This thesis titled
The Triple Bottom Line of Sustainable Fashion

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has been approved for
the Program of Environmental Studies
and the Voinovich School of Leadership & Public Affairs by

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ABSTRACT

BLASER, KRISTEENA K., M.S., August 2017, Environmental Studies

The Triple Bottom Line of Sustainable Fashion

Director of Thesis: Cassandra Paine

In recent years, a movement in the fashion industry emerged called slow fashion. This is a sustainable fashion movement that attempts to take the current fast fashion system and make the necessary changes to the industry to make the fashion industry more sustainable. The slow fashion movement is centered on this ideal of the triple bottom line of sustainability, which is something lacking greatly from the currently fast fashion system. However, there seems to be very little change among the fast fashion companies, even though consumers are demanding sustainable options at a much higher level than previously seen in system. The goal of this thesis is to undertake a literature review to understand the fast fashion and slow fashion system and once that information has been gathered and presented, I will attempt to apply this triple bottom line lens of sustainability to the fashion industry to build a sustainability metric (See Appendix C) that will test the sustainability of a fashion company. The goal is that fast fashion companies will use this sustainability metric (See Appendix C) to test their sustainability and find areas where they can improve their sustainability and implement more sustainable methods into their business practices. Furthermore, there is an exploration of what it would mean for the environment, as well as the people inhabiting the planet, if the fast fashion industry continues to use nonrenewable resources and unsustainable practices.
DEDICATION

To my amazing mom, without you, helping to mold me into person that I am, none of this would have been possible. You are inspiration for all things that I do.

To my loving boyfriend, thank you for being everything to me, I could not have survived graduate school without your constant support, praise and love.
ACKNOWLEDGMENTS

Thank you to my amazing committee chair, Cassandra Paine, without her this thesis never would have happened. She kept me on track when I need direction and was always there to give me guidance when I need it. To my other committee members, who took time out of their busy schedules to be a part of this thesis, thank you. Thank you to the Voinovich School, for providing me with the opportunity to make my dream of getting a master’s in environmental studies possible.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Dedication</td>
<td>4</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>5</td>
</tr>
<tr>
<td>List of Tables</td>
<td>8</td>
</tr>
<tr>
<td>List of Figures</td>
<td>9</td>
</tr>
<tr>
<td>Chapter 1: The Triple Bottom Line</td>
<td>10</td>
</tr>
<tr>
<td>The Current Fast Fashion System</td>
<td>14</td>
</tr>
<tr>
<td>The Evolution of Slow Fashion</td>
<td>17</td>
</tr>
<tr>
<td>Research Boundaries</td>
<td>21</td>
</tr>
<tr>
<td>Chapter 2: Fibers and Their Impacts</td>
<td>23</td>
</tr>
<tr>
<td>Cotton</td>
<td>27</td>
</tr>
<tr>
<td>Genetically Modified Cotton</td>
<td>38</td>
</tr>
<tr>
<td>Organic Cotton and Fair Trade Cotton</td>
<td>42</td>
</tr>
<tr>
<td>Wool</td>
<td>44</td>
</tr>
<tr>
<td>Silk</td>
<td>50</td>
</tr>
<tr>
<td>Wild (or Peace) Silk</td>
<td>55</td>
</tr>
<tr>
<td>Spider Silk</td>
<td>56</td>
</tr>
<tr>
<td>Rayon</td>
<td>58</td>
</tr>
<tr>
<td>Polyester</td>
<td>61</td>
</tr>
<tr>
<td>PET Recycling</td>
<td>63</td>
</tr>
<tr>
<td>Bast Fibers</td>
<td>64</td>
</tr>
<tr>
<td>Linen (Flax)</td>
<td>65</td>
</tr>
<tr>
<td>Hemp</td>
<td>69</td>
</tr>
<tr>
<td>Bamboo</td>
<td>74</td>
</tr>
<tr>
<td>Ingeo</td>
<td>79</td>
</tr>
<tr>
<td>Soya</td>
<td>81</td>
</tr>
<tr>
<td>Tencel (Lyocell)</td>
<td>83</td>
</tr>
<tr>
<td>Chapter 3: The Real Cost of Fashion: People</td>
<td>87</td>
</tr>
</tbody>
</table>
History of Textile Mills, Garment Factories and Sweatshops ........................................... 88
Feminization of the Global Labor Force .................................................................................. 90
The Race to the Bottom ........................................................................................................ 93
Bangladesh ............................................................................................................................. 96
  Rana Plaza ............................................................................................................................ 105
Chapter 4: Styling a New Industry ......................................................................................... 113
References .............................................................................................................................. 118
Appendix A: Chemicals ........................................................................................................... 128
Appendix B: Pictures ............................................................................................................. 136
Appendix C: The Sustainability Metric ................................................................................... 144
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1: Textile Fibre Types</td>
<td>24</td>
</tr>
<tr>
<td>Table 2: World Fibre Production in 2010</td>
<td>26</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Cotton Plant</td>
</tr>
<tr>
<td>2</td>
<td>The Aral Sea in 1989 (Left) and 2014 (Right)</td>
</tr>
<tr>
<td>3</td>
<td>Sheep</td>
</tr>
<tr>
<td>4</td>
<td>Wool Before and After Scouring</td>
</tr>
<tr>
<td>5</td>
<td>The Silk Route</td>
</tr>
<tr>
<td>6</td>
<td>Silkmoth or Bombyx mori</td>
</tr>
<tr>
<td>7</td>
<td>Silkworm Cocoon</td>
</tr>
<tr>
<td>8</td>
<td>Raw Silk</td>
</tr>
<tr>
<td>9</td>
<td>Details of the Flax Plant, from which Linen Fibers are Derived</td>
</tr>
<tr>
<td>10</td>
<td>Differences Between Sativa and Indica Cannabis</td>
</tr>
<tr>
<td>11</td>
<td>Cannabis Satvia L. subspecies sativa</td>
</tr>
<tr>
<td>12</td>
<td>Bamboo Stalk</td>
</tr>
<tr>
<td>13</td>
<td>Bamboo Forest, Taiwan</td>
</tr>
<tr>
<td>14</td>
<td>Garment Factories in Bangladesh</td>
</tr>
<tr>
<td>15</td>
<td>Dhaka Savar Building Collapse</td>
</tr>
<tr>
<td>16</td>
<td>Rana Plaza Taken One Year Before the Collapse</td>
</tr>
</tbody>
</table>
CHAPTER 1: THE TRIPLE BOTTOM LINE

Sustainability is one of those terms that never seem to have a concrete definition; it can vary from person to person, state to state or business to business. In fact, there are roughly seventy different definitions of sustainability used around the globe and this number is only increasing as time progresses (Farrer & Fraser, 2011). However, no matter the confusion around what it truly means to be sustainable, in recent years every country, industry and entity has strived to be “sustainable” and incorporate sustainable practices into their businesses, lives or homes. Although, the question remains, what does it even mean to be sustainable?

Schumacher, a prominent statistician and economist, first introduced this concept of sustainability in 1972. The term was defined as “‘permanence’ where ‘nothing makes economic sense unless its continuance for a long time can be projected without running into absurdities’” (Gardetti & Torres, 2013, p.3). However, in 1983 the term sustainability received a new definition by the World Commission on Environment and Development (WCED), this definition was later formalized in the 1987 Brundtland Report, Our Common Future. The report specifically defined sustainability as “development which meets the needs of the present without compromising the ability of future generations to meet their own need” (Gardetti & Torres, 2013, p. 3). While the definition of sustainability that was introduced in the Brundtland Report remains one of the most commonly used definitions of sustainability, there are two others that are often used as well, which are: “an activity that can be continued indefinitely without causing harm and doing unto others as you would have them do unto you” (Joy, et. al, 2012, p.
However, while these definitions may be used, the Brundtland Report definition revolutionized the meaning of sustainability. With this report, sustainability was no longer simply viewed in a business or economic context or reduced to meaning “the environment.” Sustainability was no longer centered on a business’s ability to earn a profit but rather the “triple-bottom line”, meaning the entity needs to be environmentally, socially and economically sustainable. The Brundtland Report incorporated this idea of the triple bottom line by stressing not only the importance of environmental sustainability but also social and economic sustainability (Gardetti & Torres, 2013).

Not everyone viewed this revolution as a good thing; this distinction in definitions has led to a divide in the understanding and application of sustainability. Economists tend to stick to the pre-Brundtland definition of sustainability, which focuses on the potential profits that can be earned. While environmentalists stress the importance of all three pillars of sustainability: social, economic, and environmental (Gardetti & Torres, 2013). This divide in the understanding and definition of the word sustainability, has led to industries being able to claim they are sustainable, without having to meet the triple bottom line. The biggest problem with large businesses, companies, and industries being able to claim they are sustainable is that when they use terms such as sustainability, it usually only pertains to one portion of the supply chain and not the entire system. Thereby, making the use of the word “sustainable” often misleading because they are not truly sustainable according to the Brundtland Report definition. There are still many parts of the system and supply chain that have incredibly negative environmental, social and economic impacts that need to be remedied for the company to be sustainable.
Furthermore, by using the world sustainable they are misleading the consumer. Terms such as green, organic, environmental, sustainable, ecological, recycled or natural are used interchangeably in the world today, often misleading the consumer with their use (Shepard & Pookulangara, 2013). No industry is guiltier of this tactic than the fashion industry.

Collectively the fashion industry refers to many sub-categories that are all included when using this umbrella term, such as: the garment, footwear, accessory, cosmetics and fragrance sectors of the fashion industry (Anguelov, 2016). Furthermore, the clothing or fashion industry can pertain to many different parts in the life cycle of a fashion product. These parts include: “obtaining and processing raw materials, i.e. the preparation and production of textile fibers… the production of yarns, and production of fabrics, finishing activities which give the textiles visual…such as bleaching, printing, dyeing and coating.’ As well as, ‘transformation of textiles into garments that can be either fashion or non-fashion garments,” (Gardetti & Torres, 2013, p. 4) all of these parts are generally known as the clothing or fashion industry. However, reducing fashion to just a piece of clothing would be a mistake. Fashion is not simply just an item in one of these different sectors or parts, is it something so much larger. “Fashion can be lust, vanity, art, and an eternal search for and realization of the perfect lines and beauty…Fashion can be status, social class, and social belonging. It reflects and arises from people’s lives and living conditions and is influenced by political, economic and social currents” (Johansson, 2010, p. 20). Fashion is a way to express oneself and to
present to the world what you want them to see. It is an expression of history, culture, ethnicity and all the things that make the world diverse and individual.

Recently, many issues have arisen in the fashion industry: such as the quality of the product being produced; the wages that the individuals producing the clothing are receiving; the conditions they are working in; the toxic chemicals they are being subjected to as well as being put into the air and water surrounding the production site; and the extensive use of fossil fuels to produce both the materials and sustain the supply chain of these items. The fashion industry is one of the largest on the planet, which means that these issues have a long and lasting effect on the economy, the environment, and the people, found all over the world. The fashion industry is a multi-billion-dollar industry worldwide, which employs roughly 40 million people around the globe (Gordon & Hill, 2015). Although, the 40 million could be a gross underestimate because it is extremely difficult to estimate the exact number of individuals working in the entire clothing sector (Gardetti & Torres, 2013).

The fashion industry is fast paced and ever changing. To create demand in today’s society, the fashion industry went from having eight seasons to now having mini-collections, which essentially translates into a new season every week (Gardetti & Torres, 2013). A season in the fashion world includes an influx of an entire new fashion collection. This massive change from a few seasons to almost weekly changes in entire fashion collections is linked to consumption and speed of the fast fashion industry. One of the main goals of the fashion industry today is speed, how fast they can produce products and how fast they can get those products to the consumer. This speed and
consumption has caused the production, manufacturing and distribution of fashion products to become more and more environmental and socially degrading and destructive.

Historically on the spectrum of sustainability, the fashion industry has fallen on the weak side of sustainability. Ashby et al (2013, p.65) further elaborate on this idea by saying “the clothing industry has traditionally operated at the weak end of the sustainability spectrum with an emphasis on the economic dimension and transactional relationships, and an inherent acceptance of the negative social and environmental impacts that occur along the supply chain.” In recent years, a trend called slow fashion has been introduced into the fashion industry to attempt to fix this typically weak sustainability. Slow fashion is a sustainable movement that is attempting to alter the current fast fashion system into something that is truly long lasting and sustainable (Fletcher, 2014). The slow fashion designers do not wish to eliminate the fast fashion industry but rather be incorporated into the massive global industry. Furthermore, slow fashion designers do not simply wish to only change the environmentally degrading practices of the fast fashion system but rather this movement focuses on all three pillars of sustainability: environmental, social and economic.

The Current Fast Fashion System

In the 1980s, prior to the fast fashion model, companies needed to have designs that were standardized and hardly ever changed, due to design restrictions placed by the factories where the clothing was produced (Bhardwaj & Fairhust, 2010). When there was a sudden increase in cheap imports from undeveloped nations of women’s apparel that
differed from the mass-produced items typically found on the market, this sparked a change in the entire industry. This shift led to the current system of fast fashion, which is often characterized by four different stages: “introduction and adoption by fashion leaders, growth and increased in public acceptance, mass conformity (maturation), and finally the decline and obsolescence of fashion” (Bhardwaj & Fairhurst, 2010, p.167). However, upon the introduction of the fast fashion model, for a company to be successful they needed to have lots of products that could be mass-produced at a very low cost and quickly. Fast fashion has often been linked with the fast food industry; many have stated that the fast fashion industry was even modeled from the fast food industry (Fletcher, 2010). This conclusion was made due to the massive amount of similarities in the structures of each system. Fast-fashion, much like fast food is mass produced at an incredibly large scale and standardized throughout the industry (Fletcher, 2010).

Each of the items produced by the fast fashion industry is so cheap that consumers are convinced that the price is unbeatable anywhere else and therefore buy these items immediately even if the consumer does not necessarily need or want the item of clothing. Each of the clothing items is designed to be cheap, easy and quick to produce. This method of “quick and easy” is included in every step of the supply chain: from the materials used to create each item, to the labor used to construct each item, the shortened lead times, as well as the massive amounts of items that are produced in the end (Fletcher, 2010). Fast fashion is defined by massive quantities of clothes being produced at such a rapid speed that has never been seen in history. These items are meant to mimic items found on the fashion runway, which were once seen as exclusively available to the
rich and famous because these items were considered luxury or “high-end” items
(Fletcher, 2010). However, fast fashion took these luxury items and made them available
to the average consumer. Fast fashion defines the fashion industry today; almost every
piece of clothing that is produced by large clothing manufacturers is subject to this
system of fast fashion production and manufacturing.

Fast fashion allowed the lead-time from runways to consumers to be shortened as
well. This shortened lead-time was used to provide products to consumers immediately as
trends emerged (Joy, et al., 2012). The problem with this model is that the clothing
produced became “throw-away clothing” or perishable because new styles or trends were
brought into stores so rapidly that clothing went out of style almost immediately,
therefore new clothing needed to be purchased. Furthermore, the incredibly low prices of
these fast fashion items, typically allow for people to over consume them at a high rate to
keep up with the ever-changing trends (Joy, et al., 2012). Fast fashion, rather
intentionally, encouraged fashion consumers to buy clothing more often with this model.
However, with today’s economy, consumers are expected to buy more clothing, due to
the rapid rate of trends and production, with less money than in the past.

From a somewhat positivist perspective of fast fashion, per the documentary
“True Cost,” the price of clothing has decreased over the past decade, which is a drastic
change from most things on the market that have increased in price since the Recession.
This decrease in price has created a market for the millions of people, who are part of the
lower income portion of the world, to be able to purchase clothing at a very affordable
price. This made it possible for low-income families and young adults to be able to afford
the “latest runway” trends that were previously far out of their price range. Furthermore, the fashion industry is driver of the economy and essential to the survival of many people and countries. However, the incredibly low prices of these fast fashion items, that drive the economy, do not show the true cost of the environmental and social degradation that happened to produce it. This is where slow fashion comes into the equation; it is through this system that designers and consumers hope to increase the visibility of the fashion supply chain.

The Evolution of Slow Fashion

The inspiration for the slow fashion movement arose in Italy following the slow food movement that began in the 1980s. The slow food movement included a move away from the homogenized mass-produced food that the people of Italy were accustomed too and a move towards more sustainable and local food choices (Shepard & Pookulangara, 2013). In addition, to more sustainable food options, the people in Italy wanted a greater community connection as well. They believed that this community connection could be achieved through creating great food and cooking in social settings that the entire community would take notice of and be a part of (Shepard & Pookulangara, 2013). This move towards more sustainable food options was made possible due to the increased access to information and the increased knowledge regarding where their food was originating. The slow food movement provided inspiration for individuals, designers, and consumers alike to demand that the fashion industry, which is often linked with the fast food industry, to change its un-sustainable ways (Shepard & Pookulangara, 2013).
Since the slow fashion movement first emerged, there has been a race to set a concrete definition for what slow fashion encompasses. Some people stuck to the roots of the word and aligned it holistically with the slow food movement and everything it encompassed. This would include a move away from the everyday mass produced items of clothing that everyone has, to more unique and sustainable options. Some individuals simply clung onto the word “slow,” meaning that the movement was outside of contemporary fashion trends (Shepard & Pookulangara, 2013). This step outside of contemporary fashion trends was achieved by “incorporating more classic silhouettes and neutral colors into garments made by skilled laborers that are paid a living wage” (Shepard & Pookulangara, 2013, p.12). Other interpretations of slow fashion were more true to the actual meaning behind the movement. These included fashion products that were both socially and environmentally sustainable, and this was achieved through “organic materials, recycling, purchasing used garments, and repairing old garments” (Shepard & Pookulangara, 2013, p.12). Slow fashion was meant as a way to get away from the fast fashion concept of “disposability” or “single-use items.” These slow fashion products were meant to last and were constructed with materials that would withstand the average consumers use cycle.

However, the reception of the “fashion-ability” of slow fashion was not positive at first. Terms such as “eco-friendly” or “green” evoked images of the 1960s and 70s and the clothing that many hippies wore during that time (Shepard & Pookulangara, 2013). On the other hand, some consumers believed that slow fashion was made with such care and detail that they were intended to be classic pieces, rather than the trendy ones, which
young consumers were looking for. Many consumers began to associate slow fashion with older generations, whereas fast fashion was associated with the much trendier, younger generations (Shepard & Pookulangara, 2013). This made the generations who were guiltiest of buying fast fashion products, younger generations, even less likely to buy slow fashion products because they were not seen as trendy or fashionable if associated with older generations. These associations made the marketability of slow fashion, as well as the adaptation into mainstream fashion questionable for many consumers.

The slow fashion movement was meant to be a way to get away from the disposal fast fashion system that much of the world had succumb too. Many of the designers in the slow fashion movement wanted to produce high quality fashion pieces that would last for the typical consumer use cycle. Furthermore, they wanted to design pieces that were unique from the over-produced fast fashion items to get back to the roots of what fashion meant: individuality and expression. Much of today’s fast fashion promotes a uniform dress around the globe (Cataldi et. al, 2010). Consumers all over the world are purchasing clothing that gives the planet a homogeneous look, which will inherently not satisfy the individual’s need for creativity and uniqueness (Cataldi et. al, 2010). Slow fashion attempts to remedy this issue by creating unique and individual pieces that also meet the requirements of the triple bottom line of sustainability.

In the slow fashion movement, workers are paid a living wage and are even provided with safe and healthy working conditions, which is considered a luxury for most garment workers in the fast fashion industry (Cataldi et. al, 2010). Slow fashion does not
simply wish to improve the environmentally degrading qualities of the fast fashion system but rather hopes to improve the overall quality of life of the people making the garments as well. Contrary to its name however, slow fashion is not opposed to speed, but would rather have clothing produced at a speed that does not harm the world around it, including its environment and people. Slow fashion further promotes the “local,” meaning small-scale, local production and manufacturing, as well, as an integration of individual craft techniques done by hand in many small villages (Fletcher, 2014). Lastly, the slow fashion movement demands a heightened sense of self-awareness in the consumer (Fletcher, 2014). The consumer is equally responsible for the effects that the garments have on the people and environment, as is the company producing the clothing. The slow fashion movement works to make that connect between production/manufacturing and the consumer much more visible.

The main problem with these two industries is that people believe them to be complete opposite, with no commonalities. However, when slow fashion was founded this was the opposite of its designer’s intentions. Fast fashion has been repeatedly described as the anti-slow fashion or the antithesis of sustainability (Shephard & Pookulangara, 2013). Fast fashion and slow fashion were not meant to be opposites but rather to be integrated with one another to create a superior fashion supply chain that was better for the environment, economy and had a sense of social responsibility (Shephard & Pookulangara, 2013). Perhaps, this is why the slow fashion movement has been lackluster in its success so far, due to the perceptions surrounding the movement itself. However,
some fast fashion designers have even begun incorporating slow fashion designs into their companies, making the future looker brighter for the slow fashion movement.

There are several slow fashion or sustainable fashion brands and designers, which are doing everything they can to bring affordable sustainable alternatives to consumers. Some of these affordable sustainable brands include: Threads for Thought, Everlane, My Sister, Pact Apparel, Urban Renewal by Urban Outfitters, Green Room by ASOS, Conscious by H&M, Fair Collection, Shift to Nature, People Tree and several hundred other brands.

Research Boundaries

The general statement of research is as follows: Apply the triple bottom line of sustainability to the life cycle of a garment, specifically the materials and production portions, and use the information gathered during the literature review to create a sustainability metric (See Appendix C) to test the sustainability of fashion companies according to the triple bottom line. The goal of this thesis is to understand the current fast fashion system and compare this model to slow fashion to find the areas where fast fashion is lacking in terms of sustainability. Furthermore, the slow fashion model will be used to find areas where fast fashion companies can be tested on their sustainability in the sustainability metric (See Appendix C) later developed in this thesis.

The definition of fast fashion in simple terms for the purposes of this thesis is: “trend-driven clothing that is made as cheaply and quickly as possible, and that is intended for wear for a small number of times before disposal” (Gordon and Hill, 2015). The definition of slow fashion for the purposes of this thesis is: “a method of clothing
production that centers on transparent production models, the use of local resources and economies, and the creation of high quality goods with greater value and longer lives” (Gordon and Hill, 2015).

Research Objectives:

1. Introduce the fast fashion and slow fashion industries, materials used in these industries, as well as their production and labor practices.

2. Apply the triple bottom line of sustainability to the first two stages of the life cycle of a garment: fibers/materials and production portions.

3. Identify places where there is a lack of sustainability in the current fast fashion model and provide alternatives to correct the sustainability issues.

