MASTER THESIS

Exploration of the feasibility and implication of introducing bioplastic to the clothing industry: Towards circular fashion

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ABSTRACT

The textile industry is one of the largest industries worldwide, facing significant challenges due to its adverse environmental impacts, including high greenhouse gas emissions, energy consumption, and waste generation. This study focuses on the potential of bioplastics as a sustainable solution to promote circularity in the clothing industry. Bioplastics, derived from renewable resources or agri-food waste could reduce environmental harm caused by traditional plastics. However, their successful integration into the clothing market depends on various drivers and barriers. This research aims to identify the significant factors influencing the development and commercialization of bioplastic applications in the clothing industry, along with analyzing the social readiness for sustainable clothing. The study employs a qualitative and quantitative research methodology, including interviews, surveys, and literature review. The technical factors, encompassing bioplastic properties, available resources, and technology, play a crucial role in the development of bioplastics applications. Overcoming technical barriers requires addressing issues such as production infrastructure and scaling. Economic factors, including production costs, market demand, and raw material prices, also influence the adoption of bioplastics in the clothing industry. Strategies like price contracting and incentives from public authorities are recommended to facilitate the commercialization process. The social acceptance of bioplastic- based clothing is investigated through social readiness framework, revealing consumers' willingness to pay a premium for sustainable materials and extend the lifespan of their clothes to reduce waste. However, fashion trends remain a key consideration. Building trust in sustainable clothing technologies can be achieved through open access to life cycle assessment reports, enabling consumers to track the environmental impact of their apparel. The study findings demonstrate that bioplastics have the potential to contribute to circularity in the clothing industry. However, further research and development are necessary to overcome technological barriers. The willingness of consumers to embrace sustainable clothing options and their willingness to pay a premium provide opportunities for the successful commercialization of bioplastics. Enhancing social awareness of the environmental impacts of the clothing industry and promoting sustainable clothing technologies are essential to prepare society for the transition to sustainable clothing.

Keywords: bioplastics, clothing industry, circular economy, social readiness, sustainability

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CHAPTER 1: INTRODUCTION

1.1 Background

The textile industry is one of the largest industries in the world, with a global production value of over 2.5 trillion USD in 2020 and an anticipated production value of 3.12 trillion USD by 2025 (Shishoo, 2012). This industry, which produces fibers, fabrics, carpets, furniture, apparel, and other textile products, is vast. The industry is typically broken down into three subsectors (Muñoz-Torres et al., 2022):

- The upstream sector creates fibers and yarns.
- The midstream sector includes textile mills that produce fabrics and other materials.
- The downstream sector includes companies making clothing and different home and industrial textiles.

Extreme challenges and several adverse environmental effects, including high GHG emissions, high energy consumption, and significant waste creation, have resulted from the massive demand for inexpensive and fast-fashion items (Connell, 1995). The textile industry plays a significant role in greenhouse gases (GHG) emissions, emitting 1.2 billion tons of CO2 yearly, and is responsible for approximately 10% of the world's GHG emissions (European Environment Agency, 2021). The textile industry plays a vital role in the European economy, and it is reported that there was a sharp increase of 40% in the volume of clothes Europeans bought between 1996 and 2012 (Reichel et al., 2014). Additionally, it is reported that 5.7% of household spending in the EU is on clothing and shoes, with 80% of this total amount on clothes while shoes share is 20%. (Gray, 2017). Also, clothing and textile waste comprises a significant amount of European household waste. For example, the Netherlands and Germany report 4.2 kg and 3.5 kg of textile waste per capita, respectively, while Italy has the highest generated textile waste in Europe with 7.2 kilograms per person (Gray, 2017). As a result, reforming the textile and apparel sector is essential to attaining the objectives of the EU's circular economy.

