"	29"	5'5"	37"	Hutto, TX	39
Better shorts	S	4-6	14"	20"	38"	28"	5'4"	33"	Chicago, IL	27
Better shorts	S	4-6	15"	20"	38"	30"	5'2"	35"	Portland, or	36
Better shorts	S	4-6	13.5"	18"	36"	27.5"	5'4"	30"	Portland, OR	24
Better shorts	S	4-6	12.5 “	16.25 “	35 “	27 “	5'7"	33.5 “	Washington , DC	31
Better shorts	S	0-2	13	20	36.6	25.5	5' 4.5"	34	San Francisco, CA	29
Better shorts	M	8-10	14 “	19 “	39 “	32 “	5'9.5' '	34 “	Durham,nc	47
Better shorts	L	12-				34 “	5'8	32 “	Austin	25
Better shorts	L	12-				34 “	5'8	32 “	Austin	25

		14							Texas	
gloves that fit and are good for cycling	M	8-10	14.75 in	20.25 in	40 in	28.5	5'5"	33 in	Portland,OR	44
jeans	M	10	14.75"	22"	42"	35"	5'4"	30.5"	Durham	40
Merino undershorts w/thin chamois	XS	0-2	12 inches	18.75 inches	35"	27.5"	5'1"	28.5"	Portland, OR	48
New fleecy tights for winter rides	M	8-10	12.5"	17.5"	35.25"	29.5"	5'8"	41"	Bethesda, MD	30
Nothing? If I find a top or bottom I love I buy it regardless.	M	4-6	16"	21.5"	39.25"	31.25"	5'3"	34.75"	Costa Mesa, CA	34
rain gear	M	8-10	16.5 inches	20 inches	43 inches	34 inches	5'1"	36 inches	NY,NY	44
Reflective jacket for riding at night	S	4-6	13 inches	19.5 inches	36 inches	27.5 inches	5'6"	36 inches	Eugene, Oregon	31
smaller arm warmers	XS	0-2	13"	16.5"	34"	23"	5'3"	34"	Beverly, MA	28
Stylish shoes! We've come SO FAR with men's clipless tennis shoes, but women's casual bike shoes are UNFLATTERING	M	10-12	15.75"	20"	41"	31"	5'8"	37"	Chicago, IL	29
Underwear	M	8-10	14 “	20 1/2 “	40 1/2	32 “	5'6	30	NV	67
Waterproof yet breathable gloves that fit my small hands	S	8-10	15 “	21 “	38.5 “	32.5 “	5' 0"	34 “	United Kingdom!	35

Average age of respondent: 38.9 years old

Measurements as compared to self-reported sizing:

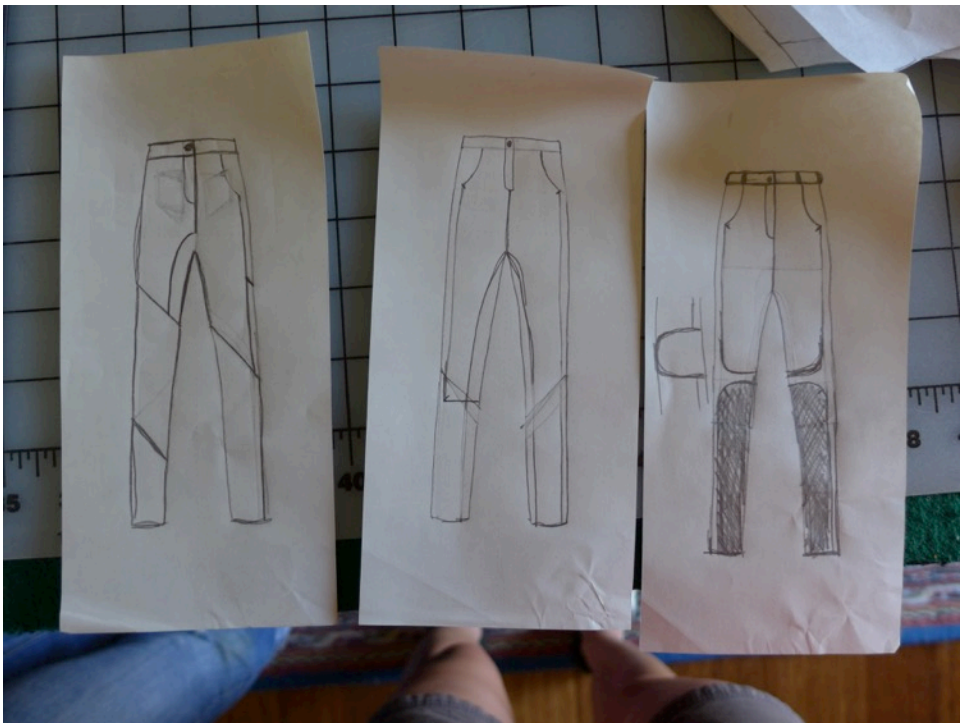
	Calf	**Thigh**	**Hip**	**Waist**	**Leg Length**
0	13	18.5	35	25.6	32.5
4	14	20	38	29	34
8	14.5	20.5	38	30.5	37
12	15	21	40	34	34
14	17	25	46	37	33

Most requested garments:

Garment	**#**
Pant	44
Shorts	29
Shirt / Top	23
Dress / Skirt	18
Jacket	5

Appendix C: Pants Design

Process

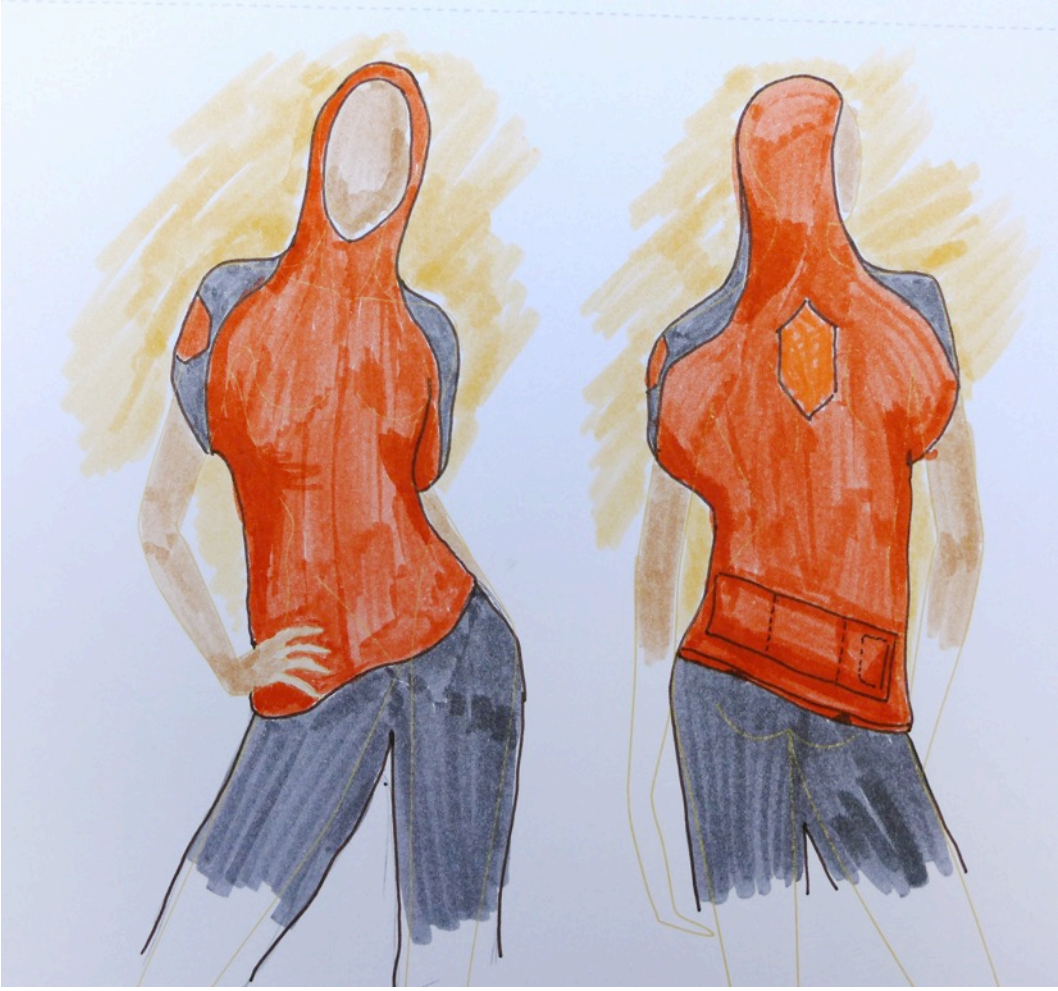


Final

Appendix D: Top Design

Process

Final



Appendix E: Brand Identity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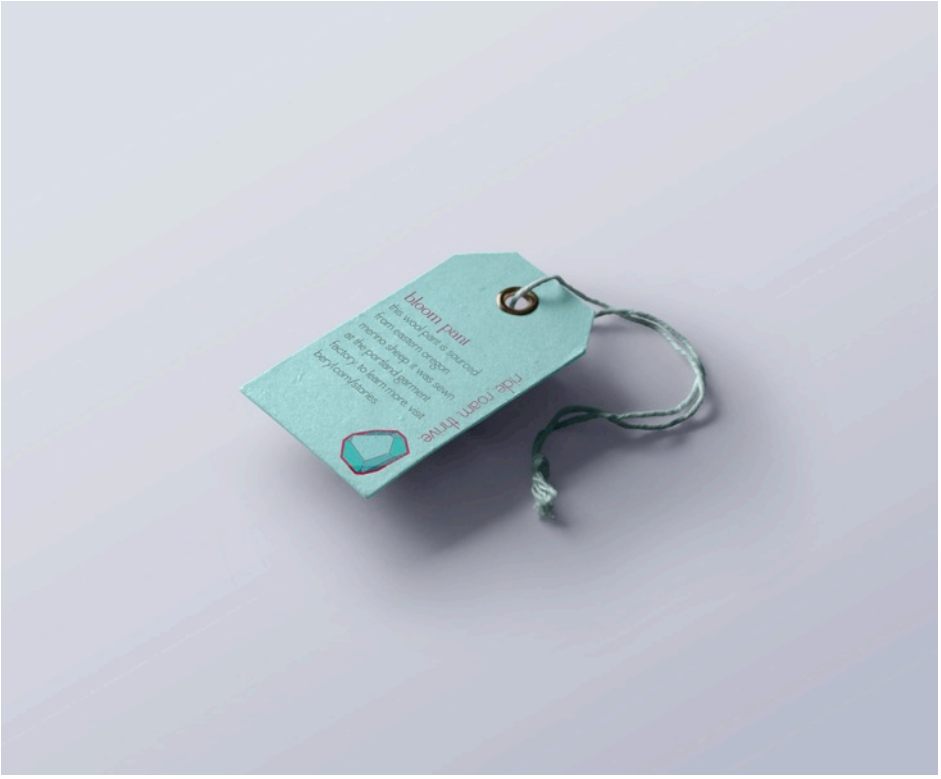
ride. roam. thrive.


bloom pair
this wool pant is sourced
from eastern oregon
merino sheep. it was sewn
at the portland garment
factory. to learn more visit
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