4. Create a sustainability metric to test the sustainability of a company and materials.

The following two chapters, chapter two and chapter three, include an in-depth analyze of the first two portions of the fashion supply chain or the lifecycle of a textile: the fibers/materials and the production portions. The lifecycle of a textile specifically refers to the journey that a fashion product takes from the first portion of the supply chain, the extraction of the raw fibers, to the final portion of the supply chain, which includes the point where it is disposed. These two portions are the two sections of the fashion supply chain that remain under researched or under examined, which is why I choose to focus on these two portions. Furthermore, they are also the two sections of the supply chain that tend to have the most negative impact regarding the triple bottom line of sustainability.
CHAPTER 2: FIBERS AND THEIR IMPACTS

The first section of the fashion supply chain includes the materials/fibers that are used to produce fashion products. In this chapter, the sustainability impacts of fibers will be analyzed to show the impacts of the current fibers used for production, as well as sustainability alternatives that are beginning to be used. The most basic components of an article of clothing are fibers. A fiber is defined as the “smallest visible components of most fabrics” (Humphries, 2009). There are three main categories of fibers: natural fibers, synthetic fibers, and human-made fibers.
To put it simply, “natural fibers are based in agriculture and synthetic fibers are based in manufacturing” (Black, 2011, p. 107). Natural fibers are fibers that can be found in nature, such as cotton, wool, silk or flax. Natural fibers are further broken down into two main sources, cellulosic fibers coming from plants, and protein-based fibers which come from animals. Synthetic fibers are derived from petroleum and petro-chemicals, and include fibers such as polyester and acrylics. The final category of human-made

<table>
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<tr>
<th>Natural Fibers</th>
<th>Manufactured Fibers</th>
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<td>Plant</td>
<td>Animal</td>
</tr>
<tr>
<td>Cotton</td>
<td>Wool</td>
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<td>Flax</td>
<td>Silk</td>
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<td>Hemp</td>
<td>Cashmere</td>
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<td>Jute</td>
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<td>Sisal</td>
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<td>Banana</td>
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<td>Pineapple</td>
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fibers is formed from natural sources of cellulose, such as beech wood, eucalyptus and bamboo (Mass, 2009). Cellulose is a substance that is derived from the cell walls of plants and is a vital part of human-made fibers. Synthetic fibers were developed at the end of the nineteenth century and it was through the development of these fibers that an entirely new world of possibilities regarding textiles, fibers, and products were created. People even went as far as to say, that these fibers were “miracle fiber” because of how revolutionary they were (Black, 2011). However, it should be noted that these synthetic fibers can only be produced in factories because their processes are either oil-based or cellulose-based, which requires some form of mechanization.

In today’s fashion and textile industry, it is hard to find diversity among the fibers used. For example, in 2010 cotton and polyester accounted for almost 85 percent of the world’s fiber production (Fletcher, 2014). Even more alarming is that this percentage continues to grow every year.
Table 2. World Fibre Production in 2010 (Million tons). Courtesy of Kate Fletcher (2014).

<table>
<thead>
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<th>Natural fibres</th>
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<td>1.12</td>
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<td>Silk</td>
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<td><strong>Total</strong></td>
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<thead>
<tr>
<th>Manufactured Fibres</th>
<th>World Fiber Production</th>
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<td>Cellulosics</td>
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<td><strong>Total Synthetics</strong></td>
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<td><strong>Total</strong></td>
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As these two fibers often have the highest demand for water and pesticide use among all the fibers on the market, there are significant impacts associated with the use of just these two fibers. To increase the sustainability of the fashion world there needs to be an increase in the diversity of textiles used in the industry. By replacing some of the cotton that is used with sustainable alternative such as organic or Fairtrade cotton, flax,
hemp or lyocell, it would drastically improve the sustainability of the fashion industry. The rapid rise of synthetic fibers since the mid-twentieth century has increased dependency on an already non-renewable resource, oil. There is now a significant demand for oil-derived polymer fibers for things such as clothing, interior textiles and technical textile products, as synthetic fibers account for around 60 percent of all textiles produced (Black, 2011). By replacing the use of polyester with alternatives such as wool, Ingeo (fibers made from corn starch) and other biodegradable and renewable alternatives, it would decrease the impact of the fashion industry on the global petroleum industry as well. To many fashion consumers, buying sustainably means buying products that are naturally occurring, such as cotton or wool and avoiding manufactured and synthetic fibers as they are often petroleum or oil based. However, upon further analysis of the fibers used to produce textiles it is not that simple, the fashion supply chain is a complex and interwoven system.

Cotton

Cotton is perhaps the oldest and most widely used fiber in the world. Gordon & Hill (2015, p. 62) state “it has been cultivated continuously for at least 5,000 years…” It is single-handedly the most important apparel fiber in the world, due to its adaptability as a fiber. It is believed that the cultivation of cotton began almost simultaneously in India and South America, some 6,000 years ago (Hallett & Johnston, 2010). It was then exported to Mesopotamia, now Iraq, during the third millennium BC, where the fiber was then spread to Egyptians of the Nile valley area (Hallett & Johnston, 2010). However, during the period of the British Raj and colonial rule in the eighteenth and nineteenth
centuries, the once thriving cotton industry in India was repeatedly sabotaged (Hallett & Johnston, 2010). This was done by the British East India Company to make the cotton industry obsolete in India. The company wanted to make the cotton that Indian producers used less valuable and in turn force them to buy cotton from Britain, at much more expensive price than the cotton grown in India (Hallett & Johnston, 2010). Cotton did not obtain global success until the Industrial Revolution when it became the leading export from Britain. Following the invention of the spinning jenny and the spinning frame, cotton products could now be mass-produced and sold globally.

It is estimated that the production and export of cotton products can be found in more than 100 countries, and is believed to employ 350 million people between its production, farming, transportation and manufacturing industries (Hallett & Johnston, 2010). The largest producer of cotton is China, producing four and a half million tons annually. China consumes an estimated 40 percent of the world’s raw cotton (Black, 2011). However, even though China is the world’s largest producer of cotton it must supplement its domestic production with imported raw materials because it cannot grow enough cotton domestically to meet the global demand of Chinese-made cotton products (Hallett & Johnston, 2010). The southern United States, also commonly referred to, as the “cotton belt” is the second largest producer of cotton. “California has the largest global yield per acre, while Texas leads in production” (Hallett & Johnston, 2010, p. 146). Other primary cotton producers include: India, Pakistan, southern Brazil, Burkina, Uzbekistan, Australia, Greece, and Syria. The United States and Israel are considered the two highest-cost cotton producers in the world, while Australia, China, Brazil and Pakistan are
considered the world’s lowest-cost cotton producers globally (Hallett & Johnston, 2010). Major manufacturing hubs for cotton includes: Bangladesh, Indonesia, Thailand, Taiwan and Russia (Hallett & Johnston, 2010). The US and the UK consume 45 percent of the world’s cotton products, even though these two countries combined only make up 13 percent of the world’s population (Black, 2011).

Cotton is a natural cellulosic fiber that is considered renewable and “intrinsically biodegradable” (Chen & Burns, 2006). The plant itself is a small shrub with greyish green tri-lobed leaves, a flower that ranges in color from white to yellow, with purple to red spots near the base (Hallett & Johnston, 2010). However, the cotton fiber itself is the white hair like material that covers the seeds in the ‘fruit’ capsules of the plant (Hallett & Johnston, 2010) (See Appendix B, Figure 1). Once the flower blooms on the cotton plant, it lasts for approximately three days before it drops off the plant, leaving behind the pods or cotton balls ready for gathering. Cotton grows in tropical climates and is considered a perennial crop. There are 43 different species of the cotton plant and four species have been primarily domesticated (Hallett & Johnston, 2010). These four species include: Gossypium hirsutum founded in Central American by the Maya civilization, Gossypium barbadensa founded in South America by the Inca civilization, Gossypium herbaceum founded in South Asia by the Harappan civilization, and Gossypium aboreum founded on the North Africa Indo Pakistan subcontinent by the Egyptian civilization (Hallett & Johnston, 2010). However, most cotton that is grown today is one of two varieties of the South American species: Gossypium hirsutum and Gossypium barbadense (Hallett & Johnston, 2010).
Before cotton can be harvested, massive amounts of chemicals are sprayed or applied to the plant, including pesticides and defoliants, which are used to make the leaves fall off the cotton plants to ensure that the cotton fibers are not stained. Per Hallett & Johnston (2010) the processing of cotton from raw material to finished yarn and fabric is as follows:

1. Cultivating/Harvesting
   a. A cotton picker is the person responsible for removing the cotton from the boll, or protective case, without damaging the plant.
   b. Following the hand picking, a cotton stripper machine will remove the entire boll that contains any remaining fibers from the plan, to ensure as much of the cotton is harvested as possible.

2. Modular bales
   a. A machine called a module builder is used to compress the cotton into large blocks that are covered and stored in the fields.
   b. This is temporary because trucks specifically designed to transport cotton, collect the cotton and move it to the next stage of the process, the gin.

3. Ginning seed cotton
   a. Ginning is a generic term that is used to describe the entire process of turning the cotton bolls into fibers, and the building where these various processes occur is called a gin.
   b. The large blocks that were created during the last phase are delivered and broken apart, so that they can be fed into the ginning machine.
i. This machine completely and efficiently separates the cotton fibers from the seedpods. It removes leaves, burns, dirt, stems and the fuzzy down, which is known as linters.

c. The left-over seeds are refined and made into cottonseed oil.

d. The linters are used in the manufacturing of paper, as well as in the plastic industry.

e. The ginning machine is also important because it cleans the cotton, which is now referred to as lint instead of seed cotton.

4. Spinning mills

a. Spinning is a generic term that refers to the processes that the fibers undergo in order to become yarn that will be used for weaving or knitting.

b. Upon arriving at the spinning mills, are also referred to as “spinners”, the bales are opened and cleaned again to remove any vegetable matter that remains as residue and short lint.

c. Following this step a machine, called a picker, beats, loosens, and mixes the fibers.

d. They are then passed through toothed rollers that vary in size to remove further residue vegetable matter.

e. At the end of this process, the fibers become batts, which are large bundles of multiple strands of fibers. These fibers are now ready to be carded.

f. The carding machine lines up each of the fibers so that they are easier to spin.
After this is done, silvers are produced; these are simply untwisted ropes of fibers.

These silvers are combined to equalize thicker and thinner parts to create a more consistent size.

As these are now too thick, they must be separated into rovings, which are long, narrow bundles of fibers that a twist is added to hold them together.

5. Optional combing process
   a. This simply makes the fibers smoother.

6. Fabric mills
   a. Weaving/knitting

After the cotton plants have been harvested, the land is typically tilled to begin preparation for the next round of cotton to be planted. There are typically two methods of tilling land involved in cotton production: the conventional method and the conservation method. The conventional method of tilling calls for any of the remaining reaming stalks to be cut down and the soil to be turned. The conservation method requires that the stalks be left in the fields, as well as any plant residue that may remain on the surface of the soil. Then the new seeds are planted through what is called the “litter” that remains on the tops of the soil (Hallett & Johnston, 2010).

Before the fibers can be turned into textiles, the waxy outer layer on the cotton must be dissolved in an aqueous sodium hydroxide (see Appendix A), this is done through a process called scouring (Chen & Burns, 2006). Scouring is done so that the dyes that
will be applied to the cotton will penetrate the fibers better. Next, most cotton that is harvested must be bleached (see Appendix A) before the fibers are dyed or printed so that a better color can be achieved. Following this step, chemicals like formaldehyde (see Appendix A) or similar products are applied in the durable-press finish to improve the overall “wrinkle-free” quality of the fibers (Chen & Burns, 2006). Aside from the chemicals that are used during each of the phases of cotton production, there are several other environmental and social impacts of cotton production.

Cotton is considered one of the most “thirsty” fibers in the world and has been responsible for depleting water sources all around the globe. The exact quantity of water needed to irrigate cotton crops can vary according to the agricultural practices used, as well as the climate where the crop is grown, however it can be up to 3800 liters of water per kg of cotton (Fletcher, 2014). One of the most visible examples of the consequence of cotton cultivation has been the drying up of the Aral Sea, after water was diverted from its two tributary rivers to irrigate cotton crops (Fletcher, 2014).

The United Nations Environmental Programme (UNEP) has deemed the draining of the Aral Sea as “one of the most staggering disasters of the twentieth century” because “political and economic control for immediate gain have devastated natural ecosystems and ruined livelihoods” (Black, 2011, p. 107) (See Appendix B, Figure 2). The Aral Sea is in the great deserts of Central Asia, its drainage basin covers 1.8 million square kilometers within seven nations: Uzbekistan, Turkmenistan, Kazakhstan, Afghanistan, Tajikistan, and Iran (Micklin, 2007). However, only Kazakhstan and Uzbekistan are riparian on the sea proper, each country possessing an equal length of the shoreline
(Micklin, 2007). The major level changes that happened prior to 1960, were the result of diverting the Amu Dar’ya westward, so that it flowed in the Sarykamysh hollow, and occasionally even further through the Uzboy Channel to the Caspian Sea, rather than into the Aral Sea (Micklin, 2007).

Over the last 10 millennia, the Aral Sea has been drained and filled repeatedly, however the most recent desiccation began in the early 1960s (Micklin, 2007). The lake level has fallen 23 meters, the area has shrunk 74 percent, the volume has decreased 90 percent, and the salinity has grown from 10 to more than 100 g/L (Micklin, 2007). The lake is considered brackish with a salinity averaging near 10 g/L, which is one-third of the salinity found in the ocean (Micklin, 2007). In the 1960s, at more than 67,000 km², the Aral Sea was considered the world’s fourth largest inland body of water per area (Micklin, 2007). The ever-increasing use of the tributary rives, the Amu Dar’ya and Syr Dar’ya rivers for irrigation has decreased discharge from the tributary rivers dramatically. The deltas of the Amu Dar’ya and Syr Dar’ya once sustained a vast diversity of flora and fauna. “They also supported irrigated agriculture, animal husbandry, hunting and trapping, fishing, and harvesting of reeds, which served as fodder for livestock as well as building materials” (Micklin, 2007, p. 50). This has had lasting ecological effects on the area surrounding the lake including: “the decimation of native fish species, initiation of dust/salt storms, degradation of deltaic biotic communities, and climate change around the former shoreline” (Micklin, 2007, p. 47).

Prior to 1960, more than 70 species of mammals and 319 species of birds called the river delta home, however today, there are only 32 species of mammals and 160
species of birds found in the region (Micklin, 2007). In 1987-1989 the Aral Sea separated into two bodies of water, a “Small” Aral Sea in the north and a “Large” Aral Sea in the south. The Syr Dar’ya flows into the Small Aral Sea and the Amu Dar’ya flows into the Large Aral Sea (Micklin, 2007). However, this is not the only effect that the diminishing of the Aral Sea due to irrigation has had; the community that surrounds the lake has been negatively affected as well.

The vital Aral fishing industries that were in Kazakhstan and Uzbekistan in the first half of the twentieth century all but disappeared by the early 1980s (Micklin, 2007). Indigenous species of fish, which were the foundation of the commercial fishing industry, disappeared due to the rising salinity of the sea and loss of shallow spawning and feeding areas for the fish, also contributed (Micklin, 2007). The Aral Salmon has gone extinct due to the draining of the Aral Sea. Due to the loss of the fishing industry, thousands of people found themselves without jobs and unable to support their families. The Republic of Karakalpakstan in Uzbekistan and portions of Kzyl-Orda Oblast in Kazakhstan has been hit the hardest. Turkmenistan has also been substantially impacted (Micklin, 2007). Furthermore, navigation on the Aral Sea has also ceased since the 1980s, “as efforts to keep the increasingly long channels open to the major ports of Aral’sk at the northern end of the sea in Kazakhstan and Muynak at the southern end in Karakalpakstan became too difficult and costly” (Micklin, 2007, p. 54).

Irrigated agriculture in the deltas of the Amu Dar’ya and Syr Dar’ya has suffered drastically due to an inadequate amount of water, because the inflow to the deltas has decreased as upstream countries heavily consume the water for irrigation (Micklin,
The people who live in the ecological disaster zone around the sea have been found to suffer from acute health problems, some are linked to the sea’s recession (“e.g., respiratory and digestive afflictions and possibly cancer form inhalation and ingestion of blowing salt and dusty and poorer diets from the loss of Aral fish as a major food source”) and other health problems have been linked to the heavy use of pesticides in agriculture production (Micklin, 2007).

There are an estimated 27 million cotton farmers worldwide and approximately three quarters of the production of cotton comes from developing nations in the global south (Black, 2011). Many of these developing countries use cotton as a cash crop, meaning that their survival is directly linked to the selling of their cotton crops. Since the production of cotton is subsidized in the United States, China, and the European Union, there has been overproduction in these countries, which has caused a fall in prices in the world markets. However, the only countries negatively or adversely affected by this are countries in the global south. This means the countries that are most dependent on the sale of cotton are the ones that are no longer able to compete on a global market. These individuals are no longer able to provide for their families and must find other means to make ends meet.

Even though the popularity of cotton has increased the total area of land dedicated to growing this crop has not significantly changed in the last 80 years, however the output has more than tripled (Fletcher, 2014). It only occupies four to five percent of agriculture land, however it consumes 25 percent of all insecticides used in the agriculture industry (Black, 2011). This increase in the productivity of cotton can be linked with the
application of massive amounts of fertilizers and pesticides to help the crop grow at a much more rapid rate than the crop can naturally grow. Pesticide use is so high on the cotton crop that it has been estimated to make up 11 percent of the global pesticide use (Fletcher, 2014). It wasn’t until the 1950s and the invention of the insecticide DDT, Dichlorodiphenyltrichloroethane (see Appendix A), those pesticides began to be used on the cotton crop. Pesticides generally refer to fungicides, herbicides and insecticides, these products are applied to a crop to deter pest infestations and weed growth. With the high usage of pesticides and fertilizers brings many environmental issues, such as: loss of biodiversity, loss of soil fertility, water pollution, resistance and adaption to certain pests, and several human health issues related to the chemicals in these toxic pesticides (Fletcher, 2014).

Organizations such as the Environmental Justice Foundation (EJF) and Pesticide Action Network (PAN) have been raising awareness of the problems that are associated with the high use of pesticides on the cotton crop and other crops that many smallholding farmers typically grow (Black, 2011). The phenomena of using high amounts of pesticides to insure quick crop growth is particularly prominent in many regions of Africa and India, as these regions rely on cotton as a cash crop (Black, 2011). One of the biggest issues related to high pesticide use that often gets overlooked is the fact that many of the pesticides being used in nations such as India and Africa, have been banned in the US and EU because they have incredibly negative health effects. However, many of these chemicals are being produced by the UK, the EU or US companies and then exported to areas of the world where they are not used safely. These areas typically are
underdeveloped or developing nations (Black, 2011). Therefore, many western countries are benefiting from selling chemical products that are not considered safe to countries and individuals that are unable to afford any of the more expensive “safe chemicals.” These individuals are unable to take measure to prevent negatives effects to their health and often did not have access to health care. Western countries are essentially directly contributing to the health decline of these developing countries due to the agro-chemicals these countries are using, which originated in western countries.

Genetically Modified Cotton

As many environmental organizations, governments and individuals have demanded to cut down on the use of pesticides on the cotton crop genetically modified (GM) cotton has emerged in recent years. It was quickly adapted and became one of the most popular fibers in the world. GM cotton uses biotechnology to make the crop pest resistant and make the management of weeds much easier on the farmer (Grose, 2013). Most recent figures have suggested that GM cotton now makes up 60 percent of the cotton grown on the planet (Fletcher, 2014). There is two main types of GM cotton on the market today: Bt, abbreviation of bacterial toxin, *Bacillus thuringiensis*, and Ht, abbreviation of herbicide tolerant (Grose, 2013).

John F. Queeny founded the Monsanto Chemical Works in 1901. However, it was not until the 1990s when Monsanto acquired Calgene Inc., DEKALB Genetics and other biotechnology firms that it became a leader in the development and produced of genetically modified crop seeds (Encyclopedia Britannica, 2017). Monsanto now bioengineers two main strains of cotton Bt and Ht cotton. Bt cotton is bioengineered so
that the bacterial toxin, *Bacillus thuringiensis*, is embedded into the genetic code of the plant so that when pests consume the crop, the toxin poisons them and kills them, drastically decreasing the demand for pesticide spraying (Grose, 2013). Bt cotton has rapidly taken over the cotton industry since its introduction into the commercial market in 1997. It is estimated that Bt cotton accounts for 50% of cotton grown around the world (Grose, 2013). Bt cotton is unlike broad-spectrum insecticides, since it only affects a narrow range of insects, specifically the bollworm family (Grose, 2013). Since only a narrow range of this type of cotton affects insects, there have rarely been any negative effects on beneficial insects. However, many experts in the cotton industry have agreed that it is only a matter of time before pests that attack cotton become resistant to even the Bt toxin (Grose, 2013). In response to this notion, the United States Department of Agriculture (USDA) recommends ‘refuge areas.’ These are areas that must be “planted alongside conventional cotton and sprayed using an insecticide other than Bt to provide a habitat where pests not exposed to Bt are then available to mate with those that have been exposed, thereby reducing the probability of genetic resistance” (Grose, 2013, p. 52). However, this practice is challenging in developing countries, because farmers are dependent on their crops for their survival, therefore they cannot risk the plants not mating.

Ht cotton is designed to be able to survive the application of a large variety of herbicides that would have otherwise killed the crop. Farmers are then able to spray the herbicide to control the growth of weeds without fear that the crop will be killed (Grose, 2013). This has also initially helped reduce the amount of labor that is spent on the care
of the cotton crop. However, after further study it has been shown that the widespread use of a single herbicide, namely Monsanto’s Roundup, which represents 96% of the Ht market, genetic resistance has rapidly developed (Grose, 2013). The active ingredient in this herbicide, glyphosate, is becoming obsolete in its efforts to combat weeds. It is believed that there are now 12 different herbicide-resistant weeds, which have spread across several states in the United States (Grose, 2013). Farmers’ immediate response to this problem is to spray more herbicides, which is the exact opposite of what should be done. For example, in California, “where Ht cotton represents 61% of the cotton crop, glyphosate volume increased 200% between 1996 and 2005” (Grose, 2013, p. 53). In response to this endemic, experts recommend that farmers implement a range of methods and techniques for weeding to prevent the further spreading of these herbicide-resistant weeds (Grose, 2013). The International Cotton Advisory Committee recommends that each farmer develop an Integrated Pest Management (IPM) and Integrated Weed Management (IWM) plans that are specific to their climate, soil, and needs, so that many of the potential problems are avoided.