The circular economy is a concept designed to minimize waste and maximize resource use by keeping materials and products in use for as long as possible (Grdic et al., 2020). The heavy reliance of the textile industry on non-renewable resources generates a considerable amount of waste makes it one of the eminent candidates for circular economy initiatives (Dhonde & Patel, 2020). The EU aims to move towards a zero-waste economy by 2030 where all waste is reused, recycled, or composted (European commission, 2020). This will involve reducing the amount of produced waste, improving the design of the products to be more sustainable and investing in waste management infrastructure(European commission, 2020). One key shift in the circular economy for the clothing industry is a transition from a linear take-make-waste model to a circular model. This involves designing circular products using materials easily recycled or repurposed or secondary materials such as industrial, food, and agricultural waste as feedstock for new products (Provin et al., 2021). Agricultural and food waste could be an essential source of initial materials for clothing production since this waste could be transformed into biomass and bioplastics (Provin et al., 2021). Bioplastics are made from renewable materials such as sugar cane, cellulose, corn starch and potato and can be biodegradable or compostable and reduce the adverse environmental impacts of plastics (*Bioplastics – European Bioplastics e.V.*, 2022).

Bioplastics have various applications, including packaging, electronics, consumer goods, and textiles. Plastics have become an integral part of our daily lives due to their practicality and low cost of production (European Environmental Agency, 2016). Usage of plastics in the clothing industry has come at a high cost to the environment, and there is growing concern about the negative impacts of plastic waste on the environment as their production is heavily reliant on fossil fuels (European Environmental Agency, 2016). On the other hand, plastic waste is a primary contributor to pollution as millions of tons

of plastic enter the world's oceans and landfills every year, which can severely impact wildlife and ecosystems. Additionally, plastics need approximately hundreds of years to break down (European Environment Agency, 2021).

The issue of plastic pollution is causing growing concern among stakeholders due to its high visibility as an environmental problem. This concern is prompting manufacturers to search for sustainable alternatives that can provide some benefits and qualities as traditional plastics without the negative environmental impact. While bioplastics could be a sustainable solution to this issue it also should be noticed that not all the bioplastics could be biodegradable. Therefore, it seems that biobased and biodegradable plastics are seen as a potential solution to plastic issue, as they can help conserve limited resources and align with the le of sustainability (Provin et al., 2021). Even though producing some of these bioplastics relies on starchy crops like maize, which can cause problems such as competition with food resources and land usage, these types of bioplastics can be produced from a wide variety of feedstock such as sludge and algae and without any competition with food crops (Brizga et al., 2020 ; Chia et al., 2020). In general, it is essential to explore the potential of the clothing industry to transition to bioplastics and reduce the social concerns surrounding plastic waste. This research aims to investigate the usage of biobased and biodegradable plastic in the clothing industry under the circular economy concept and investigating its commercialization drivers and barriers and its social acceptance. By doing so, it seeks to contribute to developing a more sustainable and environmentally friendly approach to clothing production.

1.2 Problem statement

The adaptability and exceptional plastic characteristics have produced over 8 billion tons of plastic worldwide in the past 70 years (Geyer et al., 2017).In the past two decades, synthetic, plastic-based fibers in textile production has significantly increased and are projected to grow in shares and absolute volumes (Textile Exchange, 2022a). These synthetic textiles are ubiquitous in our everyday lives, from the clothes we wear and the bed sheets we sleep on, to the furniture we sit on. Roughly 60% of textiles are created using fibers based on synthetic polymers globally, with the majority produced and processed in Asia, and Europe is the largest importer of synthetic fibers (European Environment Agency, 2019). The textile industry's linear production model, accompanied by high pollution and waste generation, must be revised. As the global population grows and consumption patterns change, the demand for clothing increases, leading to more textile waste and environmental degradation (Neto et al., 2019). Therefore, exploring new and innovative solutions that can promote a circular economy in the textile industry is necessary. One potential solution is bioplastic clothing made from biodegradable and compostable materials such as polylactic acid (PLA) and Polyhydroxyalkanoates **(**PHA).

Therefore, there is some contribution the clothing industry could make to promote sustainability by using bioplastics in this industry. The adverse environmental effects caused by the production and disposal of fossil-based plastics have made it crucial to explore more sustainable alternatives. Several bioplastics have been shown to have characteristics similar to conventional fossil-based plastics, which are commonly employed in similar applications. However, bioplastics are known as a suitable substitute for plastics in food packaging and shopping bags, but they have yet to be widely available and applied in the clothing industry (Grancarić et al., 2013). On the other hand, the Netherlands is known for its strong focus on sustainability and circular economy initiatives. The country has implemented a government-wide program aiming to reduce the use of virgin materials, including fossils and plastics, by 50% by 2030. This policy environment provides a unique context for studying the potential adoption and social acceptance of bioplastic applications in the clothing industry (Nijstad, 2017). Therefore, the main

problem addressed in this thesis is to explore the drivers and barriers to developing bioplastic applications in the clothing industry and to analyze the social acceptance of this biobased product in the Netherlands.