While these GM crops offer a variety of benefits for conventional cotton growth, they also come with many issues that poses a greater risk to the environment and human health including: genetic resistance in pests and weeds which leads to an increase in the spraying of pesticides and herbicides, as well as an increase in human labor (Grose, 2013). According to a joint report prepared for the FAO, UNEP, and WHO, “between 1 and 3% of agricultural workers worldwide suffer from acute pesticide poisoning with at least 1 million requiring hospitalization each year…These figures equate to between 25
million and 77 million agricultural workers worldwide” (EJF, 2007, p. 2). Furthermore, this increase in the spraying of pesticides and herbicides can have negative effects on human health because the chemicals are often very toxic to human beings. The acute symptoms associated with pesticide poisoning include: headaches, vomiting, tremors, and lack of coordination, difficulty breathing or respiratory depression, loss of consciousness, seizures, and death. The chronic effects associated with long-term exposure to these pesticides include: impaired memory and concentration, disorientation, severe depression and confusion (EJF, 2007). A single drop from the pesticide aldicarb, which can be absorbed through the skin, can kill an adult. This pesticide, aldicarb is commonly used in cotton production: it is used in the US and 25 other countries worldwide (EJF, 2007).

In recent years, there has been a link found between suicides of farmers in India and GM cotton. Researchers are labeling this portion of India the “suicide belt.” It is estimated that since 1995, 300,000 farmers have killed themselves in India, many of them cotton growers (Agence-France Presse, 2016). They often kill themselves in their own cotton fields, sending a very effective message to Monsanto, as well as the Indian government. Many individuals in India blame climate change, globalization, and Monsanto for pushing many of the cotton farmers to the point where they see suicide as their only option (Aaronson, 2009). Historically, the cottonseed had been one of the cheapest crops to purchase, which lead to its popularity among Indian farmers. During the harvesting stage of the cotton crop, many of the farmers would save their seeds that they cultivate for the next years growing season. However, Monsanto has abolished this practice. In 2002, when Bt cotton first emerged onto the market a box, which was
recommended for one acre of land, cost 1,400 rupees, which is equal to $35 USD, this is a substantial amount for an India farmer who usually only makes a few hundred dollars a year (Aaronson, 2009). Aside from the expensive price, farmers are unable to replant the seeds that are harvested from the crop. By replanting the seeds, the farmer would violate the farmer’s legal agreement with Monsanto. Furthermore, it is impracticable because as the crops are genetically modified there is no guarantee that the crops will come back the following year. No longer is the cotton seed the cheapest thing for farmers, it now accounts for 50 percent of a farmer’s expenses (Aaronson, 2009).

Organic Cotton and Fair Trade Cotton

The main difference that separates organic cotton from conventional cotton is that organic cotton does not use chemical pesticides, herbicides, fertilizers, or insecticides to control pests or weeds. However, the term organic can be somewhat misleading when it is used to describe textile and apparel. The word organic is defined by the standards set by the USDA Organic Foods Production Act, which was passed by Congress in 1990. This act lays out strict rules for the production and certification of organic food specifically (USDA, 2005). Organic agriculture methods rely heavily on crop rotations, to ensure the fertility of the soil. These organic farmers also use natural enemies, such as ladybirds, to suppress any insects that may be harmful to their crops (Hallett & Johnston, 2010). The cotton is grown with natural fertilizers, namely manures, and replaces the use of most pesticides, as there are organic approved pesticides, with beneficial insects that prey on insects that many harm the plant (Chen & Burns, 2006). Organic cotton also uses much less water than conventional cotton because the richer soil that organic cotton is
grown on retains more moisture. However, there are some drawbacks to switching from conventional cotton to organic cotton, as it requires a minimum of three years for the soil that conventional cotton was grown on to be replenished (Black, 2011). It is mandatory for the soil to have this three-year conversion period to obtain the organic certification.

In the last 15 years, a movement for increased availability of organic cotton has emerged, in part to a sort of “awakening” by consumers, despite this organic cotton remains a very niche market. Currently, organic cotton still only accounts for less than one percent of global cotton production (Black, 2011). Per Organic Exchange, a US based organization; the production of organic cotton is greatest in Turkey and India. As of 2005, each country was producing around 10,000 metric tonnes (Black, 2011). It is estimated that organic cotton is grown in 20 countries around the world, with India being the primary producer of this fiber (Hallett & Johnston, 2010). However, organic cotton is grown in smaller quantities in countries such as: The United States, Peru, Uganda, Egypt, Senegal, Tanzania, China and Israel (Hallett & Johnston, 2010). As there is not enough organic cotton on the market for companies to switch entirely, many companies in the US, such as Nike and Timberland, are using blends of five to fifteen percent of organic cotton with conventional cotton (Black, 2011). There is hope that the amount of organic cotton on the global market will increase in coming years because the demand for organic cotton has far surpassed the supply for many years. It is estimated that production is increasing rather rapidly at 50 percent each year (Black, 2011). Organic cotton has begun to be adopted by many of the major fashion brands, increasing the demand around the world, including: Marks & Spencer, Walmart, H&M, and Levi Strauss (Magni, 2012).
The Fairtrade label guarantees a better deal for farmers from the third world countries growing the cotton. However, cotton that contains the Fairtrade label is not to be confused with ethically traded clothing. The Fairtrade label specifically “aims to improve the position of marginalized producers in the developing world by empowering them to invest in sustainable development projects that have a wider community benefit” (Hallett & Johnston, 2010). No matter what the global market conditions are regarding cotton, Fairtrade cotton growers are offered a “fair, fixed price,” as well as longer trading conditions. Furthermore, Fairtrade also includes a 30 per cent premium that is set aside for social and environmental projects in the local community (Black, 2011). The Fairtrade standards specifically prohibit the use of genetically modified seeds, making it much easier for Fairtrade farmers to obtain cottonseeds. The Fairtrade label is specifically designed for third-world farmers, to guarantee that they are not exploited by the current capitalist system that surrounds cotton growth. However, it is important to note that not all Fairtrade cotton is grown organically. Only around 20 percent of Fairtrade cotton producers are also growing their cotton organically (Hallett & Johnston, 2010).

Wool

Wool is considered the most import animal fiber used in textiles (Chen & Burns, 2006). Wool has an incredibly long history, its cultivation can be traced all the way back to 6,000 years ago (Gordon & Hill, 2015). While wool itself only comes from sheep, the term wool is also a technical term used in the textile industry to classify and label all animal hairs such as: mohair, cashmere, alpaca, llama, camel, and angora (Black, 2011) (See Appendix B, Figure 3). Wool has many benefits, such as: acting as a natural
insulator, to keep the body warm or cool as necessary, it repels dirt, stains, and water and has been proven to be extremely versatile and durable fiber (Gordon & Hill, 2015).

Prior to the development of synthetic fibers, wool was considered cotton’s greatest rival because both fibers were suited to a variety of apparel types. Cotton was considered the most common plant-derived fiber, while wool was the predominant animal-derived fiber (Gordon & Hill, 2015). However, beginning in the early twentieth century, wool began to face other competitors aside from cotton. It was during this time that man-made, synthetic fibers became very popular. Wool has recently reemerged as a popular fiber choice, due to the sustainable fashion movement. Due to this movement, wool has been reevaluated for its potential viability as a sustainable fiber (Gordon & Hill, 2015). Wool is naturally occurring and renewable. Sheep are also an animal that can thrive on land that is unsuitable for cultivation. This leaves arable land available for food production rather than fiber production (Gordon & Hill, 2015). However, there are dangers of desertification of land due to intensive sheep rearing (Magni, 2012). Soil erosion occurs from overgrazing, if the sheep are not looked after properly and excess sheep manure creates runoff contamination (Chen & Burns, 2006).

Wool is typically considered a secondary product of sheep farming; the primary product is meat (Fletcher, 2014). Due to this aspect, sheep are rarely bred for the fineness and quality of their wool. As a result, the fiber tends to be fairly coarse, has low market value and is generally considered a wasted resource, because if the sheep were bred for their fiber quality it would be of much higher quality (Fletcher, 2014). There are many different breeds of sheep, in the UK alone there are 60 different breeds, which produce
wool used for textile production (Black, 2011). The finest quality wool used for apparel production comes from the Merino sheep. A single fleece from a Merino sheep can produce around five kilograms of fine, good-quality wool (Fletcher, 2014). The Merino sheep was originally bred in Spain and is only breed of sheep that produces “long fine luxuriant wool of the highest quality” (Black, 2011, p. 134). These sheep, while they originated in Spain, are typically bred in Australia, New Zealand and South America (Black, 2011). Over half of the wool production comes from two countries, New Zealand and Australia. However, China is another large producer of wool (Magni, 2012). Furthermore, many of the markets where wool is sold are very far from places of production. This means that when determining the environmental impacts of wool one must factor in the carbon dioxide emissions due to the transport from the field where the sheep are raised to the manufacturing/production location.

To go from sheep in a field to wool in a consumer’s closet, there are a few processes that need to happen. Per Hallett & Johnston (2010, p. 68-71), these processes are as follow:

1. First the sheep must be sheared.
   a. The fleece of the sheep is carefully shorn and removed in one piece.
   b. Shearing is the single most expensive part of the wool-production cycle, constituting around 20 percent of the total cost.

2. Removal of foreign matter
a. It is during this stage that scouring, which is a vital cleaning process, happens. Scouring is essential as it removes both the grease and debris from the wool before it is spun.

3. Classification for quality purposes and possible end user. Compressed into bales for transport to spinners.
   a. Prior to the spinning process, the wool is separated and placed into different classification categories, which are called wool classes.
      i. The diameter of the fiber is measured in microns, which is the primary component when classify wool.

4. Spinning mills
   a. The spinning process of wool encompasses three different processes: carding, combing and drawing.
      i. Carding, “a process of brushing raw or washed fibres to ensure that they are thinned out and evenly distributed to facilitate spinning. Carding can also be used to create mixes of different fibers or of different colours” (Hallett & Johnston, 2010, p. 195).
      ii. Combing, a “process of making fibres smooth prior to spinning” (Hallett & Johnson, 2010, p. 196).
      iii. Drawing and finisher drawing, “two processes that further improve the evenness and regularity of yarn, prior to final spinning. Each technique gives a uniquely different character, in both appearance
and feel, to the fabric and end product” (Hallett & Johnston, p. 197).

b. Prior to the fiber being spun, if further evenness and regularity of the yarn is desired, the woolens and worsteds can be put through two processes known as drawing and finisher drawing.

c. The final stage of the spinning process is applying a twist to the yarn. This gives the yarn a greater tensile strength and an added flexibility, which greater prepares the yarn for the knitting or weaving stages.

5. Woollen spun yarn

a. Yarn that undergoes the carding and drawing processes is referred to as woolen spun yarn.

b. Due to these two processes, the fibers tend to lay in all directions, which gives the textile product a fuzzy, textured appearance.

c. Woollen spun fibers are typically coarser; the fibers that are used are thicker and less even in length.

6. Worsted spun yarn

a. Yarn that is carded, drawn and then also combed is called worsted spun yarn.

b. This differs from woolen spun yarn, as the fibers lie almost completely parallel to each other. This creates a flatter, smoother finish and a much more visible fabric structure. These fibers often create what wearers call a “clean-cut” appearance.
7. Weaving and Knitting

a. Following being spun the fibers are now ready to be either knitted or woven into a fabric.

Sheep are treated with an injectable insecticide, a pour-on preparation, or dipped in a pesticide bath to control any parasite infection. If this type of infection is left untreated can have lasting impacts on the entire flock of sheep (Fletcher, 2014). Organophosphates, which is a chemical compound, very widely used in the United Kingdom until recently, was used to treat sheep scab, have been linked to severe nerve damage in humans (Fletcher, 2014). Due to impacts organophosphates have on human beings, they have been replaced with dips based in cypermethrin, which is a pyrethoid. While this has been proven to less harmful to human health, it has been linked to water pollution, as these chemicals are 1,000 times more toxic to aquatic life than organophosphates (Fletcher, 2014). Washing of wool is particularly tricky, as it cannot be laundered, therefore it must be dry-cleaned. Chemicals are added at various stages of processing, from washing, including detergents, surface active agents, conditioners, bleaches, etc., to spinning, weaving, dyeing treatments and finishing (Magni, 2012). Furthermore, the processing of wool requires the use of soap and alkaline solutions to clean the fibers and to further remove grease and impurities (Chen & Burns, 2006). More chemicals are then added to wool fabrics to prevent shrinkage, to further ensure machine washability, and to provide resistance to moths and stains (Chen & Burns, 2006).

Raw wool, like many other natural fibers, has many impurities. However, wool is both dirty and greasy, which results in it being the only fiber that requires wet cleaning
before the yarn is moved to manufacturing (Fletcher, 2014). During the washing of wool, the wastewaters from the dirty wool often contain traces of polluting substances that were applied to the sheep (Magni, 2012). Wooltech has recently produced a new cleaning system that uses a solvent trichloroethylene (see Appendix A) instead of water (Fletcher, 2014). Wool is also scoured with water; the water is at an incredibly hot temperature to emulsify the grease. This scouring also produces effluent, called wool grease sludge; it has high suspended-solids content and a high pollutant index (Fletcher, 2014) (See Appendix B, Figure 4). During this phase of the manufacturing process, there is a large loss of material, on average it is estimated that around 45 percent per weight (Fletcher, 2014). Wool scouring also accounts for a large portion of the energy input wool requires in the production phase, however wool’s overall energy usage tends to be relatively low. It has been found that wool production uses almost three times less energy than polyester and four to five times less energy than nylon or acrylic (Fletcher, 2014). The grease that is removed from the wool is often reclaimed from the scouring process for the use of lanolin, which is often used for cosmetic and soaps (Gordon & Hill, 2015). However, it has been found that pesticides that are applied to sheep have been found to be present even in grease that has been refined (Fletcher, 2014).

Silk

Beginning in Ancient China, the art of cultivating the silk moth and producing threads of never seen quality was perfected. However, the rulers of China realized how valuable these threads were and guarded the secret of these threads for many centuries to follow. It was not until the Silk Road around second century BC, that trade of silk fabrics
and products began to be exported to various regions of Asia. The Silk Road extended over 8,000 km, including land and sea; it connected China with Asia Minor and the Mediterranean (Hallett & Johnston, 2010). Further connected, the Silk Road Coasts of the Mediterranean to Beijing. To travel the length of the route it would take about one year. A second route was formed in the southern part of Asia to further extend the spread of silk, to Yemen, Burma and India (Hallett & Johnston, 2010) (See Appendix B, Figure 5). The trade that took place on these routes played a very significant role in the development of many great civilizations, including the civilizations in China, Egypt, Mesopotamia, Persia, the Indian Subcontinent and Rome, which helped to lead to the establishment of the modern world (Hallett & Johnston, 2010).

China, Japan, India, Thailand, Italy, Spain and France, all countries with a historical link to the silk trade, continue to be very important producers of silk today (Hallett & Johnston, 2010). Today, the largest producer of silk today is China, which accounts for 50 percent of global production (Hallett & Johnston, 2010). However, other countries are involved in the production of silk, including: Bangladesh, Bolivia, Bulgaria, Colombia, Indonesia, Iran, Israel, Kenya, Nepal, Nigeria, Pakistan, Peru, the Philippines, Sri Lanka, Turkey, Uganda, Zambia, and Zimbabwe. Together, Brazil, North Korea, Uzbekistan and Vietnam produce about four percent of the world’s raw silk (Hallett & Johnston, 2010). While silk accounts for less than 10 percent of the world’s fiber production by volume, it remains a very important textile. At the end of the twentieth century, in the United States alone, almost $2 billion-worth of silk textiles and garments was imported (Hallett & Johnston, 2010).
Silk is considered a natural protein fiber. It is an incredibly strong fiber, stronger than wool or cotton and weight for weight it is stronger than steel (Hallett & Johnston, 2010). The Bombyx mori moth pupa naturally produces it. It is believed that the wild ancestor of this moth is the *Bombyx mandarina* moore, which is a silk moth that is particularly found in China, hence the Chinese being the original silk traders (Hallett & Johnston, 2010). The *Bombyx mori* is the species of moth that produces the most smooth, fine, and round filament, more so than any other species of moth *(See Appendix B, Figure 6)*. However, this species of moth is so inbred due to the industrialization of silk production, that they cannot survive in the wild because they are blind and flightless (Hallett & Johnston, 2010). Due to these factors, they must be raised in careful, temperature-controlled conditions, that require well-ventilated, closed rooms, because the *Bombyx mori* is unable to survive in open air (Hallett & Johnston, 2010). The species has been modified so much as to produce the most silk, that the *Bombyx mori* moth is no longer able to survive in the wild. The process of producing silk is as follows:

1. Sericulture
   a. Moths lay eggs on specially treated paper placed on bamboo trays *(See Appendix B, Figure 7)*.
      i. The leaves of the mulberry tree are still often picked by hand because the quality of the silk is very dependent on the diet of the silkworm (Fletcher, 2014).
ii. After a period of about 35 days and four molting’s, the silkworms are over 10,000 times heavier than when they first hatched, and are a little over 7.5 cm in length (Hallett & Johnston, 2010).

c. Silkworms are removed from those specially treated bamboo trays and covered in straw.
   
   i. Silk worms spin protective cocoons by secreting liquid silk that solidifies upon air contact.
   
   ii. Sericin, a water-soluble protective gum, coats the liquid silk.

d. In as quickly as two or three days the silkworm will be completely encased in a protective cocoon, which contains approximately 1,600 meters of filament (Hallett & Johnston, 2010).

2. Chrysalis killed before breaking through cocoon

   a. To preserve the length of the fiber, the silkworms are often stifled by heat and killed while they are still in their chrysalis.

   b. If they naturally break out of their cocoon, there is the potential for the tread to be broken, ruining the quality of the fibers.

3. Cocoons sorted by size & quality

   a. Approximately 5.5 kg of cocoons yield 0.5 kg raw silk (Hallett & Johnston, 2010) (See Appendix B, Figure 8).

4. Marceration

   a. Cocoons cooked to soften protective sericin gum

5. Reeling
a. Several processes to extract silk filament
b. Then wound onto bobbins producing a long smooth thread

6. Thrown threads
   a. The application of twist to give alternative end uses.
   b. It is during this stage that a large variety of silk threads are produced (Hallett & Johnston, 2010).

7. Prepared for the finishing phase
   a. This process includes boiling the silk in soap, detergent and enzymes (Hallett & Johnston, 2010).
   b. Bleaching may also be required during this phase to achieve a “pure white color”

8. Dyeing
   a. There are two main ways of dyeing silk: yarn-dyed or dyed-woven and piece dyeing.
      i. Yarn-dyed or dyed-woven includes dyeing the yarns before they are woven into fabrics.
         1. This is typically done on taffeta, duchesse satin and many other pattern-woven fabrics (Hallett & Johnston, 2010).
         2. During this phase, many different colors can be woven together into one final product.
      ii. The second type, piece dyeing, is done after the produce has been woven.
1. During this method, “the fabric is fed into the dye bath through two cylinders, or fixed to a round jig, which is then immersed in the bath. The fabric is then fixed, rinsed and dried” (Hallett & Johnston, 2010).

Although silk has been around for centuries, very little is known about its environmental, social or economic impacts on the globe. Large amounts of detergents and chemicals must be used during the degumming of the silk phase. The wastewater created during this phase is usually discharged into water sources, including: lakes, rivers, streams, etc., acting as a low-level pollutant (Fletcher, 2014). The very controlled conditions that the silkworms are raised in require cooling and heating to yield maximum yields. This makes it an incredibly energy and resource intensive (Fletcher, 2014).

Wild (or Peace) Silk

Wild silk differs from conventional silk because the silkworm chrysalises are collected after the moth has emerged naturally. Hence where wild silk gets its second name, peace silk, because the silk is obtained without killing the silkworms or moths. It also has a lesser environmental impact than conventional silk, making it the much more sustainable option. It is estimated that there are over 200 different species of wild silk moths found all over the world (Hallett & Johnston, 2010). There have been a variety of wild silks produced in places such as, China, India and Europe, dating back to even the earliest of civilizations (Hallett & Johnston, 2010). However, the production of wild silk has always been a fraction of cultivated silk, due to the quality of the fibers typically produced by wild silk. There is simply more money in producing conventional silk
because the long-staple fibers of conventional silk produce a much larger profit than the short-stapled fibers of wild silk. Wild silk moths produce silk filaments that are generally irregular or flattened in form, making them much harder to use than conventional silk. These flattened threads tend to tangle much easier, thereby breaking if they are not unwound. These fibers typically have a brown color and have a much coarser texture (Black, 2011). However, the color and quality of the fibers varies greatly depending on the species, climate and food sources of the moth.

Wild silk is cultivated in open forests, rather than the climate controlled environments that conventional silk is grown in. These open forests contain an abundance of food and do not require the use of toxic chemicals to ensure the forests growth (Fletcher, 2014). While conventional silkworms feed on mulberry leaves, wild silkworms typically feed on both oak and mulberry leaves. While wild silk typically cannot obtain the lustrous quality long filament silk of conventional silk fibers, there is one type of wild silk, Tussah silk, that is looking promising (Black, 2011). When the Tussah silkworm emerges, it does not break through the cocoon like many other species of silkworm, but rather it creates a small neat hole when it is forming its cocoon. This is meant to be an escape route for the silkworm, this allows for longer filaments to be obtained (Black, 2011).

Spider Silk

Spider silk is another alternative to conventionally cultivated silk. Spider silk is one of the toughest fibers in the world. Gram for gram it is estimated to be five times stronger than steel (Quinn, 2010). Spider silk is also produced without creating any toxic
waste or pollution and is entirely biodegradable. A spider’s web is known for its great
elasticity, stretching up to 40 percent of its length before it breaks and for being able to
absorb massive amounts of energy (Quinn, 2010). Spiders are some of the most diverse
and abundant organisms on the planet, making their potential for producing
commercialized silk for textile production massive. The silk produced by spiders is
synthesized in glands that are in the abdomen of the spider. The silk is then spun through
a series of spinnerets (Winkler & Kaplan, 2000). However, each species of spider has
unique glands that produce its own types of silk for tasks necessary in that species life
(Quinn, 2010).

Due to the varying amounts of silk produced, spider silk has been classified intoive main types: minor ampullate silk, dragline silk, capture-spiral silk, aciniform silk and
tubiliform silk. The first type of silk, minor ampullate silk is considered a medium-
strength fiber. Its main use is temporary, as it acts as scaffolding when the web is initially
being built (Quinn, 2010). The second type of silk, dragline silk, is used when the outer
rim and spokes of the web is being produced. Dragline silk is perhaps the most important
of all the five types of spider silk, as it is the lifeline that keeps the spider connected to
the center of its web or the hub (Quinn, 2010). The third type, capture-spiral silk is spun
within the radius of the web and used mainly to catch prey. It is the incredibly sticky,
stretchy and tough part of the spider’s web (Quinn, 2010). The fourth type, aciniform
silk, is used once the spider’s prey is captured. Once the prey is stuck to the web by the
capture-spiral silk, the spider uses the aciniform silk to secure the prey to the web and
wrap it up for later consumption. The fifth and final type, is tubiliform silk, which is used to make protective egg sacks for the spider’s unborn children (Quinn, 2010).

There have been problems encountered with producing spider silk on a large scale or industrially. The main problem comes from raising dense populations of spiders in captivity because spiders are naturally solitary creatures and predatory by nature. Spiders are known to be territorial, aggressive and cannibalistic, making them incredibly difficult to domesticate (Quinn, 2010). Furthermore, when compared to a silk worm, spiders produce much smaller amounts of silk. Another large problem with spider silk is that silk produced by the major ampullate glands (MAS) is known for supercontraction. This means that when the fiber is unrestrained and submerged in water, it shrinks. Sometimes exceeding 50% of the fibers initial length (Guinea, et. al., 2005). A majority of research on spider silk has been done on dragline silk of the *Nephila clavipes* spider, because it has shown the most promise of being produced on a large enough scale to be used in commercial textile production. However, there still has been little success on producing this silk on such a level that it could combat conventionally produced silk.

**Rayon**

Rayon was invented in 1885 and it was the first manmade cellulosic fiber (Black, 2011). Viscose rayon was patented in 1892 by a British chemist named Charles Cross and his associates (Gordon & Hill, 2015). It was not until 1904 that the first manufacturing plant that solely produced rayon was built (Gordon & Hill, 2015). However, when it was first produced and sold in the US, in 1911, it was under the name of “artificial silk.” It wasn’t until 1924 that the name “rayon” was adopted (Chen & Burns, 2006). Rayon was
originally given the name of “artificial silk” because it can essentially mimic all the qualities of the notoriously difficult to produce silk. Silk’s luster, handle and drape could all be copied by rayon (Gordon & Hill, 2015). Furthermore, rayon was found to be stronger then silk and cheaper to produce as well. Rayon saw immediate success. From 1911 to 1938, the US produced nearly two billion pounds of rayon (Gordon & Hill, 2015).

Fibers such as rayon that are regenerated cellulosic fibers are considered ‘first generation’ manufactured fibers, compared to wholly synthetic fibers such as nylon, which is considered a ‘second generation’ manufactured fiber (Black, 2011). It is important to note that rayon is classified as a manmade fiber, rather than a synthetic fiber because rayon must be chemically produced from cellulose (Gordon & Hill, 2015). Rayon has been produced one of three ways historically: the viscose, acetate and the cuprammonium process. The fiber can be processed from most forms of natural cellulose, the most common being from either waste cotton linters or wood pulp that is derived from fast growing trees (Black, 2011). The most commonly produced rayon today, is classified as viscose rayon. Cuprammonium rayon is no longer produced in the United States because the manufacturers who used this method had extreme difficult treating the water used during the production to meet the United States government’s effluent water quality standards (Chen & Burns, 2006).

After the cellulose is gathered, it is dissolved in a chemical solvent that creates the viscous liquid that will be used to create the fiber. Next, it is “extruded like spaghetti through specifically shaped holes in a ‘spinneret’ that creates the fine endless filament
threads which then solidify and are processed to give different textural effects, then spun into yarn” (Black, 2011, p. 146). When the viscose process is used, the fiber is then classified as ‘regenerated cellulose’ (Black, 2011). Different names are ascribed to the fibers based on the type of solvents used during the manufacturing process. Viscose rayon uses caustic soda as a solvent (Black, 2011). While the rayon viscose means of production is more environmentally friendly than the other methods, it still does have lasting effects on the environment. Some of these impacts include: the wood pulp used during this process comes from mature forests and incredibly harsh chemicals in large quantities are used to clean the product (Chen & Burns, 2006).

Due to its “natural nature” rayon is intrinsically biodegradable. Furthermore, the cellulose used to produce the fiber comes from trees that are easily grown such as beech, which allows for the trees that are used to regrow with very little impact to the surrounding environment. However, producing rayon, like most synthetics is incredibly energy intensive. While the original source of material may be sustainable, it requires that the wood be ground into a pulp and then spun. Sometimes requiring that the materials go around the factory several times before the right consistency of pulp is achieved. The energy that is needed to power these types of factories is alarming. With large factories that require large amounts of fossil fuels, comes high air pollution and water pollution. Once the pulp is achieved the processing of this pulp into fiber, as well as cleaning the product after extrusion uses incredibly large amounts of chemicals that have lasting effects on the environment (Chen & Burns, 2006).
Polyester

Cotton may have reigned as the king of the fiber industry for decades however, polyester has usurped the throne. While Dupont patented polyester in 1941, it did not emerge onto the market until 1951, it was known by then its trade name Dacron (Black, 2011). However, polyester did not see the immediate success that had been predicted. The fiber was used to produce some clothing, and found its way into a few designer collections. Throughout the 1950s, the fiber remained rarely used because in the beginning stages of the fiber, there were very notable issues with the fabrics produced by polyester, which hindered its progress. A few of these issues included: “excessive static during processing, difficulty dyeing and oily soiling” (Gordon & Hill, 2015, p. 80). However, as polyester improved and the easy-care properties of polyester were discovered, such as its “light, fast drying, wrinkle resistant and highly durable” qualities, the fiber saw quick success (Black, 2011, p. 150). Furthermore, polyester has been known to retain odors, thereby requiring frequent washing. Although, there is no ironing required and polyester has a fast air dry time if the user does not want to use a drier. By 1968, the production of synthetic fibers had surpassed natural fibers, with a large amount of this success due to polyester (Gordon & Hill, 2015). Polyester is now the single largest fiber group in the world, some estimates put its production at 52 per cent of the entire global fiber market (Black, 2011).

The title of polyester is a generic one that covers several fibers that all have varying properties. However, they do share one commonality and that is polyethelene terephthalate (PET). To create most synthetic fibers, one must start with molecules that
contain carbon, which are derived from petroleum oil. Next, these molecules are linked together to form long chains of molecules or polymers with very specific chemical compositions (Black, 2011). This compound is then formed into pellets, which are melted into a liquid form. The liquid is then put through a spinneret to form the fibers. Lastly, the fibers are cooled and hardened in the air to form the final filaments (Black, 2011). While many synthetic fibers start the same way, the process of creating polyester is relatively simple compared to most synthetic fibers. This is one of the largest contributing factor to polyester’s low price and high availability. This fibers reliance on petroleum is not only environmentally degrading but it is also having lasting effects on oil-dependent communities around the world.

Aside from the environmentally degrading effects of petroleum-based products, the production of polyester is also incredibly energy intensive. The dyeing of polyester is perhaps the most energy intensive part of the fashion supply chain due to the incredibly high temperatures that must be used to get the fabrics to retain color. To successfully dye polyester, it must be done under pressure or in the presence of a carrier (Chen & Burns, 2006). Polyester also uses petrochemicals, which produces mass quantities of hazardous waste. The most common chemicals used during the production of polyester are terephthalic acid (TA) or dimethyl terephthalate, which are then reacted with ethylene glycol (Fletcher, 2014).

The most commonly used method in the manufacturing of polyester involves a process that requires the TA to be purified. This purification process is based on a bromide-controlled oxidation (Fletcher, 2014). Furthermore, the emissions from the use
of these chemicals can also cause irreversible damage to the air, soil and water (Gordon & Hill, 2015). If the water discharge is not treated properly many chemicals can find their way into waterways. The chemicals often found in the wastewater include: “heavy metal cobalt, manganese salts, sodium bromide, antimony oxide (which is licensed by law despite it being a known carcinogen) and titanium dioxide” (Fletcher, 2014, p. 17) (see Appendix A). Harmful atmospheric emissions that include particulate matter, carbon dioxide, nitrogen oxides, hydrocarbons, sulphur oxides, and carbon monoxide, find their way into the air from the manufacturing of polyester (Waite, 2009) (see Appendix A).

PET Recycling

In a more sustainable trend, due to the sheer amount of polyester that is produced, the fiber is being recycled to decrease the amount found in landfills. Polyester can be recycled numerous times into a material that is of equal quality as the original. In fact, it is one of the most commonly recycled textiles in the world (Gordon & Hill, 2015). It all began 20 years ago, when a US fiber maker named Wellman began to produce polyester from recycled plastic water bottles (Sustainable Textiles for Apparel, 2014). Polyester is now produced from recycled soda bottles that contain polyethylene terephthalate (Chen & Burns, 2006). Through this process of manufacturing 100 percent recycled polyester fibers by recycling bottles to create polyester, it is estimated that around 2.4 billion plastic bottles are not put in landfills each year in the United States (Chen & Burns, 2006). Recycled polyester can be created from either post-consumer waste or pre-consumer waste. Pre-consumer waste consists of by-product materials from the textile,
fiber, and apparel industries. Whereas, post-consumer waste consists of any textile that the owner no longer wants or has a purpose for so and decides to discard (Hawley, 2008).

There are two methods of breaking down the materials that are going to be recycled: mechanical or chemical. However, no matter what method is used to recycle the materials, the waste products begin the process by being washing, sorted, and chopped into flakes. “In the mechanical process, the flakes are melted down into the pellets or ‘chips’ which begins the process of making the polyester fibre” (Sustainable Textiles for Apparel, 2014, p. 33). The chemical process takes the flakes that were created and decomposes or “depolymerizes” them by a chemical reaction. Following the chemical reaction, repolymerization is used to create chips (Sustainable Textiles for Apparel, 2014). Of the two processes, the mechanical process does have a lesser environmental impact; it is still a labor and energy intensive process. Another benefit of producing fibers from recycled polyester is that drastically less pollution is created. Some estimates state that air pollution has been reduced by up to 85 percent when recycled polyester is used (Karthik & Gopalakrishnan, 2014). However, it has been shown that recycled polyester may not be as high of quality as virgin fibers. The fiber also requires less water than the manufacturing of many natural fibers, sometimes not needing any water at all during certain manufacturing methods.

Bast Fibers

A bast fiber, also referred to as a soft fiber, “is obtained from the phloem or inner skin of a plant. The fiber needs to be separated from the xylem or woody core and sometimes also from the epidermis, the outermost layer of cells carrying nutrients to the
leaves” (Hallett & Johnston, 2010). Bast fibers include: flax, hemp, jute, kenaf, ramie and nettle.

*Linen (Flax)*

Much like cotton and wool, linen or flax has been around for centuries, dating back to antiquity. It was extensively cultivated in Egypt and Ethiopia during ancient times. Egyptian mummies were wrapped in linen for burial. Linen was considered a symbol of light and purity in Egyptian culture and was used to express wealth (Simona & Emil, 2014). Spinning mills that were capable of producing flax on a large scale, were invented in 1787 by John Kendrew and Porthouse Thomas Darling (Simona & Emil, 2014). Following the invention of spinning mills the quality of fibers that were being produced increased drastically.

Today, the main qualities of this fiber include: high strength, luster and durability, and producing a high-quality fabric, even though the fiber is brittle with no elasticity (Black, 2011). However, the natural color of the fibers is off-white or light brown, which means that the fibers will require bleaching (*See Appendix B, Figure 9*). Linen fabrics also tend to crease, which leads to them to being coated with resins or formaldehyde compounds to create a crease resistant finish (Black, 2011). Most of the flax that is grown currently is used for human-made purposes such as flax oil or seed production (Simona & Emil, 2014). Currently, most flax is grown in northern Europe, it is estimated that 70 percent of the world’s flax is grown in this region (Sustainable Textiles for Apparel, 2014). Per the European Confederation of Linen and Hemp (CELC) this equates to over 120,000 tons per year (Sustainable Textiles for Apparel, 2014). However, linen remains a
relatively expensive fiber to produce, which creates the link between linen and luxury goods by consumers.

Linen is a fiber consisting of cellulose, however it is specifically produced from the woody stems of the flax plant, this differs from cotton, which is produced from seeds (Black, 2011). The process of producing linen is as follows:

1. Flax harvesting
   a. To obtain the fiber, it must first be extracted from the stem of the flax plant.
   b. Traditionally, the plants are harvested by hand, where the stalks are pulled from the ground, not cut down. The stalks are then either left in the fields or put into tanks or pools of water, where bacteria are used to decompose the pectin in the stalks, which binds the fibrous part of the plant together (Sustainable Textiles for Apparel, 2014).

2. Scutching mills
   c. Rippling = removes seeds
      i. A metal-toothed comb machine does this.
      ii. This process also aligns all the stalks parallel to each other for easier separation (Hallett & Johnston, 2010).
      iii. The seeds are often kept for the next season’s sowing.
   d. Retting = separates fibers from stalks
      i. Natural retting includes leaving the stalks to rot in the field for several weeks; this tends to produce the best quality fibers.
ii. By putting the stalks in pools of water the amount of time the process of separating the fibers from the stalks takes, decreases drastically.

iii. The overall retting process, which is used to degum flax fibers from the stalks involves putting small bundles of stalks in water tanks in either open retting ponds or a running water source.

iv. During this time that the stalks are exposed to water, it rots and the water causes the fibers to separate (Fletcher, 2014).

v. If this is done in a running water source, like a river, any chemicals, nutrients, or pollutants that are created during the retting process go directly into the water source, which can cause high levels of pollution and even eutrophication.

vi. To decrease the amount of time retting takes even further, chemical additives or mechanical turning can be done (Black, 2011).

vii. If chemical retting is chosen, an additive such as soda ash is added to the water, which reduces the retting time to only a few days, instead of a traditional time of a few weeks. However, this has been known to decrease the quality of fibers.

e. Threshing = extracts long-line fibers

i. The yarn may be uneven depending on the method of retting used.
f. Hackling and drafting = combs out shot fibers (tow) untangles and processes into slivers then into roves

3. Tow spinning (short fibers)

4. Scutched flax spinning (long-line fibers)

   g. Wet spinning long-line fibers has known to achieve a very fine quality yarn, which is best for bed linens (Hallett & Johnston, 2010).

5. Knitting or weaving

   While the manufacturing of linen from flax can be incredibly labor intensive, many experts claim that it is environmentally friendly (Sustainable Textiles for Apparel, 2014). To select the highest quality flax fibers, it must be done by hand, which makes the process of harvesting much costlier than if done by machine. However, following the traditional method of harvesting by hand does create jobs in local communities. It also minimizes the amount of fossil fuels that would be needed to power the machinery. Flax does commonly use pesticides during production, however as long as there is an adequate amount of water flax can grow with little to no attention from the grower, decreasing the need for fertilizers and irrigation (Fletcher, 2014).

   Through the process of crossbreeding, a strain of flax has been created that is relatively resistant to diseases and pests, further decreasing the need for pesticides. However, it is recommended that herbicides continue to be used to obtain the highest quality flax (Sustainable Textiles for Apparel, 2014). To obtain top-quality fibers, the climate that the fibers are grown in must be very moist yet mild. There has also been recent research to suggest that bast fibers such as flax can be grown on land that is
considered not suitable for food production because the plants have been shown to put nutrients back into the soil, as well as remove any heavy metals and contaminants that may have been a product of the agriculture production (Fletcher, 2014).

\textit{Hemp}

Hemp is the generic name for all plants in the \textit{Cannabis} family. However, there are several species that are cultivated, as well as wide and feral species (Hallett & Johnston, 2010) \textit{(See Appendix B, Figure 10)}. Hemp was one of the primary fibers produced in Asia, North American and Europe during the eighteenth century, alongside flax. The variety of hemp that is grown for industrial use is \textit{Cannabis sativa} L. subspecies \textit{sativa}. \textit{Cannabis sativa} L. subspecies \textit{indica} is the variety of hemp that is grown from both recreation and medical uses (Hallett & Johnston, 2010). Hemp was first used on the Asian continent, dating back to Mesopotamia over 10,000 years ago (Simona & Emil, 2014). Hemp was even used by world famous brand, \textit{Levi Strauss}, to make the first pair of pants for miners during the gold rush in the United States in the mid-1800s (Simona & Emil, 2014). Ironically, it was illegal to refuse to grow hemp in the United States in the seventeenth and eighteenth century (Simona & Emil, 2014).

In 1937, Dupont patented the manufacturing process of plastics from oil and coal. The hemp industry would have decreased Dupont’s potential new synthetic business by over eighty percent (Simona & Emil, 2014). Therefore, Dupont published several reports urging its investors to invest in this new synthetic fiber industry, rather than the natural hemp industry. Dupont, as well as William Randolph Hearst, who were both industrialists that stood to make substantial financial gains if the synthetic and petrochemical industries
took off, began to lobby the government to ban hemp. They eventually succeeded with the passing of The Marijuana Tax Act, which was passed in 1937 (Hallett & Johnston, 2010). This caused the prices of hemp to plummet and for hemp to all but disappear from the market. However, the American government saw the benefits of the fiber and during WWII, the US Department of Agriculture (USDA) created a film called *Hemp for Victory*, which stated that if farmers were to grow hemp they could receive subsidies from the government. Following the war, when the fiber was no longer needed, hemp was prohibited in the United States and Western Europe, except for France, due to the association with marijuana (Gordon & Hill, 2015). The ban on hemp remains in the United States, however it was lifted in 1993 in the United Kingdom: hemp growers are licensed annually in the UK (Black, 2011).

The lack of acceptance of hemp as a viable sustainable alternative is largely accredited to this association with marijuana. However, industrial hemp plant only contains very trace amounts of the psychoactive drug tetrahydrocannabional or more commonly known as THC. There is less than one percent, usually between 0.05 percent and one percent depending on the species of hemp grown, of THC in the varieties of hemp that are grown specifically for textile and industrial uses, compared to the three percent found in marijuana (Black, 2011). It is important to note that the different varieties of hemp are not interchangeable, meaning that the variety used for fiber production has no drug value and the variety used for drugs has no fiber value (*See Appendix B, Figure 10*).
Historically hemp fibers were incredibly coarse, making the fiber best suited for rope, canvas and sail fabrics. However, in the 1980s, a new processing method was developed that produced finer yarn, making hemp better suited for use in the apparel industry. The hemp cloth that could now be produced had a silky texture, which was more porous than cotton, meaning it took to dyes much better; it was also incredibly durable (Gordon & Hill, 2015). Due to many years of selective breeding among hemp species, there are now many different looking varieties of the plant. The process of producing hemp includes the following:

1. Hemp plant
   a. The plant itself is long and slender, it is in this long and slender part of the plant that the fibers are. They run the entire length of the plant and range from one to five meters long (Fletcher, 2014).
   b. Between 20 and 30 percent of the plant is fiber; this yield is much higher than many natural fibers (Fletcher, 2014).
   c. If the plant is harvested before it flowers, the fibers that are produced will be of much higher quality.

2. Harvesting
   d. Historically, hemp is difficult to harvest and is done best by hand. This leads to incredibly high labor costs, making it economically unsustainable.
   e. Due to the high costs associated with hand harvesting, mechanical methods of harvesting have been developed such as, enzyme retting and steam explosion.
i. These mechanical methods typically lead to the staples of the fiber to be shortened, decrease their quality (Fletcher, 2014).

ii. When mechanical methods are used, they tend to weaken and even break the fibers.

3. Retting
   f. The plant is cut 2-3 cm above the ground and left to dry.
   g. The two traditional methods of separating the fibers include dew and water retting.
   h. However, modern retting involves mechanical thermo-pulping (Hallett & Johnston, 2010).

4. Spinning
   i. Hemp is not easily spun, but it does make a very good blend. It is often blended with cotton at a 50:50 ratio (Hallett & Johnston, 2010).

Due to its association with marijuana, the incredibly ecological advantages that the hemp plant offers are often overlooked. The plant itself grows very quickly and requires only a fraction, one fifth to be exact, of the water that is required to grow cotton (Gordon & Hill, 2015). Hemp can grow to maturity in as quickly as three months or sometimes less. When compared to cotton crops, which take at least six months, the benefit of hemp is obvious (Black, 2011). It is naturally resistant to many pests, insects and weeds, which eliminates the need for pesticides, herbicides and fungicides (See Appendix B, Figure 11). Hemp is also an ideal crop for any farmer that is attempting to transition their land to obtain certified organic status. Hemp plants improve the structure
of the soil and can thrive on land that has large amounts of heavy metals in the soil (Gordon & Hill, 2015). In as quickly as 100 days after the hemp has been harvested, the soil is in better condition because the hemp plant has replenished nutrients such as nitrogen (Hallett & Johnston, 2010). In addition to replenishing the soil, hemp also controls topsoil erosion and produces very large amounts of oxygen (Hallett & Johnston, 2010). Hemp is also considered carbon negative, which means that the hemp plant is removing more carbon from the atmosphere but than the plant is putting into the atmosphere. Hemp has been found to remove five times more carbon dioxide from the atmosphere than trees (Gordon & Hill, 2015).

Hemp has often been referred to as the world’s most useful plant due to its versatility. For example: “the seeds make oil and foodstuffs for animals and humans, the woody stems produce the fibres for textiles, ropes or paper and the remaining tough fibres are used for building materials and the leaves produce animal bedding” (Black, 2011, p. 128). It is estimated that 90 percent of products that are produced today could theoretically be replaced with hemp (Black, 2011). However, hemp could not replace trees unless tens of millions of acres of hemp were grown (Black, 2011). Aside from the textile possibilities, the seeds and stalks, as well as the general fermentation of the plant, produces oil that can be used as a biodiesel fuel source (Hallett & Johnston, 2010). Hemp can also be used to produce biodegradable plastics. The uses of this plant are truly limitless.
Bamboo

Philipp Lichtenstadt holds the earliest record of a United States patent regarding bamboo textiles, dating back to 1864 (Waite, 2009). Bamboo has come a long way since 1864, as it now supports over 2.5 billion US dollars’ worth of international trade and over 2.5 billion people are involved in the trade or use of the bamboo plant (Waite, 2009). Bamboo is cheaper, as well as faster, to grow than cotton and is easier to process and extract fibers than linen and hemp (Black, 2011). Bamboo is also known to be softer than cotton, yet strong and durable with good stability and tensile strength (Hallett & Johnston, 2010). Bamboo holds great cultural significance in many East Asian countries. It has been used in these countries for thousands of years for many purposes, including: building materials, ornamental garden design, as well as a source of nutrition (Hallett & Johnston, 2010).

Bamboo is a perennial evergreen belonging to the grass family. Bamboo is native to every continent except Antarctica and Europe, however it has been introduced to Europe (Waite, 2009) (See Appendix B, Figure 12). It can grow on approximately 70 percent of the earth’s land surface (Mass, 2009). In bamboo’s native habitat, which ranges from the high altitudes of Asia down to the north of Australia and west to India and parts of Africa, as well as parts of the Americas, 90 genera and 1,000 species of bamboo can be found (Hallett & Johnston, 2010). Worldwide, there are some 1500 species of bamboo, however only 50 are used for commercial purposes (Waite, 2009). This diversity among species means that bamboo is more adaptable to the varying climate zones found around the world than any other softwood. The bamboo variety that is grown
for textile use is moso bamboo or *phyllostachys*, however it is also used for construction purposes, as well as in the food industry (Hallett & Johnston, 2010).

Bamboos are tapered and cylindrical shaped grasses, which are typically hollow, though there are some species that can be solid. Bamboo can grow to a final height of 20-25 meters (Waite, 2009). The biomass of bamboo plants is grown within 3-5 months and bamboo is 26-43% cellulose, 21-31% lignin, and 15-26% hemicellulose (Waite, 2009). However, the cellulose is the most important part of the bamboo, when it is intended for textile use. The longer the bamboo grows the more lignin produced, which translates into a decrease in cellulose and a decrease in the possibility of creating a quality textile product. Unlike typical bast fibers, bamboo is considered a stem fiber, which means that the entire stem or culms are used.