1.3 Research objective

The study aims to identify the most significant drivers and barriers to bioplastic clothing marketing in the Netherlands from an interdisciplinary perspective and to analyze its social readiness level.

1.4 Research questions

This thesis aims to answer the following research questions in order to achieve the research objectives:

Main research question

How does the application of bioplastics in the clothing industry contribute to circularity, and what factors enable or prohibit its development in the clothing market?

Research sub-questions

1. How do significant technical factors in terms of bioplastic properties and the availability of resources and technology affect the development of bioplastics applications in the clothing industry?

1.1 How could the technical barriers be overcome?

2. How do significant economic factors in terms of bioplastic production costs and marketing affect the development of bioplastics applications in the clothing industry?

2.1 How could the economic barriers be overcome?

3. What is the current level of social readiness for sustainable clothing among different consumers, and what are the key factors that affect it?

1.5 Organization of the thesis

The thesis is organized as follows: In chapter two, a review of relevant literature and theoretical concepts that inform this research is presented. Chapter three describes the research methodology, including the research framework, strategy, data collection and analysis methods. Chapter four provides the research findings derived from primary data collected through interviews and surveys, while chapter five analyzes and discusses the results in relation to the relevant secondary data in order to address the research question. Finally, the last chapter concludes the report by offering recommendations based on the research findings.

Chapter 2: Literature Review

This chapter explains the theoretical foundation and primary research that form the research perspective of the thesis. It presents theories and models related to various concepts relevant to the research topic and objectives. The first section covers the general concept of circular economy, focusing on the textile and clothing production industry and resource recovery from biomass. The second section introduces traditional plastics and their limitations, their usage in clothing, different types of bioplastics, and the potential usage of bioplastic in apparel which is the focus of the research. The third section explains the importance of social readiness and acceptance of the new technologies while the final section outlines the theoretical framework, introducing the social readiness framework.

2.1 Circular Economy

The circular economy concept advocates for a 'closed loop' system, where materials are cycled throughout entire supply chains to reduce waste (E.M. Foundation, 2012). Rather than being seen as waste products, post-use materials are viewed as valuable resources (Lieder & Rashid, 2016). At the same time, using biobased products which when returned to the environment, can refill nutrient stocks, and restore ecosystem health is in line with circular economy principals (Atta et al., 2022; Leipold & Petit-Boix, 2018). Biobased materials have several advantages over fossil-based alternatives. Firstly, they can be recycled more easily, and secondly, their production process is more efficient due to the use of biological processes like fermentation, enzymes, and biocatalysts. Additionally, biobased materials may have unique features like biodegradability and lower toxicity (Atta et al., 2022). One of the main reasons for the transition to a circular economy in Europe is its dependence on imported raw materials, which exposes the European economy to challenges like market instability, high prices, and political uncertainty (Neczaj & Grosser, 2018). The European Union (EU) is committed to advancing the transition to a circular economy by implementing its circular economy (CE) Action Plan, intending to create an economy that will promote competitiveness, sustainable economic growth, and job creation (European commission, 2020). The EU recognizes that the plastic sector is the acritical aspect of this transition, and bioplastics are seen as an important component due to their versatile features, broad applications, and renewable resources (European commission, 2008). The Brundtland report on sustainability from 1987 has been a significant inspiration for developing policies that support the production of biodegradable polymers in Europe and America (Nikodinovic-Runic et al., 2013). The Netherlands also has plans to achieve a circular economy by 2050 and has implemented a government-wide program to achieve a 50% reduction in the use of virgin materials such as fossils, minerals, and metals by 2030 (Nijstad, 2017).

2.1.1 Circular economy in the textile and clothing industry

Textiles play a significant role in our daily lives, from clothes and furniture to medical and protective equipment, buildings, and vehicles. However, Europe's textile industry's environmental impact is the fourth highest after food, housing, and transportation (European Commission, 2022). It is the third-largest sector in water and land use and the fifth largest in primary raw material consumption and GHG emissions (European Commission, 2022). European citizens throw away approximately 11kg of textile annually, and globally, a truckload of textile waste is incinerated or landfilled every second (Gray, 2017). Worldwide textile manufacturing almost doubled from 2000 to 2015, and the consumption of footwear and clothing is anticipated to grow by 63% by 2030 (European Commission, 2022). Also, Netherland was identified as a country with the high amounts of clothing found in household waste with a per capita quantity of 4.2 kg while this number was reported to be 3.5 kg per capita in Germany (Gray, 2017). On

the other hand, the average life span of the clothing was reported to be 3.8 years in Germany and Italy while in the Netherland this was about 4.1 years (Gray, 2017). At the same time, this massive expansion of the textile and apparel industry has led to an adverse impact on resources, greenhouse gas emissions, water pollution, and negative environmental impact. Therefore, the necessity to address the manufacturing and consumption of textiles is more crucial than at any time before. Research has indicated that the textile and clothing industry has significant potential to be part of the circular economy by utilizing more sustainable raw materials and initial components (Gray, 2017).

The European Energy Agency has stated that implying the circular economy in the product design of products in the textile industry and modifying raw materials to recyclable or more environmentally friendly ones could reduce GHG (European Environment Agency, 2019). The textile industry is embracing circularity through various approaches such as recycling the discarded fabrics, where waste materials are transformed into new textiles. This process helps minimize resource depletion and reduce environmental impact associated with textile production. By reusing and repurposing materials, textile industry contributes to a more sustainable and efficient use of resources, promoting the closed-loop system that maximizes the efficient usage of the resources (European Environment Agency, 2019). Another step for integrating circular economy into clothing industry could be the usage of variety of sustainable materials derived from circular sources such as bioplastics. According to Textile Exchange and comparing the life cycle assessment of PLA and fossil-fuel based type of plastic, polyethylene terephthalate (PET), the role of PLA in global warming was determined by index of 2.23 as 3.2 kgs of CO_2 equivalent for PET, while eutrophication index for PLA was 3.47 as opposed to 4.16 kgs of nitrogen for PET and water scarcity index of PLA was reported to be 0.768 in comparison with 0.252 cubic meters for PET (Textile Exchange, 2022b). Therefore, it seems that using bioplastic in textile industry could decrease the negative environmental impacts of conventional plastic on climate change. However, there is not much data available on analyzing the life cycle assessment of bioplastic in terms of their land use (He et al., 2021). Despite the growing awareness of the textile industry's environmental impact, the adoption of bioplastics in clothing production needs to be stronger (Grancarić et al., 2013). A few companies in the textile industry have adopted implying bioplastics in clothes production, but most of the sector has yet to embrace these solutions fully (Friedrich, 2021a).

2.1.2 Bioresources and bioplastics in the clothing industry

The traditional supply chain in the clothing industry starts with raw materials manufacturers. These raw materials could be natural such as cotton, which is a very water-demanding crop that needs almost 800 gallons of water for one-pound of production (Full Cycle Bioplastics, 2021). The raw materials for clothing could also be artificial materials such as polyester derived from fossil fuel, which is the most used item in apparel (Blaazer, 2022). The next player in the clothing supply chain is the raw material wholesale, which is a collecting trade that accumulates all the raw materials (Blaazer, 2022). For example, cotton is sent from different farmers in various companies to wholesale while artificial fabrics are sent directly from factory to textile company (Blaazer, 2022). Then textile companies produce yarns from raw materials, which are turned into fabrics. These fabrics are then going to be dyed or printed. In the next stage of the process, the fabric wholesaler purchases the fabrics from the textile industry and sells them to apparel manufacturing (Cao et al., 2005). The manufacturers turn the fabrics into clothing that fashion brands or companies order (Blaazer, 2022). Next, clothing wholesalers buy finished products from clothing producers and distribute them to retailers who sell them to consumers (Cao et al., 2005). However, this traditional supply chain of clothing is often criticized because of a lack of or a

few options for reusing or recycling materials which in the end, leads to significant waste(European Environment Agency, 2019). When using bioplastic in apparel, the supply chain would be different. Bioplastic producers become involved in extracting and harvesting raw materials, which they process into bioplastics to be used as ingredients in clothing. This positions them as suppliers of these initial ingredients. Also, the presence of bioplastics in clothing can offer more circularity since these bioplastics are made from renewable resources instead of petroleum-based materials, and they have a lower carbon footprint (Rosenboom et al., 2022).