“Natural bamboo is one of the world’s most prolific and fastest grown plants; it can reach maturity in about four years, compared to the typical 20 to 70 years of many commercial tree species” (Hallett & Johnston, 2010, p. 176). Bamboo typically grows in one of two patterns: clumps, also known as Pachymorph rhizomes (sympodial bamboos), and running, or Leptomorph rhizomes (monopodial bamboos) (Waite, 2009) (See Appendix B, Figure 13). However, no matter what pattern the bamboo grows in, it is harvested by the same method, clear-cutting. This means that large areas of the bamboo are cut down at specific intervals or a few culms are removed while the rest of the bamboo forest stays intact (Waite, 2009). Furthermore, many Chinese farmers use pesticides and herbicides to further enhance the already incredibly rapid growth. Since China is one of the few places were bamboo is grown on a commercial scale, as well as a
place where environmental regulation is typically lacking, this is incredibly troubling. The high demand for bamboo products is also leading to an increased amount of deforestation happening in China.

Many people do not consider bamboo a sustainable fiber due to the way that the bamboo fiber is manufactured. The point of contention within the sustainable fashion community comes when the fact of bamboo’s similarities to rayon are pointed out. Bamboo and rayon are essentially the same. Bamboo’s manufacturing process was adapted from rayon’s, using a process like the one used to produce rayon, is what allowed for bamboo to be produced on a larger scale. However, the raw materials for cellulose fibers are often described as carbon neutral, making the beginning steps of the production process sustainable (Fletcher, 2014). There are two main methods of processing bamboo into a fiber ready for fabric production: mechanically and chemically. Per Waite (2009), the mechanical process for creating bamboo fibers includes the following steps:

1. Bamboo culms are cut into strips.
2. Bamboo strips are boiled to loosen and remove inner fibers.
3. Natural enzymes are added to break the bamboo into a soft mass.
4. Individual fibers are combed out.
5. Fibers are spun into yarn.

The chemical process per Waite (2009) follows these steps:

1. Leaves and inner fibers are removed from bamboo.
2. Leaves (in some cases) and inner fibers are crushed together to make bamboo cellulose.
3. Bamboo cellulose is soaked in a solution of 18% sodium hydroxide, NaOH (also known as lye or caustic soda) at 20-25°C for 1-3 hours.

4. Bamboo cellulose and NaOH mixture is pressed to remove excess NaOH, crushed by a grinder, and left to dry for 24 hours.

5. Carbon disulfide, CS₂, is added to the mixture.

6. Bamboo cellulose, NaOH, and CS₂ mixture is decompressed to remove CS₂, resulting in cellulose sodium xanthogenate.

7. A diluted solution of NaOH is added to the cellulose sodium xanthogenate, which dissolves it into a viscose solution.

8. The viscose is forced through spinneret nozzles into a large container of a diluted sulfuric acid solution, H₂SO₄ (that hardens the viscose and reconverts it to cellulose bamboo fibre).

9. The bamboo fibres are spun into yarns (to be woven or knitted).

The chemical process can be more or less sustainable; it is dependent on the chemicals that are used. Both methods, mechanical or chemical, have lasting impacts on the environment, however the mechanical process is considered more eco-friendly than the chemical process, because the chemicals are usually incredibly harsh. The mechanical processes can be labor intensive because it is often done by hand traditionally.

Furthermore, due to these high labor costs, the mechanical processes are typically more expensive than the chemical processes. However, the chemical process uses harsh chemicals to break down the bamboo stalks, which can pollute water sources. While the production of bamboo fibers can be sustainable, most Chinese producers process bamboo
cellulose into viscose cellulose by using very harmful chemicals, including: sodium hydroxide, other caustic chemicals and further bleaching agents. This makes the otherwise sustainable fiber, much less eco-friendly because the production of viscose is highly polluting to the air. Emissions include: sulphur, nitrous oxide, carbon disulfide and hydrogen sulfide (Fletcher, 2014).

Bamboo has many advantages as both a plant and a fabric. Bamboo’s versatility is visible by the various uses of the plant including: food for pandas, as well as humans and livestock, “woven handcraft products such as baskets and mats, textile products, ingredients for Chinese medicines and construction of flooring, fences, and roofing” (Mass, 2009, p. 36). However, the plant, as well as the fiber has many other sustainable and beneficial qualities. The massive and rapid growth that the bamboo plant is known for can happen naturally when the plant is sustained by rainwater. This eliminates the need for irrigation, as well as the need for pesticides and herbicides to aid the plants growth. Bamboo sequesters more than five tons of carbon dioxide per acre, which is five times more than what an equivalent group of trees would absorb (Waite, 2009). Bamboo also releases 35 percent more oxygen into the air than an equivalent group of trees would (Waite, 2009). Furthermore, due to the great amount of oxygen that bamboo produces, greater photosynthesis happens, which results in a reduction of greenhouse gases in the surrounding area. Therefore, bamboo offers a greater greenhouse-gas to oxygen conversion rate than any other plant (Hallett & Johnston, 2010).

A naturally occurring antifungal and antibacterial agent, known as bamboo kun, occurs in the bamboo. Bamboo Kun’s natural purpose is to protect the bamboo during
growth. However, this bamboo Kun proves beneficial when bamboo is turned into fabrics. It stops odor-producing bacteria from being present in the textiles. It also causes bamboo fibers to be less likely to irritate the skin, because the chemicals that are often added to fibers for antibacterial purposes are no longer needed. The fiber is also known for its anti-static qualities. The surface of the fibers is covered with micro gaps and micro-holes, which makes the fabrics moisture absorbing, as well as provides great ventilation for the wearer (Hallett & Johnston, 2010). Bamboo fibers are especially fitted for athletic apparel because it wicks away any moisture and evaporate the perspiration instantly. This means that in humid or hot weather, bamboo fibers do not stick to the skin because it immediately wicks away sweat. Research has shown that bamboo fibers can keep the wearer one or two degrees cooler during hot days (Hallett & Johnston, 2010).

Ingeo

Recent research has begun to develop sustainable fibers from starch, mainly corn or sugar cane. Ingeo is a polymer of lactic acid, which is derived from maize. Ingeo is considered the first fiber available that is completely derived from annual renewable sources. Cargill Dow chemical company in the US developed it. However, Ingeo is now produced and marketed by a subsidiary company of Cargill Dow called NatureWorks (Black, 2011). NatureWorks recently began a joint venture with a Japanese synthetic fiber manufacture, Teijin. Teijin, which is a leading company in synthetic fiber manufacturing, has two products in production that are made from the same source. “Either a polymer plastic, used in food packaging, car panels, carpets, or the same material formed into a fiber and then spun into yarn which is branded Ingeo for clothing
and interior uses” (Black, 2011, p. 148). Ingeo is considered a biopolymer, also known as polylactic acid (PLA) and is thermoplastic polyester.

Ingeo fibers have been classified as having high strength and stability, low flammability, more resistant to UV light, more hydrophilic, meaning it attracts more water, than most synthetics (Hallett & Johnston, 2010). To produce the fiber, the starch that is stored in the corn, by means of photosynthesis, is broken down and converted into dextrose sugar (Hallett & Johnston, 2010). It is in the naturally produced sugars that carbon and other elements are used to create a biopolymer, by means of fermentation and separation to produce the lactic acid. Water is then removed, which creates a resin, then extruded into Ingeo (Hallett & Johnston, 2010). When the plant sugars are fermented and lactic acid molecules are created, they are combined into a polylactide polymer (PLA), in the form of plastic pellets (Black, 2011). Once this point is reached, the plastic pellets can be converted into fibers by the same means as many other synthetic fibers.

Sustainability is an essential part of this fiber. The process used to convert the corn into Ingeo is a relatively low-cost process (Hallett & Johnston, 2010). Furthermore, it uses very little fossil fuels during all stages of the fibers production. The source of the fiber, corn, is in great abundance. However, as GM corn cultivation continues to grow, the concerns associated with genetically modified crops grow as well. The fiber is also biodegradable, even compostable because as the fiber degrades it becomes natural compost over time. In order for the fiber to be fully composted, it must be processed in industrial composting facilities. This is because these facilities provide the right combination of temperatures and humidity, which causes the fiber to break down
properly (Fletcher, 2014). However, landfill biopolymers can have negative effects in the landfill, which include: the generation of methane, an increased level of eutrophication, eco-toxicity and production of human carcinogens (Fletcher, 2014). When compared to petrochemical based synthetic fibers, the sustainability benefits include: energy savings, fewer emissions and the use of renewable resources (Fletcher, 2014).

While this fiber is revered for its sustainability, it does have ecological impacts. There are strong ties to large-scale, monoculture, intensive agricultural that is associated with corn production, especially in the US. An argument is made that using corn, which is a staple food in many individual’s diets, as a textile is taking food away from hungry mouths that may need that food to survive. However, there are alternatives to corn for the starch or sugar supply needed to produce PLA, which include: waste biomass and marginal crops such as grass (Fletcher, 2014). During the finishing stages, when Ingeo is dyed, water can enter the fiber, which weakens the molecular bonds. This reduces the overall fiber strength (Fletcher, 2014). Furthermore, due to this feature, more dye is wasted than with other synthetics, such as polyester, are dyed. This in turn, causes dark colors of Ingeo hard to produce (Fletcher, 2014). While large-scale operations have recently emerged to produce Ingeo, it remains three times more expensive to produce than polyester, making it not a likely choice for many designers (Fletcher, 2014).

Soya

There is some evidence that states soya cultivation dates back 5,000 years to China, where it was first harvested (Hallett & Johnston, 2010). However, today the United States is the largest producer of soybeans. Soybeans were introduced to the United
States almost by accident in the early 1800s. Yankee clippers were trading with China, where they often used soybeans as inexpensive ballast and as the products from China entered the US, so did soybeans (Hallett & Johnston, 2010). Soybean based fibers are considered a part of a class of regenerated materials that come from proteins. However, this protein can come from either vegetable, like soybeans, or from animals, like milk (Fletcher, 2014). While protein based fibers were originally produced in the 1950s, as a demand for environmentally friendly fibers increased, a renewed interest in protein based fibers was found. This soybean-based fiber is being marketed as a replacement for petrochemical based synthetic fibers.

Soya-bean protein fibers are considered an advanced textile fiber, which is produced by bioengineering technology from a soybean ‘cake’ (Hallett & Johnston, 2010). The protein, an essential part of the fiber, is distilled from the soybean cake and further refined. The structure of the protein changes into a confected substance through various processes, as well as the use of auxiliary agents and biological enzymes (Hallett & Johnston, 2010). After the structure of the proteins change, they can then be extruded into a fiber by a wet-spinning process. Once this is done, a fiber may finally be obtained once it is stabilized and cut into short staples (Hallett & Johnston, 2010).

Soybean fibers, much like PLA fibers, are considered green fibers that are completely biodegradable. The auxiliary agents that are used are non-poisonous (Hallett & Johnston, 2010). The waste that is created during the manufacturing process can be used as animal feed, once the protein has been extruded (Fletcher, 2014). The largest concern regarding soybean textiles sustainable pertains to the environmental impact of
soybean agricultural production. “Commercial, large-scale soybean farming is water-, fertilizer-, and pesticide-intensive, and is commonly reliant on GM technology and widespread herbicide use supported by biotechnology companies” (Fletcher, 2014, p. 41). If GM soybeans are used, the crop may have been sprayed with pesticides and herbicides, making them not usable in animal feed. Some soybeans fibers are currently being marketed are organic and receiving organic certification. However, soybean fibers remain around 30 percent more expensive than organic cotton (Fletcher, 2014).

**Tencel (Lyocell)**

Lyocell is also known by its brand name, Tencel and was originally created by Courtaulds Fibers. The fiber was developed as a part of Courtaulds Fibers’ “Genesis” project in 1987 and it was made commercially available shortly after its development in the late 1980s (Gordon & Hill, 2015). The “Genesis” project was originally developed to produce a product that would be able to compete with the cost and physical characteristics of viscose rayon, but the product also needed to be ecologically sustainable to meet the company’s goals (Gordon & Hill, 2015). By 1993, Tencel was already being used in clothing lines created by Calvin Klein, Girbaud and Esprit, among many other major labels. Today, Tencel is the only fiber to be awarded the Europe Union based eco-label.

Lyocell is one of the most revered sustainable fibers currently on the market. Lyocell is a cellulosic fiber, meaning that it is a substance that is made from the main part of the cell walls of plants. Lyocell specifically comes from wood pulp, normally eucalyptus. Eucalyptus is an evergreen plant that can grow up to a height of 131 feet
(Hallett & Johnston, 2010). However, other fast growing woods such as beech and pine can be used as the source for cellulose. The wood pulp that is harvested is grown specifically for this end use. However, it can be derived from other easily grown woods such as beech and pine (Gordon & Hill, 2015). The forest where the wood is gathered is specifically grown for the end purpose of being used for textiles. These forests are incredibly carefully managed and maintained to make them as sustainable as possible.

The process of producing lyocell is as follows:

1. **Wood**
   a. Usually derived from easily grown wood sources such as, beech, pine, but mainly eucalyptus.
   b. The wood that is harvested is grown specifically for this end use.
   c. The forests where the wood is grown as carefully managed and maintained to make them as sustainable as possible.

2. **Pulp**

3. **Dissolving**
   d. The wood pulp is dissolved in a solution of amine oxide, which has low-toxicity and is a low-skin irritation solvent (Hallett & Johnston, 2010).

4. **Spinning**
   e. The pulp is placed in a spinneret to be spun into fibers.
   f. The spinneret produces long fibers to be dried and later woven into cloth (Hallett & Johnston, 2010).

5. **Washing**
g. It is during this process that the remaining solvent is extracted from the fibers.

h. Aside from any evaporation of water, the manufacturing process recovers 99.5 percent of the solvent (Fletcher, 2014).

i. The solvent is then purified and recycled back into the fiber creation process.

j. The solvent is non-toxic, non-corrosive and all the effluent that is produced is non-hazardous.

6. Finishing

k. There is no need for bleaching prior to the processing of the fiber because it is already considered a “very clean” fiber (Fletcher, 2014).

l. Due to its classification as a “very clean” fiber, this reduces the need for chemicals, water, and energy during the dyeing processes.

7. Drying

8. Fiber

m. Fully biodegradable within six weeks of it being placed in an aerated compost heap (Gordon & Hill, 2015).

n. It also requires very little laundering and ironing, minimizing its impact during the “use” phase.

Even factories that produce lyocell are “designed and operated to achieve world-class low levels of emissions and minimize energy consumption” (Gordon & Hill, 2015).
This makes lyocell one of the few textiles on the market that is sustainable throughout the entire fashion supply chain.

It is during the next portion of the fashion supply chain, the production portion, that these fibers are turned into fashion products or textiles. However, it is during this portion of the supply chain that we see many sustainability related issues, including but not limited too: poor working conditions and low wages, high usage of dangerous chemicals in the work place, various forms of pollution, as well as extensive use of energy. The following chapter analyzes this production portion of the supply chain, specifically focusing on Bangladesh, with mention of Rana Plaza.
CHAPTER 3: THE REAL COST OF FASHION: PEOPLE

It is estimated that there are 1.3 billion women in the global labor force, with the service sector employing approximately half, agriculture employing a third and industry employing a sixth (English, 2013). However, it is in this last category of industry, that women are the most negatively affected by globalization. As of 2009, the UNIFEM reported that women in export processing zones, places where there are constant low-wages, poor working conditions and an unregulated business environment, “constitute 90 percent of the workforce in Nicaragua, 80 percent in Bangladesh, and 75 percent in Honduras, the Philippines and Sri Lanka” (English, 2013, p. 75). In these areas, excessive working hours, poor living conditions, poor working conditions, sexual assault, and sexual harassment are incredibly common. Many of these developing countries are considered a part of the “global south.” The terms global south and north were developed alongside the Brandt Line in the 1980s, as a way to divide the world into relatively richer and poorer nations. According to the Brandt Line: “richer countries are almost all located in the Northern Hemisphere, with the exception of Australia and New Zealand. Poorer countries are mostly located in tropical regions and in the Southern Hemisphere” (RGS, n.d., p. 1).

While today, the world may be much more complex than simply taking a line, and dividing the world into two parts, as the Brandt Line does, it does provide a good frame for where most apparel factories are located and where most of the apparel consumers are located. In the last few decades, the apparel and textile industry has seen, capital and technology moving from the global north to the global south increasing the
mechanization of production in the global south, increasingly global supply chains, and a profit-based framework for factories that has created a race to the bottom in terms of the wages and working conditions.

History of Textile Mills, Garment Factories and Sweatshops

Historically, in developing economies the textile and garment industries are often the first established due to the low capitalization requirements, the relatively low start-up costs, and the manufacturing of the products does not require a highly skilled workforce (English, 2013). This phenomenon is specifically common in economies that are transitioning away from an agriculture dependent economy. A country’s transition away from specifically an agriculture dependent economy creates an expensive surplus in young and female workers, who initially seek and find employment in new the textile and garment industries. “The historic rubric remains the same today: industrial work in textile and garment assembly jobs provides an entry point for participation by rural women in the formal economy” (English, 2013, p. 68).

The textile, garment and apparel industry offer new opportunities for these young women workers who may not be fit for agricultural work. Many scholars will argue that having jobs in this industry is better than the crushing abject poverty many of these women would be living in without these jobs. However, what it fails to acknowledge is that women often occupy the lowest level jobs in these factories. Therefore, as the country continues to develop and industrialize, the low-wage workers, namely women, will not be privy to the benefits of the export-led development. This is because all the profits are distributed between the retailers and the middlemen of the fashion supply
Furthermore, women are often unable to advance in their jobs, commonly known as the “glass ceiling”, and remain at the lowest level of jobs and income.

Men are given the higher paying; more “difficult” jobs or the jobs that require “skilled workers” in the textile and apparel factories because many believe women are unable to perform these types of “difficult” tasks. Furthermore, men are often given promotions over women in the factory, leading these men to become managers. Even if the women working the lower paying jobs are qualified, they are often passed over for job promotions (English, 2013). Global production and globalization has only served to increase these problems and challenges for female workers, because the global supply chain created a never-ending work force that is ready to take a job from workers who attempt to unionize, protest, demand higher pay, demand fewer working hours, etc. The globalization of the garment and textile industry directly contributed to exponential growth of the women’s work force that was seen in the early 2000’s. This growth created the three trillion US dollar fashion industry today (United Fashion, 2015).

There are roughly 60 to 75 million people employed in the textile, clothing and footwear sector worldwide, as of 2014, when compared to the roughly 20 million people that were employed by the industry as of 2000, the growth of the textile and clothing industry is vast (Stotz & Kane, 2015). It has been further estimated that of the 60 to 75 million people employed, about three quarters of these workers worldwide are female (Stotz & Kane, 2015). As of 2014, the world’s women wear industry was worth $621 US dollars, the men’s wear industry is worth $402 billion US dollars, and the children’s wear
industry is worth 186 billion US dollars (Stotz & Kane, 2015). The top five garment producing countries include: China, Bangladesh, India, Turkey and Vietnam. While the top emerging garment producing countries include: Panama, Mali, Samoa, Burundi and Ethiopia (Stotz & Kane, 2015). The clothing that is produced in these countries is often shipped to western countries, the top five importing countries include: the EU, at 38% of the world’s garment imports, the US, at 20%, Japan, Hong Kong, China and Canada (Stotz & Kane, 2015).

Feminization of the Global Labor Force

English (2013) states since most workers in the textile, apparel and garment industry were women this led to the emergence of a gendered wage structure. Women are often considered secondary to their male co-workers and often viewed as temporary because it was believed that a female worker would leave her paid job to get married and have children (English, 2013). Therefore, the factory managers and owners found no reason to invest the money and time into training these women to become “skilled workers” prepared to handle the “difficult tasks.” So more often than not, men were given these skilled jobs, as to make a “smart investment.” The gendered wage gap emerged from the idea that women were subordinate in a male-headed household, meaning they only preformed labor that was supplemental to the breadwinning male head of house (English, 2013). It was this framework that led to women’s wages being set based on need rather than value, productivity or skill (English, 2013). Furthermore, it was this idea that led to the acceptance of defining a woman’s “proper place” as in the home, caring for her family, not in the global work force. Women are further subjected to the “double-
burden” of having to work all day then come home to run their households, care for their child, cook, clean, etc. This labor goes completely unpaid and it is often not viewed as actual labor that can or should be paid. In the decades following the World War II, “there was a worldwide movement of low-wage, largely unregulated and unorganized work to the global South” (English, 2013). Dating back to WWII, women entered the work force to replace the men that were drafted into the war, however women in the work force were always viewed as temporary. When the men returned from the war, the women who had been working for years were now expected to simply return back to their lives as a housewives, which many women no longer wanted to do. The view of women as secondary citizens, especially in the work force, led to the very few options and opportunities that are given to women for paid employment today.

The gendered division of labor and wages continued to grow as new technologies began to be introduced into factory settings. This meant the process of constructing clothing was now broken down into smaller and simpler tasks that were often given to women to accomplish (English, 2013). There could sometimes be hundreds of different operations that went into constructing an article of clothing. The increased use of technology removed all skill that was previously necessary to create an article of clothing (English, 2013). It was women, who were often immigrants or migrant workers, which took these “deskilled sewing jobs,” which meant they were producing articles of clothing for pennies per item (English, 2013).

Even today, these same gendered assumptions and labor divides persist. As even more technology is introduced and the distribution of work continues to go global,
women’s opportunities for work continue to become deskillled, leading to even less pay and even worse working conditions. Scholars refer to this phenomenon, as the “feminization of the global labor force” (English, 2013). This phenomenon not only refers to the dramatic increase in the number of women workers who are earning wages, but also the “historically-shaped social prescriptions that have produced and reproduced gendered inequalities in the workplace through the sex-typing of jobs and gendering of wages” (English, 2013, p. 72).

Until the 1960s, the textile and apparel industry in western countries such as the US and UK relied heavily on domestic subcontracting (Bhuiyan, 2012). More specifically, cutting and stitching operations were subcontracted to small garment factories around those countries. The small garment factories relied on the use of cheap female labor, while the much larger, more difficult work and the merchandising of the products were undertaken by the larger firms that were located domestically (Bhuiyan, 2012). However, as industrialization began and wages began to rise, these companies set out to find much cheaper labor, which they did in developing or under-developed nations. Since then, textile manufacturers have been incredibly dependent on the global assembly line to produce their clothing. The assembly line was as follows:

The retailer in the developed countries placed work orders to the offshore garment manufacturers often through buying agents, and they also helped the garment markets in various ways to produce and ship the merchandises. Such subcontracting reduced the risk of doing business with foreign partners since it did not require any direct investment. In essence,
it was a triangular trade between the garment manufacturers and the foreign buying agent on the one hand, and the retailer and the buying agent on the other (Bhuiyan, 2012, p. 40).

This global assembly line is incredibly problematic because it relies heavily on a globally decentralized and feminized work force (English, 2013).

As the labor was outsourced, producers looked for countries with the lowest wages and the laxest regulations. Producers found these countries mostly in the underdeveloped or developing world in places like: China, Bangladesh, Cambodia, and many other Asian and African countries. The ready-made-garment (RMG) industry saw rapid growth in countries all over the developing world. The factories that ended up producing clothing for much of the western world ended up having the lowest working standards and living standards in the world. Outsourcing further created this South-to-South competition among countries in the global south. The contracting and subcontracting of work put massive amounts of pressure on the global south to keep their production costs at the lowest rates globally (English, 2013). Since women’s labor was often seen as the most cheap and flexible labor in the world, the textile and garment industry became an industry particularly suited for young women.

The Race to the Bottom

Since the big boom of the global apparel industry, there has been what scholars are deeming a “race to the bottom,” in terms of labor standards in the apparel industry. Many of the workers that find themselves in these factories producing items for Western consumers identify as migrant workers. Commonly, these migrant workers are young
women, who are in search of a better, higher paying job than the farming opportunities offered to them in their rural village. What they soon discover upon reaching cities such as Dongguan, which has been dubbed a “manufacturing city”, is that the job they were promised or expecting does not exist. The assembly lines of Dongguan, which is one the largest factory cities in China, specifically drew in young and unskilled workers that were estimated to be 70 percent female (Cheng, 2009).

Workers who accepted jobs were required to say a minimum of six months and even if they did want to quit, they were often not given the permission to do so. These women also did not want to quit before the six-month mark because the factory held the first two months’ pay of every worker they employed (Cheng, 2009). If a worker left without approval or walked off the job, they were forfeiting the money that the factory held (Cheng, 2009). Even though a day on the assembly line for some women could last from eight in the morning until midnight, which meant they were working thirteen hour days with only two breaks for meals, women were often too scared to quit and start completely over at a new factory (Cheng, 2009). There was no way to tell if the next factory they went to would be any better than the one they left, thereby forfeiting two months’ pay for nothing.

Lu Qingmin, who went by Min, a woman who worked at a factory for Carrin Electronic in Shenzhen, a fast-growing industrial city, told Cheng (2009) of her experiences in the factory. Even though the legal working age was eighteen, Min turned seventeen during her first week on the job. It was common knowledge among the so called “factory girls” that factories which freely broke labor laws, what Min dubs “the
very blackest factories,” would hire someone of her age. She came to this industrialized city because she thought it “would be fun to work on an assembly line” (Cheng, 2009). She goes on to say, “I thought it would be a lot of people working together, busy, talking and having fun. I thought it would be very free. But it was not that way at all” (Cheng, 2009, p. 6). She quickly found out that talking on the job was forbidden and if you were caught doing so you received a five-yuan fine, bathroom breaks were only allowed to last ten minutes and there was a sign-up list (Cheng, 2009).

In order to escape the mundaneness of her job, she would make frequent trips to the bathroom to look at the window and see the world outside. Her manager quickly figured out what she was doing and her factory enforced a policy that limited their workers to one bathroom break every four hours, if the workers violated this rule they were subject to another five-yuan fine (Cheng, 2009). The pay for workers such as Min, a migrant worker, are often lower than the official minimum wage, which can range from fifty to eighty dollars a month and their work hours stretch well beyond the legal limits (Cheng, 2009). Many of these factories provide rooms for their workers to sleep; however these rooms are far from “luxurious” or even livable sometimes. In Min’s factory, girls slept twelve to a room, in the incredibly tight confines of a dorm (Cheng, 2009). The women who slept in these close quarters knew nothing or very little about the people that they lived and worked with.

In countries, such as China, which is the largest apparel producer in the world, factory girls are worked so hard, that they are lucky to see a day off or a day of rest for every ten days of work, even though the country’s laws demand a day of rest for every
seven (Ross, 2006). These women may be subjected to working seventy or more hours a week, even though they are restricted to working only forty-nine, even in the most extreme of cases (Ross, 2006). Furthermore, the firms that run these factories are often multi-national organizations responsible for hundreds of factories. These firms often fire workers who join unions, and harass and even assault workers who take advantage of the firm’s medical clinics (Ross, 2006). As we move to an increasingly interconnected and globalized world, that now has very few import restraints, there is increasing alarm among workers that all labor standards in the apparel and textile industry will rapidly descend to these types of conditions.

Bangladesh

When the newly independent Bangladesh introduced nationalization as a cornerstone of its economic program in 1972, the government also acquired 85 percent of the capital assets of the industrial sector (Ahmed, 2004). Setting the stage for Bangladesh to become an industrial heavy country, where the government controlled the entire industrial sector of the country. However, following the death of the Prime Minister, Shikh Mujibur Rahman in 1975, a new military government came to power. This new government pursued privatization with a passion in an effort to attract foreign capital (Ahmed, 2004). They specifically pursued export-orientation strategy that involved currency devaluations, reduced trade barriers and restrictions on repatriation for foreign investor profits (Ahmed, 2004). In turn this created a great tax incentive for foreign companies to set up factories in Bangladesh. These foreign investors were establishing garment factories and creating Export Promotion Zones (EPZs). This made it much easier
for foreigners to participate in the Bangladeshi economy, specifically in business ventures in the country; it even allowed foreigners to own businesses (Ahmed, 2004). In the early 1980s, the government even issued licenses to foreign investors that allowed them to import machinery to produce garments for export purposes, duty free (Bhuiyan, 2012). As Bangladesh is considered a country with poor land-to-people ratio, the country was unlikely to prosper simply through the agricultural sector alone. Therefore, industry found a successful home in Bangladesh as it allowed a portion of the population previously unable to work a way to contribute to the country’s GDP. Today, Bangladesh has a population of more than 160 million people, which gives Bangladesh the highest population density in the world (Stotz & Kane, 2015). The garment industry comprises 12 percent of the country’s GDP and 80 percent of Bangladesh’s exports (Stotz & Kane, 2015).

Two factors played a vital role in the growth of the ready-made-garment (RMG) industry of Bangladesh, these factors included: a favorable condition created by the Multi Fiber Agreement (MFA) quota system and the incredibly low wages found in Bangladesh (Bhuiyan, 2012). Bangladesh’s economy is mainly an export economy, however the ready-made-garment (RMG) industry is 100 percent export based. The RMG industry has grown from $6.4 billion US dollars in 2005 to $12.5 billion dollars in 2010 to $21.5 billion dollars in 2013 (Stotz & Kane, 2015). Experts have predicted that the RMG sector in Bangladesh will reach the $50 billion US dollar mark by 2021 (Al-Muti, 2016). Furthermore, this industry accounts for “80 percent of the country’s export earnings and 14.5 percent of national GDP” (Parker, 2011, p. 7). In the span of 15 years, Bangladesh
exploded onto the apparel and textile world by emerging as the eighth largest garment exporter to the United States by 1991 (Ahmed, 2004). There are roughly 5,000 factories, which employ some 4 million workers, mostly women (Rubya, 2014). Today, the garment industry has become a 20 billion dollar a year industry in Bangladesh, making it the second largest garment exporter after China (Taplin, 2014). However, four fifths of the $20 billion profit USD is returned to western countries (Burke, 2013) (See Appendix B, Figure 14).

Due to the rapid growth of the RMG industry, there has been an increase in the number of women, particularly in the numbers of working mothers, found in this industry (Absar, 2001). The garment industry meant jobs for women, so “almost overnight a labor force of approximately 200,000 young women appeared in Dhaka city, the capital of Bangladesh…The Bangladesh garment industry is the largest employer of women in the formal manufacturing sector globally” (Ahmed, 2004, p. 35). Furthermore, Bangladesh has the cheapest unit labor cost in South Asia (Absar, 2001). For example, to produce a t-shirt in Bangladesh it only costs 11 cents, while it costs 79 cents in Sir Lanka and 26 cents in India (Absar, 2001). Bangladesh now exports approximately 100 different types of garments to 50 countries around the globe (Ahmed, 2004).

Per a 2001 report that was conducted by the National Labor Committee, 85 percent of the individuals working the garment industry were women between the ages of 16 to 25 (Taplin, 2014). These women are often forced to work 12 to 14 hour days, seven days a week. They occasionally must work 20-hour shifts, which are mandated by their employers (Taplin, 2014). This overworking of the employees remains a common thread
in Bangladeshi factories, even though the 1965 Factory Act only allows women to work overtime hours until eight at night. Some women have reported that they were forced to work until three in the morning, only to return five hours later, for another 20-hour shift (Absar, 2001). These women are often forced to work months at a time without a day off, even though this goes again the 1965 Factory Act, which states that an employee must be granted a day off when they work more than ten consecutive days (Absar, 2001). Furthermore, even though child labor has been outlawed by the nation of Bangladesh, it is estimated that there are still seven million children workers working in the garment industry (Taplin, 2014).

The use of women as employees in Bangladesh is strategic, as they have historically been paid less, worked longer, and been less likely to demand more pay or quit. “It is the ‘docility and dispensability’ of these women that makes them so attractive to employers” (Ahmed, 2004, p. 38). In the garment industry, tasks are largely assigned based on the sex of the employee. For example, in the sewing section of a factory one will find all women, while in the cutting, ironing, and finishing sections, one will find all men. One would be hard pressed to find a woman working as a line supervisor or quality controller. Furthermore, female cutting masters do not exist in Bangladesh garment factories. When analyzing a factory setting, women often occupy the lowest level jobs, while men dominate the administration and management jobs. However, no matter the job, women are always paid less than their male counterparts. For example, female mill operatives earn wages that are 54 percent lower than males (English, 2013).
The 5,000 factories located in Bangladesh pay the lowest wages, significantly lower than those of China, and half of the wages earned by those in Vietnam (Miller, 2014). These incredibly low labor costs have attracted companies from all over the world to build factories in Bangladesh. Women are incredibly reluctant to unionize because they often face backlash or even assault from fellow workers, as well as bosses, if they do so. The garment factory owners are compelled to keep an ever-decreasing cost of labor; therefore, they are incredibly vigilant to the threat of unionization (Ahmed, 2004). However, class divisions and issues, as does the imminent threat of getting fired, prevent any true solidarity among garment workers in a union setting (Ahmed, 2004).

Many of the factories that are found in Bangladesh are lacking in both safety and health standards. More often than not the factories are built with substandard building materials, to save money on construction costs. Sometimes, the factories are even housed in buildings that are not intended for industrial use at all (Rubya, 2014). It is incredibly common for RMG factories to lack sprinklers, fire alarms, emergency exits, non-electrical emergency lights, and firefighting equipment (Rubya, 2014). This is incredibly problematic as the workers are often exposed to incredibly flammable products and chemicals, as well as exposed to overloaded electrical circuits (Rubya, 2014). Furthermore, workers hardly ever receive safety training or are exposed to emergency procedures, and there are no safety officers in the factories. Moreover, “there are only about twenty occupational health and safety inspectors for the 50,000 registered factories in the nation [Bangladesh], which amounts to 2500 factories designated to each inspector” (Rubya, 2014, p. 692).
Some factories in Bangladesh do not provide housing and that is one of the biggest problems faced by the women, migrant workers. The salary women make in the factories is not enough to rent an apartment, especially not on their own. Furthermore, they must pay for electric, heating, water, etc., which adds additional costs. Therefore, many women live in what are termed “bostees,” which are squatter settlements (Absar, 2002). In Bangladesh, these bostees “comprises a group of thatched or tin-roofed one-room houses that stand next to each other with inadequate shared sanitation facilities” (Absar, 2002). The rent for these houses is 800-1,800 taka per month, while sometimes there is electricity, a stove and private bath facilities; this is not always the case (Absar, 2002). If these bostees are lacking these facilities, residents are often reliant on polluted bodies of water for bathing, cooking, and drinking. They also must cook with fuel wood and burn a kerosene lamp or hurricane lamp to substitute for electricity (Absar, 2002). Since these bostees are squatter settlements, they are often uprooted by law enforcement agencies because these settlements are built on the landowner’s land without permission or the proper paperwork needed (Absar, 2002).

Absar (2002), interviewed 35 women about their experiences working in Bangladeshi garment factories. All 35 women collected their water from the Badda/Gulshan Lake that was adjacent to their homes. They used this water for cooking, bathing, doing their dishes, and laundry (Absar, 2002). There was no private or modern toilet or kitchen; they had to use a public latrine and shower by the lake (Absar, 2002). Of the 35 women that the author spoke to all 35 of them began to develop health problems from using the polluted water source and strenuous working conditions. They began to
suffer from the following: eye strain, headaches, backaches, flu, fever, cough, gastric problems and general weakness (Absar, 2002). All 35 women stated that at one point or another these health problems forced them to miss work or be unable to care for their children.

Many property owners that have land-surrounding factories are considering building mess halls, or dormitories, on their land. However, many women face a stigma and unsafe or insecure living conditions if they choose to live at such places (Absar, 2002). The women that choose to live in these places are often victimized because the mess halls often have a motel-oriented atmosphere. This means that anyone could say overnight and disappear the next day, with none the wiser, creating a link to prostitution for these women (Absar, 2002). Since many of the women working in these factories are young and unmarried, living alone in Bangladesh is not only considered “taboo” by their culture but it is also very unsafe.

The government of Bangladesh had not adjusted its minimum wage for twelve years until 2006. However, when the minimum wage was raised it was still well below the cost of living. The minimum wage rate set in 2006 was still not sufficient for most workers. So, in the summer of 2010, thousands of female apparel workers in Bangladesh shut down dozens of factories, when they took to the streets to protest their horrible working conditions and demanded of an increase in the national minimum wage, which is the lowest in the world (English, 2013). These women protested for months, and the protests were marked with police harassment, brutality and arrests, as well as the detention and torture of labor leaders. Following the months of protests, the government
agreed to increase the national minimum wage (English, 2013). The government raised the minimum wage from $38 dollars a month to $68 dollars a month, however this did fall short of the $103 a month that the workers were demanding (Miller, 2014). This is estimated to be just one third of the value of a living wage, as estimated by the Asia Floor Wage campaign (Parker, 2011).

The problem with minimum wages is that when government set them, they are supposed to “balance the interest of workers with what they see as the need to remain competitive in the global market and pressure from companies to keep wages low” (Parker, 2011, p. 16). However, it is blatantly obvious that the interests of workers are hardly considered when minimum wages are set in countries such as Bangladesh. The pressure to keep wages low is entirely too great to make the minimum wages livable. This translates into minimum wages often bearing no correlation to the cost of living, which means that mean families in these countries live well below the national poverty line. This is especially problematic as the cost of living continues to rise in many garment-producing countries. The actual success of the protests in changing the lives of these factory women in Bangladesh is subject to question because three short years later the worst disaster in the history of the global garment industry happened, the collapse of Rana Plaza. As of 2014, Bangladeshi garment workers were receiving a wage of 5,300 taka a month, which translates into $68 US dollars, while the living wage calculated by Asia Floor Wage was 25,687 taka, which equates to $332 US dollars (Stotz, 2015).

Bangladesh, a country of more than 160 million people, which employees some 4 million workers in the garment industry, only has 40 building inspectors qualified to
inspect factories (Kuttner, 2013). This led to many of the factories going un-inspected due to the sheer number of factories versus the number of inspectors. Furthermore, one of the most prestigious monitoring groups in the world, Social Accountability International, gave a factory that was owned by Ali Enterprises in Karachi, Pakistan, a gold star in safety following an inspection. A month later, the factory burned down, killing 300 workers that were trapped in the building because they were forced to work behind locked doors (Kuttner, 2013). In Bangladesh, since 2005, roughly 600 garment workers have died due to fires. However, when building collapses are factored in, the number of garment workers killed since 2005, more than doubles to 1800 (Rubya, 2014). Between the years of 1990 and 2012, there were 275 factory accidents reported in Bangladesh (Rubya, 2014).

Rana Plaza may have been the largest of its kind, however it was not the first building to collapse in Bangladesh. Five months prior to the Rana Plaza collapse, Bangladesh found its way into newspapers around the globe due to a fatal fire at Tazreen Fashions, which killed 112 workers that were producing clothing for companies such as Wal-Mart (Manik & Yardley, 2013). In 2005, 64 workers at Spectrum Garments were killed during a building collapse (Manik & Yardley, 2013). In January of 2012, Fair Labor Association (FLA) was hired by Apple to review the conditions of a factory of Foxconn, located in China. Once again, this factory was found to be in pristine condition. Two weeks later, The New York Times published an exposé on what the conditions in the factory were like, which included up to 70-hour workweeks and an unusually high amount of worker suicides (Kuttner, 2013). Even after this exposé was published the
head of the FLA toured the facility that *The New York Times* wrote about and claimed that it was “first class” (Kuttner, 2013). Some other disasters include: the Shifa Apparels and Omega Sweaters Fire that happened in 2004, the Garib & Garib Sweater Factory fire of 2010, and the Condense Apparel and Fahmi Factory Fire in 2011 (Rubya, 2014).

**Rana Plaza**

Rana Plaza disaster, also known as the 2013 Savar building collapse, happened on the 24th of April 2013. The building was located just outside the capital city of Bangladesh, in Savar Upazila of Dhaka, Bangladesh. During early morning rush hour, the eight-story building collapsed, killing 1,138 workers and injured at 1,000 others, some of these injuries inflicting serious long-term pain (Miller, 2014). However, some counts list it at approximately 2,500 people being rescued from the building alive, these survivors had varying degrees of injury (*See Appendix B, Figure 15*). The true number of individuals killed during the incident remains unknown as many individuals are still considered “missing” following the collapse of the building. Several hundred bodies that were found in the rubble following the collapse were brutally severed to the point where they were unrecognizable or buried so far down that they were unable to be reached by rescuers. Civic groups that were helping with the rescue efforts buried over 230 bodies that were unclaimed (Rubya, 2014). Rescue efforts by soldiers, firefighters, paramilitary police officers and volunteer citizens to pull survivors from the rubble lasted twenty days (Rubya, 2014). Many of the rescuers reported that they could hear the heart-shattering screams of people in the wreckages for days, but they were simply unable to reach them (Rubya, 2014). Of the 1,100 workers that were killed during the collapse most of them
were young women who were working for a little bit more than a dollar a day, making only $37 dollars a month (Kuttner, 2013). This collapse was considered the deadliest garment factory disaster in the history of the global garment industry.

Rana Plaza was eight floors, with the top six floors containing garment factories and the lower two levels housed a bank, apartments and several other shops (See Appendix B, Figure 16). The top two floors of the building were constructed illegally, by the owner, Sohel Rana, who was also a local politician known for his connections to local municipal authorities. Rana’s building only had permits to for a six-story building. The five garment factories, located on the top six floors, produced apparel for more than a dozen different international fashion companies. Some of the brands included: J.C. Penny, Wal-Mart and Benetton (Kuttner, 2013). Many of the workers reported that the day before the collapse, on Tuesday, the 3,500 workers at Rana Plaza were sent home early from their workday due to “electrical problems” that the building was facing. However, in fact an engineer was examining large cracks that had appeared that day (Burke, 2013). After the engineer visited the building and found it to be structurally unsound, the bank and shops on the lower levels immediately closed. The workers who had jobs on the upper levels, mainly the clothing factories, were forced to return to work. Many of the woman said that they were still in bed when their supervisor showed up at their front door to make them return to work (Burke, 2013). The building’s owner completely ignored the warning from the engineers and made many of the workers continue working despite the massive cracks continuing to crawl up the walls of the building. The next morning, the building would collapse and taking 1,138 lives with it.
Following the collapse of the building, an investigating committee, which was appointed by Bangladesh’s Interior Ministry, began to investigate the disaster. They found that Rana Plaza was constructed with extremely substandard iron rods and cement. Furthermore, the heavy weight and vibrations from the garments manufacturing equipment contributed to the collapse. After a two-month long investigation, led by the Bangladesh Garment Manufacturers and Exporters Association (BGMEA), an eleven-member probe committee submitted a 400-page report to the Bangladeshi government. The report indicated nine main factors that lead to the collapse of Rana Plaza. Some of these factors were: the illegal addition of the two floors, the use of substandard quality building materials, the installation of heavy machinery, and the inability of the building’s pillars to support a high load capacity (Rubya, 2014). This 400-page report went on to hold inspection department officials responsible for issuing permits to the owner of the building. Government officials as well as Savar municipality officials were also found guilty for failing to oversee that the building complied with permits during the construction phase, and for approving blueprints (Rubya, 2014). The “turning of a blind eye” by officials was credited to Sohel Rana, as he was known for bribing local officials. Finally, the committee that published the report recommended to the Bangladeshi government that Sohel Rana, should be charged with a life sentence for culpable homicide (Rubya, 2014). The Bangladesh University of Engineering and Technology (BUET), examined samples of the soil and building that were collected from the wreckage. They found that “a portion of the building was constructed on land which had been a body of water before and was filed with rubbish” (Rubya, 2014, p. 690). They
went on to say, “the land itself had been ‘swampy with shallow water’” (Rubya, 2014, p. 690).

Most of the victims of the Rana Plaza disaster had their hospital expenses paid for by the government of Bangladesh or the Bangladesh Garment and Exporters Association (BMGEA). Family members who had lost someone in the disaster were given an immediate payment of 20,000 taka to cover the funeral expenses of that loved one. However, as many of the victims were buried in ancestral villages that require traveling far distances for their relatives, the money they received was barely adequate to cover the costs (Burke, 2013). Furthermore, the government promised these families a further sum of between 100,000 and 600,000 taka. However, this money was to be released at an “unspecified date” (Burke, 2013). The BMGEA has taken on the task of paying the survivors of the disaster their outstanding salaries for the month of the collapse, as well as a month’s pay for every year that person worked at Rana Plaza (Burke, 2013). The survivors have reported that very few of them have received the amount promised.

While the many disasters that have happened in garment factories around the world, Rana Plaza brought these issues to an entirely new playing field. Following the disaster, international labor organizations, NGOs, and major global retailers, negotiated a legally binding agreement that became known as the Accord on Fire and Building Safety in Bangladesh (Rubya, 2014). This forces the clothing companies that sign this agreement to help finance safety inspections and building improvements of their RMG factories in Bangladesh. Furthermore, the Bangladeshi government began to make amendments to the Bangladesh Labour Act of 2006, which aimed to improve occupational health and safety
(Rubya, 2014). This new legislation states that employees will no longer need the approval of their factory’s owner to form a union, and factories are now required to set aside five percent of their profits to fund an employee welfare program (Ruyba, 2014). There are now more than 400 unions, which is three times more than the number of unions in 2012 (Burke, 2015). However, while unions may be somewhat easier to form, the 2013 Labour Amendments did not change the stipulation those union leaders may only be permitted to select the leader of the union from their own establishments (Rubya, 2014). This is incredibly problematic because employers can fire leaders if the owners or factory managers do not like the formation of the union, without needing to have a good cause for doing so.