2.1.3 Importance of considering technical and economic aspects of bioplastic-based clothing

Efficiency and resistance are key technical factors that directly impact the performance of bioplastics in clothing (Farrington et al., 2005). The efficiency of bioplastics refers to their ability to meet the functional requirements of clothing such as durability, comfort, and aesthetic appeal. Resistance on the other hand, pertains to the ability of bioplastics to withstand various conditions, including mechanical stress, washing, and exposure to heat and light, without comprising their quality and performance (Farrington et al., 2005). It is crucial to understand how these technical factors influence the feasibility and acceptance of bioplastics as viable alternatives to conventional materials in clothing production. Additionally, advancements in manufacturing technologies, textile engineering and processing techniques can enhance the quality, versatility, and cost effectiveness of bioplastics, thereby driving their adoption in the clothing sector (Farrington et al., 2005). On the other hand, production costs play a crucial role in determining the commercial viability and competitiveness of bioplastics compared to conventional plastics (Guo et al., 2020). Understanding the cost implications of bioplastic production, processing and manufacturing expenses is essential for addressing their feasibility and potential cost-saving opportunities (Guo et al., 2020). Furthermore, effective marketing strategies are instrumental in promoting the adoption of bioplastics in the clothing industry. Consumer acceptance and demand for bioplastic-based clothing products can be influenced by factors such as product labeling, brand reputation, and communication of the environmental benefits (Guo et al., 2020). Therefore, this research aims to investigate technical, economic, and social challenges of integrating bioplastic-based clothing.

2.1.4 Actors in the production chain of clothes from bioplastics

Bioplastic researchers play a crucial role since they could investigate the bioplastic opportunities, limitations, and their improvements for application in apparel, while bioplastic producers were also affecting actors in the supply chain responsible for manufacturing bioplastics and making their application suitable for the clothing industry. Textile manufacturers, retailers, and brands could play an important role in adopting bioplastic clothes by creating demand through their marketing strategies and product offering. Consumers and their demand and readiness for sustainable clothing can also drive the adoption of bioplastics in the textile industry since it encourages retailers and brands to prioritize the use of bioplastic in their products. To answer research questions, this study collected data from bioplastic producers, bioplastic researchers, experts, and consumers who play a vital role in the supply chain of clothes from bioplastics.

2.2 Reasons for switching from traditional plastics to bioplastics

Over the last fifty years, the usage of plastic has increased by twenty times, and it is expected to double within the next twenty years (Nijstad, 2017). In 2013. The global production of plastics was 299 million tons, with Europe alone contributing 20% of this amount (Nijstad, 2017). While new plastic materials

have been developed with exceptional durability and physical properties, most of these products are used only once, particularly in medical and food packaging applications. These plastics are non-biodegradable and their accumulation in the environment is harmful and undesirable (García et al., 2018). This has led to an alarming yearly accumulation rate of approximately 25 million tons of plastic waste, which negatively impacts the feeding and habitat of surrounding fauna, sometimes leading to the death and extinction of certain species (García et al., 2018). As plastics break down into smaller micro and nanoparticles, they also negatively affect the ecosystem and food chain (Nijstad, 2017). To address these challenges, more biodegradable and biobased alternatives to fossil-based plastics are being developed and marketed, especially for situations with high environmental risks (Nijstad, 2017).