Further changes include improvements to workplace safety and dispute resolution. Among the amendments that were added to the safety measures, gangways and stairs must be better regulated and are required to be monitored under closed-circuit cameras and remain open during business hours (Rubya, 2014). This was to prevent any further incidences where employees were put behind locked doors to keep them in their workspaces, which is a massive fire safety hazard. Furthermore, employers must now provide personal safety equipment, as well as provide safety training so that employees can use the equipment. However, one blatant problem still exists with the Labour Act. The new amendments did not address the punishments for factory owners and other individuals found culpable in health and safety violations.

For example, according to the 2006 Act, the penalty for failing to notify authorities of any accident which results in a serious bodily injury is a fine
of up to 1000 taka, which is equivalent to about $12.66 USD. If the
accident resulted in the loss of life, the penalty for failing to report it is
imprisonment of up to six months, or a fine of up to 3000 taka—
approximately $38.00 USD—or both… The highest fine an RMG factory
owner can receive for an unreported incident, including a deadly one, is
about the same as the monthly minimum wage in the nation’s RMG
sector. The nonmonetary punishments for labor law violations are weak as
well. For instance, the maximum sentence for a contravention of the law
by an act that results in the death of a worker is imprisonment for up to
only four years (Rubya, 2014, p. 697-698).

Due to the massive amount of media coverage, the public outrage and the protests
that followed the Rana Plaza collapse, some 180 apparel brands and retailers that do
business in Bangladesh signed a legally binding contract. However, of those 180 apparel
brands and retailers only 16 of those were from the U.S (Miller, 2014). Most of the
brands and retailers that did sign onto the Accords were based in Europe. It is important
to note that many of the US retailers that have factories in Bangladesh not only refused to
the sign the Accords, they outright objected to the financial commitment and to the
legally binding nature of the Accords (Miller, 2014). The signatories of this contract
agreed to a five-year period were some 1,639 of the 3,498 factories in Bangladesh that
make garments for export that are going to have their working conditions improved. It
was signed on May 15, 2013, by around 40 of the 180 different fashion brands that do
business in Bangladesh from around the globe (Kuttner, 2013). This contract made big
retailers and apparel companies and producers finally responsible for the condition that their factories were in. No longer could they claim innocence because these companies were now responsible for the factories that produced their clothing.

Per Miller (2014, p. 10) the Accord created many important improvements to the garment industry in Bangladesh including:

- It was negotiated with two global unions, UndustriALL and UNI (Global).
- It sets up a governing board with equal numbers of labor and retail representatives, and a chair chosen by the ILO.
- Independent inspectors will conduct audits of factory hazards and make their results public on the Accord website, including the name of the factory, detailed information about the hazard, and recommended repairs.
- The retailers will provide direct funding for repairs (up to a maximum of $2.5 million per company) and assume responsibility for ensuring that all needed renovations and repairs are paid for.
- Most importantly, the Accord is legally binding. Disputes between retailers and union representatives are subject to arbitration, with decisions enforceable by a court of law in the retailer’s home country.

The retailers that refused to sign the Accords drafted their own legislation called the Alliance for Bangladesh Worker Safety. Retailers such as Wal-Mart, JC Penny, The Gap, and Sears, along with 21 other North American retailers and brands, have around 770 factories in Bangladesh (Miller, 2014). The Alliance is not legally binding like the Accords, which was a main draw for the companies that signed the Alliance.
Furthermore, it lacks language that allows for labor-organization representatives, and lessened the financial commitment to a sum of $1 million per retailer, which is to be used to implement the safety plan and needed repairs (Miller, 2014). However, there is no legally binding commitment that demands they pay for any repairs beyond that.

Using the information presented in the first three chapters of this thesis, I developed a sustainability metric (See Appendix C) that test the sustainability of a company, regarding the first two portions of the fashion supply chain: materials/fibers and production. The sustainability metric is presented in Appendix C: The Sustainability Metric.
CHAPTER 4: STYLING A NEW INDUSTRY

As the examples in this thesis have shown, sustainability is slowly integrating itself into the fashion industry. In a sense, the fashion industry is beginning to green itself. However, even though this greening is taking place, the fashion industry is an increasingly global and complex industry that makes it difficult, as well as daunting, to completely transform. While this daunting task, due to the increasingly horrific working conditions and environmental degradation, may make individuals feel helpless or like they will have little impact on the industry, many sustainable fashion brands are undertaking this daunting process to empower the consumer to realize their impact on the fast fashion industry. The fast fashion industry would not exist without consumers, it is the consumers that drive this industry, therefore if consumers began to demand more sustainable clothing options or more sustainable practices from the company, the company would be forced to comply or face going out of business.

Fast fashion has caused a move away from what clothing were originally intended for, individualism and self-expression. Fast fashion created a well-dressed army of young consumers that are all dressed identically, with little to no individuality. Slow fashion attempts to remedy this by creating pieces that are individualistic and unique from one another, giving the wearer back their own sense of style. Fashion originated as a cultural expression that was deeply embedded into its fashion wearers. It was meant to show others what the wearer wanted them to see about themselves. However, fast fashion has mechanized the fashion industry so much so that this is no longer possible. Fashion has become all about what the current trend is or what the next trend will be, creating
something that was no longer individualistic but rather something incredibly superficial. Slow fashion brands have attempted to fix the new meaning of fashion but slowing down the entire fashion supply chain. By decreasing the speed at which items are produced, it allows the pieces that are created to differ from one another. This in turn still creates an incredibly well dressed mass of people, but rather than an army of people, each person differs from one another, returning fashion back to its original meaning and intent.

Slow fashion further attempts to alter the current fast fashion model by changing the very materials that are used to create the fashion products. Gone are the traditional fibers such as: cotton, wool, polyester, rayon, silk, etc. They are now replaced with sustainable alternatives such as: organic cotton, spider silk, Ingeo, lyocell, soya, etc. However, some sustainable alternatives have not been embraced with open arms, hemp remains on the outskirts of the fiber industry, as it is still illegal to grow hemp in the United States. Although, the UK has recently repealed legislation that banned the growing of hemp, it now offers annual subsidies to farmers that grow hemp. Furthermore, as there is such a massive demand for fast fashion products, many of these sustainable alternatives are not able to meet the demand. They simply are not grown or produced in an amount that would be able to replace the conventional fibers. However, the demand for these sustainable fiber alternatives has increased dramatically in recent years, as the consumer’s sustainable knowledge has also increased. So, there is hope that this demand increases, so too will supply, which in turn will phase out many of the incredibly unsustainable fiber options such as cotton, wool, silk, polyester and rayon. As the demand for sustainable alternative increases so does the research done into alternatives,
further creating more and more sustainable fiber options, which will eventually find their way into the market.

Aside from the environmental impacts of the fashion industry, the industry has incredibly negative impacts on the people who find work in this industry. Arguably the most unsustainable part of the fashion industry is the way that workers are treated. There is a horrific connection between most of the work being outsourced to third world countries and the working conditions and treatment decreasing drastically once the work leaves a western country with heavily enforced labor standards. The fast fashion industry, which often employs women who lack many other options for employment, pays these women pennies a day, exposes them to incredibly harmful chemicals, and exposes them to horrific working conditions. These women are often forced to work overtime for no pay, work much longer work days than originally promised to them, and are often not given breaks during their work days. Furthermore, these women are not given a voice or empowered to speak up against the wrongful treatment they are exposed to for fear of losing their jobs. Some women who attempt to form unions to empower other women to stand up against their horrible treatment are fired, beaten or even killed, for their efforts. This in turn frightens any other women from taking a stance and trying to improve their working conditions.

These are the wrongs that the sustainable fashion, aka slow fashion movement, attempts to right. While they do have factories in the same developing countries that fast fashion brands do, they empower the women working for them by paying them the country’s minimum wage rather than the dollar a day that they are used to, teaching them
skills that will better their future, offering them health benefits, offering them healthy housing options, and many other options to make sure that the women in their employment are happy and taken care of. Rather than produce the garments at any cost, that fast fashion is known for, slow fashion slows down the process and uses many of the traditions that are original to the villages in these countries and empowers these women. While these slow fashion brands typically come from the western countries of the world, they focus on the “localness” of these villages and do not imply the principles of fast fashion, which often strips these countries of their traditions.

Despite all its downfalls the fashion industry has incrementally implemented sustainability improvements to better the industry as a whole. These include: environmental degrading fibers being replaced with low-chemical, low-water use, low-energy use, rapidly renewable fibers such as lyocell, PLA, organic cotton, and other plant based fibers, an improvement in environmental regulations that have contributed to the improvement in water, air and soil quality, the adoption of Environmental Management Systems and Corporate Social Responsibility (CSR) initiatives, a number of brands adopting and incorporating sustainable design practices, such as Patagonia’s Common Threads recycling program and Nike’s CSR reporting initiatives, as well as increasing the consumers awareness of the environmental and social impacts of their consumption habits.

The slow fashion movement is currently in its infancy and it will only grow over time with help from consumers. The consumers of fashion products need to realize the power that they have to effect change in the fashion industry. The fast fashion industry
needs demand to produce their endless supply of clothing, however if consumers were to begin demanding more sustainable products then the fast fashion industry would have to adapt to those demands. The multi-billion-dollar industry of global fashion is just responding to what we, as the consumers, ask of it. Society demanded fast turnaround on clothing, increased number of trends yearly and a “disposal wardrobe” and they got this through fast fashion. However, society is now seeing the errors of its way and demanding sustainable fashion products, to which the industry responded with the slow fashion movement. Slow fashion is slowly making its way through the fashion industry and changing the industry from the inside out.
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APPENDIX A: CHEMICALS

**Sodium hydroxide** is a white crystalline, odorless solid that absorbs moisture from the air (CDC, 2014). Sodium hydroxide separates in water to sodium cations and hydroxide anions, which ultimately decrease the acidity of the water. In the case of the ocean, if it were to become more acidic it would cause marine life such as, clams, mussels, etc. to produce weaker shells and eventually lead to their death. Furthermore, if coral were exposed to a more acidic ocean, it would be drastically affected due to it being made of calcium carbonate (Stoller-Conrad & Mansfield, 2017). The mass die outs of coral in recent decades due to climate change has shown how important coral is to our environment because it produces food and oxygen for marine life. The ocean must maintain a delicate balance of salt and if there is an excess of salt in the ocean it makes the water heavier, which affects the oceans currents (Stoller-Conrad & Mansfield, 2017).

**Bleach** can also be known as **sodium hypochlorite**, it is a colorless or slightly yellow watery liquid with an odor of household bleach, it mixes with water (CDC, 2014). Once bleach reaches a water source, the chlorine reacts with other minerals found in the water to form various dangerous toxins. The toxins that are created include: dioxins, furans and PCDDs, these are often referred to as persistent organic pollutants as they take many years to disappear from water sources and soils (Beach, 2015). The environmental action organization Greenpeace has called dioxin “one of the most dangerous chemicals known to science,” the organization warns that it can contribute to cancer, endocrine disorder and various other very serious health effects (Beach, 2015). Furthermore, a study done by
the West Virginia University Extension found links between chlorine-based compounds, such as dioxins, with a low sperm count, testicular cancer and breast cancer due to the chemicals ability to mimic human hormones (Beach, 2015). This study also found that if animals are exposed to these chemicals it poses great risk to local wildlife populations, as cancer has been found in laboratory animals (Beach, 2015). Dioxins were directly responsible for the devastation of the bald eagle population and it further reduces the number of fish and bird species near the Great Lakes (Beach, 2015). If chlorine beach is emitted in the air it remains in the air, where the chemicals further contribute to air pollution.

**Formaldehyde** is a colorless, flammable gas that has a distinct, pungent smell (ATSDR, 2015). The biggest problem with formaldehyde is that it slowly over time gives off toxic vapors over time, which can have impacts to human health as well as to animals. However, formaldehyde is quickly removed from the air by reactions with other chemicals found in the atmosphere. It also breaks down quickly from water and soil, usually within a few days. However, it can damage crops if they are directly exposed or the soil they are growing in is exposed (ATSDR, 2015).

**DDT**, which has been banned in many developed countries, can still be found in many under-developed or developing nations. DDT is known to have incredibly negative health effects as well as environmental impacts. Some health impacts include: tremors, seizures, sweating, headaches, nausea, vomiting, dizziness, and deterioration of the nervous system
(ATSDR, 2015). The effects to the environment are even more severe, these include: surviving in soil, air and water for longer periods of time, carrying long distances, evaporating into the air and being deposited in other places, sticking strongly to soil, can seep into groundwater, accumulates to high levels in fish and marine mammals (such as seals and whales), and many more (ATSDR, 2015).

Exposure to **trichloroethylene** in the workplace has been linked with scleroderma, which is a systemic autoimmune disease. Some men who are exposed to trichloroethylene have showed a decrease in sex drive, sperm quality and reproductive hormone levels (ATSDR, 2016). There is also strong evidence that shows it can cause kidney cancer and live cancer, as well as malignant lymphoma (ATSDR, 2016). It also has negative environmental impacts, as it is remains in groundwater sources because it is unable to evaporate as it would in the air or open water sources.

**Cobalt** enters the environmental through various natural sources, however the main source comes from the burning of coal or oil. Cobalt can only change form or attach to or separate from particles, meaning it does not break down easily in the environment (ATSDR, 2011). Cobalt can either benefit or harm human beings, as it is naturally occurring. However, high levels of exposure to cobalt can lead to negative effects in the lungs and heart, as well as lead to dermatitis. Liver and kidney effects have also been seen in animals that have been exposed to high levels of cobalt (ATSDR, 2011).
**Manganese** is a naturally occurring element, it can be found in many types of rocks, soil, water, air and food. If manganese finds its way into water sources, it tends to attach to particles in the water and settle into the sediment (ATSDR, 2015). Inhalation or ingestion of manganese can result in central nervous system pathology, because the brain is a critical target organ for manganese deposition (Rollin & Nogueria, 2011). High levels of exposure to manganese have been known to lead to manganese poisoning, manganism, and Parkinson’s disease (Rollin & Nogueria, 2011).

Acute exposure to **sodium bromide** can cause mild skin irritation, eye irritation, respiratory tract irritation, gastrointestinal tract irritation with nausea and vomiting, abdominal pain, and constipation. However, prolonged exposure can cause dermatitis and damage to the central nervous system (CDC, 2014). This chemical is not known to cause cancer in animals or human. Sodium bromide is an inorganic salt. It fully dissociates in water to bromide and sodium ions. It also undergoes degradation in soil to bromide ions (HaloSource, Inc, 2007).

**Antimony** is a silvery-white metal that is found in the earth’s crust. When antimony is released into the air it may attach to very small particles that can stay in the air for several days (CDC, 2014). However, most often antimony ends up in soil, where it attaches to particles that contain iron, manganese, or aluminum (CDC, 2014). It can be found in low levels in some rivers, lakes and streams (CDC, 2014). Due to its naturally occurring nature, exposure to antimony in small amounts it does not result in negative health
effects. If an individual breathes in large levels of antimony for long periods of time can irritate eyes and lungs, and cause heart and lung problems, stomach pain, diarrhea, vomiting and stomach ulcers (CDC, 2014). Lung cancer has been found in some studies of rats that breathed high levels of antimony. In short-term studies where animals breathed very large levels of antimony, the animals died (CDC, 2014). Titanium dioxide has been found to cause redness and irritation in humans, if inhaled. There are no known environmental impacts (CDC, 2015).

**Greenhouse gases** that contribute to global warming include: water vapor, carbon dioxide and methane. Carbon dioxide is the primary greenhouse gas that is emitted by human activity. In 2014, CO$_2$ accounted for about 80.9% of all U.S. greenhouse gas emissions (EPA, n.d.). The main human activity that emits CO$_2$ is the combustion of fossil fuels, namely, coal, natural gas, and oil. These are mainly used for energy and transportation. These greenhouse gases absorb energy, while slowing or preventing the loss of heat to space (EPA, n.d.). Greenhouse gases, in a sense act like a giant blanket over the planet, trapping in heat and making the Earth warmer than it would be without the presence of those greenhouse gases. This is commonly known as the greenhouse effect. Carbon dioxide is not destroyed by time but rather it moves among different parts of the ocean-atmosphere-land system (EPA, n.d.). While some of the carbon dioxide will be absorbed rapidly by the ocean surface, however some will remain in the atmosphere for thousands of years, continuing to act like a blanket on the planet.
**Nitrogen oxides** are a mixture of gases that are composed of nitrogen and oxygen (ATSDR, 2002). These chemicals find their way into the air from the exhaust of motor vehicles, the burning of coal, oil or natural gas, and during processes such as welding, electroplating, engraving, and dynamite blasting (ATSDR, 2002). Nitrogen oxides are broken down rapidly in the atmosphere by reacting with other substances that are commonly found in the air. This reaction of nitrogen dioxide with chemicals, leads to the formation of nitric acid, which is a major constituent of acid rain (ATSDR, 2002). Nitrogen oxide, also reacts with sunlight, causing the formation of ozone and smog conditions. Very small amounts of nitrogen oxides can evaporate from water and soil sources, but most of it will react with the water and create nitric acid and other compounds (ATSDR, 2002). Low levels of nitrogen oxide exposure can irritate your eyes, nose, throat and lungs, leading you to cough and potentially experience shortness of breath, tiredness, and nausea. However, high levels of exposure to nitrogen oxides can cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of body tissues, a build-up of fluid in your lungs and death (ATSDR, 2002).

**Hydrocarbons** can also be known as *total petroleum hydrocarbons (TPH)*, these describe a large family of several hundred chemical compounds that originally come from crude oil (ATSDR, 2014). If some TPH fractions are exposed to water sources, they will float on the water and form surface films, while others may sink to the bottom sediments (ATSDR, 2014). Some TPH fractions can move from the water into the soil,
where they will stay for a long period. If human beings are exposed to TPH compounds it can affect your central nervous system. One compound can cause headaches and dizziness at high levels in the air, while another compound can cause a nerve disorder called “peripheral neuropath”, while other compounds can cause effects in the blood, immune system, lungs, skin and eyes (ATSDR, 2014). Studies done on animals have shown that TPH compounds have effects on the lungs, central nervous system, liver, and kidneys, as well as affect reproduction and the developing fetus of animals. The International Agency for Research on Cancer (IARC) has determined that one specific compound, benzene, is carcinogenic to humans. Other compounds such as benzo[a]pyrene and gasoline, are probably and possibly carcinogenic to humans (ATSDR, 2014).

**Sulfur dioxide** is produced mainly from activities that involve burning coal and oil at power plants or form copper smelting. However, it can be produced in nature from volcanic eruptions (ATSDR, 2014). When sulfur dioxide is exposed to air, it is converted to sulfuric acid, sulfur trioxide, and sulfates. It dissolves in water; however, it can form sulfuric acid (ATSDR, 2014). If a human being is exposed to high levels of sulfur dioxide it can be life threatening. Symptoms include: burning of the nose and throat, breathing difficulties, severe airway obstruction and lung function changes (ATSDR, 2014).
Carbon monoxide, CO, is found in the fumes produces from burning fuel in cars or trucks, small engines, stoves, lanterns, grills, fireplaces, gas ranges or furnaces (CDC, 2015). However, carbon monoxide is especially dangerous because it is odorless and colorless, essentially indictable. The most common symptoms include: headache, dizziness, weakness, upset stomach, vomiting, chest pain, and confusion. These symptoms are commonly described as “flu-like” (CDC, 2015). Exposure to carbon monoxide impedes the blood’s ability to carry oxygen to body tissues and vital organs (CDC, 2015). When carbon monoxide is released into the air, it remains in the atmosphere for an average of about 2 months (CDC, 2015). Eventually in the atmosphere, carbon monoxide will react with other chemicals and compounds to create carbon dioxide, further adding to greenhouse gas emissions. Furthermore, microorganisms found in soil and water sources can also convert carbon monoxide into carbon dioxide (CDC, 2015).
APPENDIX B: PICTURES

Figure 1. Cotton Plant. Photo Courtesy of the United States Agriculture Department.

Figure 2. The Aral Seal 1989 (Left) and 2014 (Right). Photo Courtesy of NASA.
Figure 3. Sheep. Photo Courtesy of the Agriculture Research Service.

Figure 4. Wool Before and After Scouring. Photo Courtesy of CSIRO.
Figure 5. The Silk Route. Photo Courtesy of NASA.

Figure 6. Silkmoth or Bombyx Mori. Photo Courtesy of J. Ash Bowie.

Figure 7. Silkworm Cocoon. Photo Courtesy of Gerd A. T. Muller.
Figure 8. Raw Silk. Photo Courtesy of Armin Kubelbeck.

Figure 9. Details of the Flax Plant, from which Linen Fibers are Derived. Photo Courtesy of Franz Eugen Kohler.
Figure 10. Differences Between Sativa and Indica Cannabis. PhotoCourtesy of Medicinal Genomics.

Figure 11. Cannabis sativa L. subspecies Sativa. Photo Courtesy of Barbetorte.
Figure 12. Bamboo Stalk. Photo Courtesy of Alain Van der Hende.

Figure 13. Bamboo Forest, Taiwan. Photo Courtesy of Bernard Gagnon.
Figure 14. Garment Factories in Bangladesh. Photo Courtesy of Fahad Faisal.

Figure 15. Dhaka Savar Building Collapse. Photo Courtesy of Rijans.
Figure 16. Rana Plaza Taken One Year Before the Collapse. Photo Courtesy of Sean Robertson.
APPENDIX C: THE SUSTAINABILITY METRIC

The metric was developed through incredibly extensive research and through a literature review method showcased in the first three chapters of this thesis. I used a variety of academic articles, books, journal articles, newspaper articles, etc. to discover the currently unsustainable practices that the fast fashion industry was using, as well as sustainable ways to remedy these unsustainable practices. In order to construct this thesis I used various other sustainability metrics as a model, mainly using the Higg Index, which was created by the Sustainable Apparel Coalition. The Higg Index is considered a metric that focuses on apparel and footwear industry self-assessment standard for assessing environmental and social sustainability throughout the supply chain, there are two separate indexes, which focus on production or the brand. Furthermore, another metric that instrumental in the construction of this metric was The Sustainability Metrics, Sustainable Development Progress Metrics, recommended for use in the Process Industries created by the Institution of Chemical Engineers in 2002.

I divided the sections of the metric as follows: general questions about the company, environmental sustainability, social sustainability and economic sustainability. While the sustainability metric will not be tested during this thesis, it is ready to be tested. The metric begins with general questions about the company to understand where the company stands on the sustainability scale. The lower the score on the first seven questions, typically the lower the score will be for the overall metric. When answering the questions that this metric poses, there are some positive values and some negatives ones, the positive ones are to reward a company for their steps toward more sustainable
practices, while the negative values are to show that the company is lacking in that
department of sustainability. Furthermore, this metric allows for further research as the
first two portions of the fashion supply chain, the materials/fibers and production phases,
are the only two that are measured by this metric. However, there are five total steps of
the fashion supply chain: materials/fibers, production, retail, consumer use, and end-of-
life. It was not in the scope of this thesis to be able to do a literature review and build the
metric to test all five portions of the supply chain.

The company using this metric will be given a numeric value after each of these
sections, which will later be added together to give them a grand total. This overall score
will translate into six possible ratings: excellent, very good, good, weak, poor, fail. The
excellent rating will include scores from 110 through 66, very good will include scores
from 65 through 21, the good rating will include scores from 20 through -24, weak will
include scores from -23 to -67, poor will include scores from -68 through -111, and fail
will include scores from -112 through -153. A company can lose points while using this
metric to test their sustainability, if the practices they currently use are unsustainable,
which is why it is possible for a company to get a negative score at the end. Furthermore,
if the company loses points on a question because they do not use this sustainable
method, there is already a sustainable method at their disposal through this metric to
remedy their unsustainable practices. If this practice were implemented then they would
gain back the point that they previously had lost.
General Questions

1. Has the company conducted a full life cycle assessment (LCA) of the entire fashion supply chain of at least one of its products to assess sustainability? (if yes, +1, if no -1)
   a. Are the LCA results and data shared publicly? (if yes, +1, if no -1)
2. Does the brand regularly report their sustainability efforts and performance? (i.e. Sustainability Report, CSR Report, Integrated Report etc.) (if yes, +1, if no -1)
3. Does the brand follow internationally recognized standards for their sustainability reporting? (if yes, +1, if no -1)
4. Does the brand have this information externally reviewed or verified? (if yes, +1, if no -1)
5. Does the company make this information readily available to the public? (if yes, +1, if no -1)
6. Does the brand set targets and goals to reduce their environmental and social impacts? (if yes, +1, if no -1)
7. Has a formal Social Life Cycle Analysis (SLCA) been done on some of the products produced by this site or brand to inform social performance impacts, social performance strategy and priorities? (if yes, +1, if no -1)
   a. Describe the products that were used for testing.
   b. Describe the results of the SLCA

Possible Points Range: -8 to +8

Your total: _____________
Environmental Impacts

1. Does the company have negative environmental impacts? *(if no, +1, if yes -1)*
   a. Please list any negative impacts:

### Resource Usage

(a) Energy usage
   a. Factory

<table>
<thead>
<tr>
<th>Energy Value</th>
<th>Quantity used per year</th>
<th>Usage rate GJ/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>kJ</td>
<td></td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>kJ/kg</td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>kJ/kg</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>kJ/kg</td>
<td></td>
</tr>
<tr>
<td>Steam</td>
<td>kJ/kg</td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td>kJ/kg</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Has the site had an energy audit conducted in the last three years by a certified professional to identify potential energy and cost savings? *(if yes, +1, if no -1)*
   a. If yes, answer the following:
      i. When was the audit conducted? *(if energy audit done in 2017 +2, in 2016 +1.5, in 2015 +1, if done in 2014 +.5, done after 2014 +0)*
      ii. What opportunities for reducing energy were identified in the audit?

3. Has the site implemented any energy conservation or efficiency measures? *(if yes, +1, if no -1)*

4. Have any of these measures been implemented? *(+1 for each measure implemented in the table below)*
1. Energy conservation measures

<table>
<thead>
<tr>
<th>Energy conservation measures</th>
<th>If so, mark with an X</th>
<th>Describe the energy conservation measures</th>
<th>Year measure were implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat exchange or heat recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal energy storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formal retro-commissioning process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved preventative maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central building management system (controls)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High efficiency motors and/or variable frequency drives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computerized facility climate control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimize compressed air system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broiler renovation/replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam leak repair program</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain steam traps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulate pipes and hot vessels and tanks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel switch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-site renewable energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy efficient lighting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daylighting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. What percentage of your energy use is from any on-site or off-site renewable sources (e.g. wind, solar, hydro-electric, geothermal, biomass, etc.)? (+1 for each type of renewable used in the table below)
<table>
<thead>
<tr>
<th>Renewable Energy Source</th>
<th>Quantity used/year</th>
<th>Usage rate GJ/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiant energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geothermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Water**

<table>
<thead>
<tr>
<th>Source of water used</th>
<th>If so, mark with an X</th>
<th>Quantity of source used</th>
<th>What is the major end use(s) of this water source?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal water or third party water supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water (river, stream, lake, ocean)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclaimed/recycled water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. How much water is used at the site year each?
   a. Usage
   b. Unit of measurement
2. Has your site had a water audit conducted to identify potential water and cost savings in the last three years? *(if yes, +1, if no -1)*
   a. If yes, answer the following:
      i. When was it conducted? *(if energy audit done in 2017 +2, in 2016 +1.5, in 2015 +1, if done in 2014 +.5, done after 2014 +0)*
      ii. Was it conducted by a third party or internally? *(+1 for third party, +.5 for internally)*
         1. If done internally did a third party verify it? *(+.5 if yes)*
iii. What opportunities were identified?
iv. What opportunities were implemented?

3. Is water used on site recycled internally? (if yes, +1, if no -1)
a. Where is water captured and where is it reused?

Aquatic Acidification

(For every substance found from the table below that is a direct result of site -1)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tones W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfuric acid</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>0.027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen fluoride</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic acid</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“The potency factor is the mass of hydrogen ion released by unit mass of acid i.e. the number of hydrogen ions released divided by the molecular weight. The unit of Environmental Burden is te/y of H+ ions released. The calculation of the H+ ion is the preferred method of driving the potency factor in this category, however measured pH values may also be used” (Institution of Chemical Engineers, 2002).

Ecotoxicity to Aquatic Life

(For every substance found from the table below that is a direct result of site -1)
**Emissions**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>16.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>0.125</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“The potency factor is equal to the reciprocal of the Environmental Quality Standard (EQS) divided by the reciprocal of the EQS of copper. The unit of Environmental Burden is te/y copper equivalent” (Institution of Chemical Engineers, 2002).

Other Substances

(For every substance found from the table below that is a direct result of site -1)
**Emissions**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanide</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2-Dichloroethane (EDC)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>166.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexachlorobutadiene</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrophenol</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>0.125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethylene (PER)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene (TRI)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xylenes</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“The above potency factors are equal to the reciprocal of the Environmental Quality Standard (EQS) divided by the reciprocal of the EQS of formaldehyde. The unit of Environmental Burden is te/y formaldehyde equivalent” (Institution of Chemical Engineers, 2002).

**Eutrophication**

*(For every substance found from the table below that is a direct result of site -1)*
### Emissions

<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO₄ (III-)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>3.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Eutrophication is defined as the potential for over-fertilization of water and soil, which can result in increased growth of biomass. The species above are those considered to be responsible for eutrophication. The unit of Environmental Burden is te/y phosphate equivalent” (Institution of Chemical Engineers, 2002).

### Wastewater

<table>
<thead>
<tr>
<th>Does your site have any of the following?</th>
<th>If so, mark with an X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dying</td>
<td></td>
</tr>
<tr>
<td>Tanning</td>
<td></td>
</tr>
<tr>
<td>Lamination</td>
<td></td>
</tr>
<tr>
<td>Wet finishing</td>
<td></td>
</tr>
<tr>
<td>Boiler blow-down</td>
<td></td>
</tr>
<tr>
<td>Steam generation</td>
<td></td>
</tr>
<tr>
<td>Cooling waters</td>
<td></td>
</tr>
<tr>
<td>Printing</td>
<td></td>
</tr>
<tr>
<td>Screen printing</td>
<td></td>
</tr>
<tr>
<td>Degreasing (machinery)</td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td></td>
</tr>
<tr>
<td>Landscape irrigation</td>
<td></td>
</tr>
<tr>
<td>Stormwater runoff</td>
<td></td>
</tr>
</tbody>
</table>

1. Is all the wastewater produced at your site being treated with primary and secondary treatment? (**if yes, +1, if no -1**)
   a. If yes, answer the following:
      i. Where is the primary and secondary treatment occurring (on-site, off-site, or a combination of both)? (**On site +2, combination of both +1.5, off-site +1**)

---

**Substance**

**Potency Factor**

**PF**

**Tonnes W**

**EB Value = W x PF**

**TOTAL**
1. If treatment is occurring on-site, what specific types of treatment are used: primary, secondary or tertiary? (for each type used +1)

2. If any treatment is occurring off-site, what treatment facility used and where is it located?

2. Is there any monitoring system in place that records the quantity and quality of the wastewater produced? (if yes, +1, if no -1)
   a. If yes, answer the following:
      i. What contaminants are found in the effluent?
      ii. At what frequency and levels are these contaminants found?

3. How much wastewater is produced daily?

4. Describe your process for testing wastewater quality.

Material Usage (excluding fuel and water)

<table>
<thead>
<tr>
<th>Material Usage</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total raw materials used, including packaging</td>
<td></td>
</tr>
<tr>
<td>Raw materials recycled from other company operations</td>
<td></td>
</tr>
<tr>
<td>Raw materials recycled from consumer</td>
<td></td>
</tr>
<tr>
<td>Raw material used which poses health, safety or environmental hazard</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total raw materials used per kg product</td>
<td>kg/kg</td>
</tr>
<tr>
<td>Total raw materials used per unit value added</td>
<td>kg/US $</td>
</tr>
<tr>
<td>Fraction of raw materials recycled within company</td>
<td>kg/kg</td>
</tr>
<tr>
<td>Fraction of raw materials recycled from consumer’s</td>
<td>kg/kg</td>
</tr>
<tr>
<td>Hazardous raw material per kg product</td>
<td>kg/kg</td>
</tr>
</tbody>
</table>

1. Select the following fibers used by company.
### Fiber Amount Used Percentage of Total Fibers Used

- **Cotton**
- **Genetically Modified Cotton**
- **Organic Cotton**
- **FairTrade Cotton**
- **Wool**
- **Silk**
- **Wild (or Peace) Silk**
- **Spider Silk**
- **Rayon**
- **Polyester**
- **Recycled PET**
- **Linen (Flax)**
- **Hemp**
- **Bamboo**
- **Ingeo**
- **Soya**
- **Lyocell (Tencel)**

6. List the name and location of the following entities that you use:

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dye houses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washing facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundry suppliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanneries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outsole manufacturers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embroiders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screen printing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trim suppliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing suppliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcontractors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Atmospheric Acidification**

*(For every substance found from the table below that is a direct result of site -1)*
<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>1,400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorodifluoromethane, R22</td>
<td>1,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloroform</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloropentafluoroethane, R115</td>
<td>9,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichlorodifluoromethane, R12</td>
<td>8,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichlorotetrafluoroethane, R114</td>
<td>9,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difluoroethane</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexafluoroethane</td>
<td>9,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>310</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen Oxides (NOx)</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentafluoroethane, R125</td>
<td>2,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfluoromethane</td>
<td>6,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrafluoroethane</td>
<td>1,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethane (1,1,1)</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichlorofluoromethane, R11</td>
<td>4,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichlorotrifluoroethane, R113</td>
<td>5,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifluoroethane, R143a</td>
<td>3,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifluoromethane, R23</td>
<td>11,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile Organic Compounds</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“These potency factors are based on a 100-year integrated time horizon. The unit of Environmental Burden is te/y carbon dioxide equivalent – the global warming potential” (Institution of Chemical Engineers, 2002).

<table>
<thead>
<tr>
<th>Substance</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>1.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCl</td>
<td>0.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂SO₄ mist</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“The potential of certain released gases to form acid rain and acids to water is the potency factor for atmospheric acidification. The unit of Environmental Burden is te/y Sulphur dioxide equivalent” (Institution of Chemical Engineers, 2002).

**Possible Points Range: -80 to +43**

**Your Total: ____________**
Social Sustainability

1. Do workers receive a contract starting from the first day of hiring? (if yes, +1, if no -1)
2. Do workers receive a full explanation of the content of their contract? (if yes, +1, if no -1)
   a. Demonstrate how.
3. During the hiring process are the following check? Please mark which ones apply. (+1 for reach of the following that is checked)
   - ID Card
   - Birth Certificate
   - Education Certificate
   - Family Card
   - Previous Employment Record
4. Are workers directly paid by the facility or through a third party?
   a. If paid through third party, who issues checks?
   b. Are paychecks always issued on time? (+1 for yes, -1 for no)
   c. Are there instances where pay is held for an unwarranted reason? (+1 for no, -1 for yes)
5. Based on country of origin, what is the national minimum wage?
   a. Are workers receiving at least that? (if yes, +1, if no -1)
      i. Write amount workers receive here __________
   b. What is cost of living in country?
   c. Is pay grade livable compared to cost of living? (if yes, +1, if no -1)
6. Does this company employ workers under the age of the local minimum working age? (+1 for no, -1 for yes)
7. Are workers provided with affordable and livable housing? (if yes, +1, if no -1)
8. Are overtime hours voluntary or mandatory? (+1 for voluntary, -1 for mandatory)
   a. If mandatory, what pay are workers receiving? (+1 if pay is above normal, -1 if it is the same or less than normal pay)
9. Is time off offered in accordance with country’s labor laws? (if yes, +1, if no -1)
10. Are workers provided with breaks during work day? (if yes, +1, if no -1)
    a. If so, how long are breaks?
    b. How often are they given breaks?
11. Is there the option for workers to join a union? (if yes, +1, if no -1)
    a. Have previous workers experienced any backlash for joining the union? (+1 for no, -1 for yes)
12. Have there been any incidences of work place violence or sexual assault in the last year? (+1 for no, -1 for yes)
    a. If so:
       i. How many?
ii. Was the victim offered help paying any medical costs associated? (if yes, +1, if no -1)

iii. Was the assailant charged with the crime? (if yes, +1, if no -1)

13. Primary means of transportation for workers? Walking, buses, bikes, cars?

14. Average commute for workers _______________miles/per day

15. Are workers offered and have access to any benefits? (+1 for each one offered from table below)

<table>
<thead>
<tr>
<th>Benefits workers are offered and have access to:</th>
<th>If so, mark with an x</th>
<th>Explain options offered:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation subsidies and/or free transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child care services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing subsidies and/or free housing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food subsidies and/or free food</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free potable water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food available for voluntary purchase by workers at the Facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing is available for voluntary purchase by workers at the Facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of living increases or bonuses are given when the company has a profitable year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(+1 for each one offered for free to employees)

<table>
<thead>
<tr>
<th>Does your site have the following?</th>
<th>If so, mark with an X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canteen</td>
<td></td>
</tr>
<tr>
<td>Dormitories</td>
<td></td>
</tr>
<tr>
<td>Washrooms</td>
<td></td>
</tr>
<tr>
<td>Laundry/washing</td>
<td></td>
</tr>
</tbody>
</table>

16. What is the number of complaints reported in the last year?
   a. How are they addressed?

17. What is the number of corruption charges or industrial relations action in the last year?
18. What is the number of safety incidences and environmental accidents with an impact on the community or workers that have taken place in the last year?

**Human Health**

1. Do workers come into direct contact with chemicals? (if no +1, if yes -1)
   a. If yes, please list chemicals below:

2. Are any of these chemicals used in the workplace considered harmful to human health? (if no +1, if yes -1)
   a. If yes, please list the chemicals and their effects.

Annotations:
BMGV—biological monitoring guidance values
Carc—capable of causing cancer and/or heritable genetic damage
Sen—capable of causing occupational asthma.
Sk—can be absorbed through the skin. The assigned substances are those for which there are concerns that dermal absorption will lead to systemic toxicity.

(-1 for each of the chemicals the employees are exposed to)
<table>
<thead>
<tr>
<th>Substance</th>
<th>CAS Number</th>
<th>Potency Factor PF</th>
<th>Tonnes W</th>
<th>EB Value = W x PF</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony &amp; compounds except stibine, as SB</td>
<td>7440-36-0</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic &amp; compounds except arsine, as AS</td>
<td>7440-38-0</td>
<td>160</td>
<td></td>
<td></td>
<td>Carc</td>
</tr>
<tr>
<td>Benzene</td>
<td>107-13-1</td>
<td>3.6</td>
<td></td>
<td></td>
<td>Carc, Sk</td>
</tr>
<tr>
<td>Beryllium &amp; compounds</td>
<td>8000</td>
<td></td>
<td></td>
<td></td>
<td>Carc</td>
</tr>
<tr>
<td>Cadmium &amp; compounds</td>
<td>640</td>
<td></td>
<td></td>
<td></td>
<td>Carc (cadmium metal, cadmium chloride, fluoride and sulphate)</td>
</tr>
<tr>
<td>Carbon disulphide</td>
<td>136-23-6</td>
<td>0.5</td>
<td></td>
<td></td>
<td>Sk</td>
</tr>
<tr>
<td>Chromium (VI) compounds</td>
<td></td>
<td>320</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt &amp; compounds</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td>Carc (cobalt dichloride and sulphate), Sen</td>
</tr>
<tr>
<td>Cotton dust</td>
<td></td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>50-00-0</td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man-made mineral fiber</td>
<td></td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel &amp; inorganic compounds</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td>Sk, Carc (nickel oxides and sulphides), Sen (nickle sulphate)</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCB)</td>
<td>1336-36-3</td>
<td>160</td>
<td></td>
<td></td>
<td>Sk</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“The potency factor for this table above has been derived from the reciprocal of the Occupational Exposure Limits (OEL) set by the UK Health and Safety Executive. The OEL for benzene has been chosen as the normalizing factor for this category. For other chemicals take the OEL in mg m$^{-3}$, calculate the reciprocal and divide it by the reciprocal of the OEL for benzene (0.0625) i.e. $PF_{substance} = (OEL_{benzene} / OEL_{substance})$. Chemical with an OEL greater than 500 mg m$^3$ will have a minimal impact on the total weighted impact. The unit of Environmental Burden is te/y benzene equivalent” (Institution of Chemical Engineers, 2002).

**Other Potential Harmful Chemicals**
(-1 for each of the chemicals the employees are exposed to)
<table>
<thead>
<tr>
<th>Substance</th>
<th>Workplace exposure limit</th>
<th>Comments</th>
<th>Mark if employees come in contact with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long-term exposure limit (8-hr)</td>
<td>Short-term exposure (15 min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>mg.m$^{-3}$</td>
<td>ppm</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>5000</td>
<td>9150</td>
<td>15000</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>30</td>
<td>35</td>
<td>200</td>
</tr>
<tr>
<td>Ethanol</td>
<td>1000</td>
<td>1920</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>200</td>
<td>-</td>
<td>400</td>
</tr>
<tr>
<td>Formic acid</td>
<td>5</td>
<td>9.6</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>100</td>
<td>183</td>
<td>-</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Phenol</td>
<td>2</td>
<td>7.8</td>
<td>4</td>
</tr>
<tr>
<td>Sodium hydrogen sulphite</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphuric acid (mist)</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Titanium dioxide</td>
<td>-</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>total inhalable respirable</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>100</td>
<td>550</td>
<td>150</td>
</tr>
</tbody>
</table>

*The Health and Safety Executive gathered the above information from EH40/2005 Workplace exposure limits book published.*

3. If workers have contact with any potentially harmful chemicals, are there medical professionals on site to monitor their health? *(if yes, +1, if no -1)*

4. Does the facility provide free, voluntary and confidential medical screenings? *(if yes, +1, if no -1)*
   a. If yes:
i. Are the screenings provided on-site? (if yes, +1, if no -1)
ii. Are employees informed of these screening opportunities? (if yes, +1, if no -1)

5. Are the workers offered health care plans? (if yes, +1, if no -1)
6. Do workers that encounter these harmful chemicals have the appropriate health safety measures in place, as stipulated by the MSDS form? (if yes, +1, if no -1)
7. Are there any action plans in place or being implemented to improve chemicals management performance that is reviewed and updated at least annually? (if yes, +1, if no -1)
8. Is proper training given to employees that will be handling these potentially harmful and toxic chemicals? (if yes, +1, if no -1)
9. Is there a health and safety officer on staff to monitor employees? (if yes, +1, if no -1)

Women in the Workplace

1. Are women employees offered maternity leave? (if yes, +1, if no -1)
2. What is average pay women are receiving compared to male employees? (if yes, +1, if no -1)
3. Number of women in higher-level jobs or management positions compared to men.

Possible Points Range: -59 to +53

Your Points:
Economic Sustainability

**Profit, Value and Tax**

<table>
<thead>
<tr>
<th>Description</th>
<th>$/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td></td>
</tr>
<tr>
<td>Cost of goods, raw materials and services purchased</td>
<td></td>
</tr>
<tr>
<td>Value added</td>
<td>$/y (see note a)</td>
</tr>
<tr>
<td>Gross margin</td>
<td>$/y (see note b)</td>
</tr>
<tr>
<td>Net income before taxes</td>
<td></td>
</tr>
<tr>
<td>Taxes (total paid to all taxing authorities)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

a) *Value added by the operation is the value of sales less the cost of goods, raw materials (including energy) and services purchased.*

b) *Gross margin is the value of sales minus all variable costs.*

**Investments**

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of direct employees (full-time)</td>
<td></td>
</tr>
<tr>
<td>Number of new employees</td>
<td></td>
</tr>
<tr>
<td>Number of employees with higher education</td>
<td></td>
</tr>
<tr>
<td>Total wages expense</td>
<td>$/y</td>
</tr>
<tr>
<td>Total benefits expense</td>
<td>$/y</td>
</tr>
<tr>
<td>Payroll expense = wage + benefits</td>
<td>Total $/y</td>
</tr>
<tr>
<td>Total training expense for direct employees</td>
<td></td>
</tr>
</tbody>
</table>

1. What is the country of origin’s GDP?
2. What is the country of purchase’s GDP?
3. Have the sustainable development goals been adopted in the country of origin? *(if yes, +1, if no -1)*
   a. If yes, what goals have been implemented?
4. What is the employment rate in country of origin?
5. What is the unemployment rate in country of origin?
6. Is the distribution of wealth even in the country of origin? *(if yes, +1, if no -1)*
7. Do workers have a percentage of disposable income? *(if yes, +1, if no -1)*
8. Are there population areas in the country of origin with poverty levels more than 1.5 the state rate? *(if yes -1, if no +1)*
9. Are there households with incomes more than 200% above the poverty line? *(if yes, +1, if no -1)*
   a. If yes, what is the percentage of households?
10. Are there population areas with per capita incomes less than 70 percent of US? *(if yes -1, if no +1)*

**Possible Points Range:** -6 to +6

**Your points:**
Grading Scale

Excellent = 110 through 66
Very good = 65 through 21
Good = 20 through -24
Weak = -23 through -67
Poor = -68 through -111
Fail = -112 through -153

General Score = _______________
Environmental Sustainability Score = ______________
Social Sustainability Score = ______________
Economic Sustainability Score = ______________

Total Score = __________________