2.3 Bioplastics

Bioplastics are usually categorized into two different types of plastics: biobased plastics and biodegradable polymers (Van Den Oever et al., 2022). Biobased polymers could be derived from renewable resources such as cellulose, sugar, and food waste partially or completely (Valpak, 2010). The need to reduce GHG emissions and contribute to mitigating climate change's adverse effects has led to the development of biobased plastics as a substitute for fossil-based polymers. On the other hand, biodegradable plastics can be biobased or fossil-based that can be broken down biologically through bacterial or fungal action which shows its importance when considering end-of-life disposal and waste management techniques for plastics (Valpak, 2010) Biodegradable plastics are a part of sustainable raw materials that could bring environmental, economic, and social benefits (Nikodinovic-Runic et al., 2013). It should be noted that biodegradable plastics could be biobased or petrochemical based. For instance, polymers such as PLA and PHA are biobased and biodegradable, while Polycaprolactone (PCL) is a non-renewable biodegradable polymer (Valpak, 2010). Figure 1 shows the general categorizations of bioplastics which are presented by European bioplastics. It is projected that the worldwide capacity for producing bioplastics will increase from approximately 2.1 million tons in 2019 to 2.4 million tons in 2024. This growing trend is mainly because of innovative biopolymers like PLA and PHA (European bioplastics, 2022). The EU bioplastic market is expanding by about 20% annually, and this growth is fueled by rising demand for sustainable and innovative solutions. For instance, PHA bioplastics are expected to quadruple by 2023 (European bioplastics, 2022; European Commission, 2008). On the other hand, PLA is one of the most widely used and commercially available bioplastics derived from biomass, and it is an aliphatic polyester primarily made from starch or sugar-rich crops. PLA has desirable characteristics such as high transparency and surface gloss and also physicochemical properties such as resistance to oils and fats, which make it an ideal substitute for conventional plastics like polyethylene terephthalate (PET) and polyvinyl chloride (PVC) (Rosenboom et al., 2022).

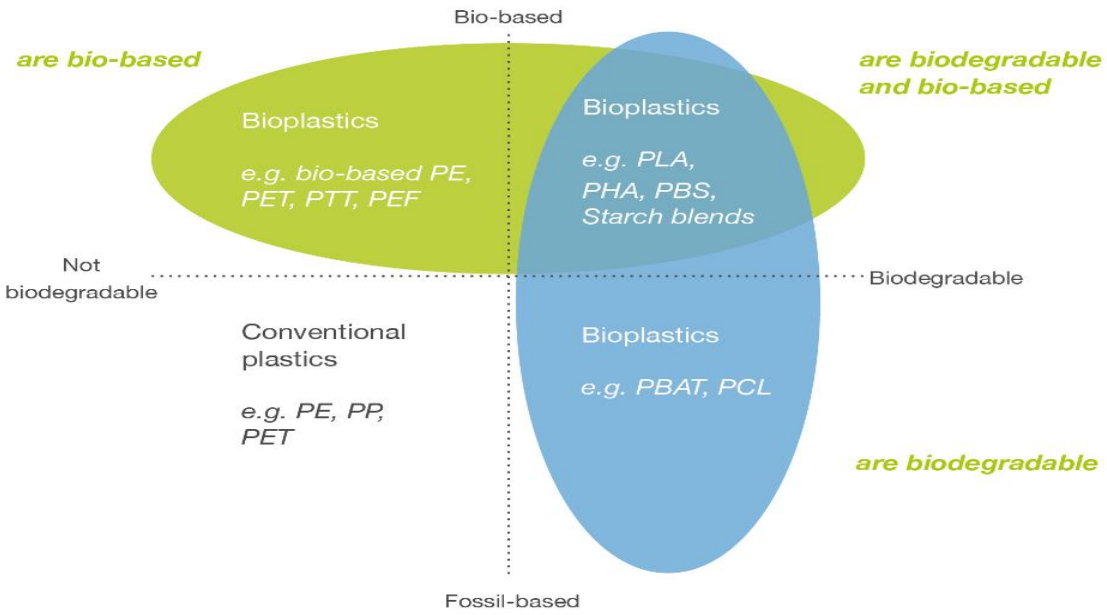

Figure 1: Categorization of bioplastics (Bioplastics – European Bioplastics e.V., 2022)

2.3.1 Biobased and biodegradable plastics

These types of plastic are derived from renewable resources such as plants, food and microorganisms and can be biodegradable and compostable. They could be a suitable alternative to conventional non-renewable and petroleum-based plastics. PLA, PHA, polybutylene succinate (PBS), and cellulose acetate are the most common biobased and biodegradable plastics (European bioplastics, 2022). In table 1, the different biobased and biodegradable plastics, their source and their applications are described as below:

Table 1 : list of biobased and biodegradable plastics

Plastic type	Source	Applications
PLA	Derived from cornstarch or sugarcane and different kinds of food waste and biomass such as potato, banana, dairy (Chafran et al., 2019).	As a substitute for polyolefin films or polystyrene foams and applications such as packaging, disposable tableware, and textile (Chafran et al., 2019).
PHA	produced by certain bacteria and algae and can carbon-rich sources such as food residues (Chafran et al., 2019).	Bulk packaging, paper cups and potential usage in textile (Mendhulkar & Shetye, 2017).
PBS	Derived sugars, crop residue, wood and starched-based materials (Xu & Guo, 2010)	Production of films, photography, or food packaging (Xu & Guo, 2010)
Cellulose Acetate	Modified cellulose from plants (Orelma et al., 2020).	Textile fibers and food packaging (Orelma et al., 2020).

2.4 Social readiness for more sustainable clothing

Sustainable clothing refers to garments that are produced in a manner that minimizes negative impacts on the environment (Full Cycle Bioplastics, 2021). It encompasses various practices, including the use of eco-friendly materials such bamboo and hemp instead of cotton which requires a lot of water and pesticides (Full Cycle Bioplastics, 2021). Sustainable clothing could also be made from recycled materials such as recycled polyester (Textile Exchange, 2022a).

According to (Hasan et al., 2021) which evaluated the purchase behavior of consumers regarding organic cotton clothing across different segments of the apparel supply chain, we can learn insights into how people and society reacted to sustainable clothing in the past. In this study, data was collected from the United States and Bangladesh and the findings revealed interesting differences between two consumer groups. For US consumers, sustainability knowledge played a significant role in having positive attitudes toward sustainable clothing. However, in the case of Bangladeshi consumers, social norms which was referred to shared beliefs, attitudes and found to have a strong influence on attitude formation (Hasan et al., 2021).

Therefore, introducing new technologies and products is not only a technical issue. It is also important to consider the social aspects of new technologies. For example, a study by Lin et al investigated the social behavior toward reusable bags through the Attitude- Behavior- Context (ABC) model (Klein et al., 2020). This study found that prior product experience, general consumer values (GCV), and attitudes towards bioplastics are the most influential factors in promoting a preference for bio-based apparel (Klein et al., 2020). On the other hand, a study by Bellamy, using social readiness framework, identified knowledge about technology, the aim of the technological project, the effects of technology, and trust in the control of technology as four important aspects for evaluating social readiness of new technologies (Bellamy, 2019). Although this study will evaluate suppliers' readiness to move toward bioplastic-based clothing through interviews, it will also investigate consumer readiness for sustainable and bioplastic-based clothing using a survey designed using the social readiness framework. For this study, social readiness framework is considered a better option than the ABC model in this case due to several reasons. Firstly, since bioplastic-based clothing is not yet available in the market, it is difficult to assess consumer attitudes and preferences through traditional choice-based models like ABC. On the other hand, the social readiness framework aligns well with the context of introducing a novel product like bioplastic-based clothing. Secondly, social readiness framework provides insights into the broader social, cultural and environmental factors that influence the acceptance of a technology, offering a more comprehensive understanding of the potential challenges and opportunities associated with the adoption of bioplastic-based clothing. Therefore, by examining social readiness this study can provide valuable insights and recommendations for effectively introducing and promoting bioplastic-based clothing among the target audience, particularly the young generation (Bellamy, 2019).

2.4.1 Social readiness framework

According to Bellamy, despite the knowledge that the social factors are as important as technical ones when speaking about technology adaptation, there is still huge gap between considering these two types of factors (Bellamy, 2019). To solve this issue and analyzing the social readiness about new technology or product, Bellamy undertook a theory based on five major theoretical theories that were psychometric paradigm, the technology control dilemma, cultural theory, technology acceptance models, and responsible innovation. Based on these five theories, Bellamy recognized knowledge of technology, scope of technological projects, impacts of technology, and trust in the control of technology as four major aspects of perception of new technologies (Bellamy, 2019). For analyzing the

social readiness to move toward more sustainable clothing, this study will apply social readiness framework analyzing below items:

- **knowledge of technology:** In the social readiness framework the importance of knowledge about technology in shaping perceptions, specifically regarding awareness, precedence, and ease of use, has been captured by synthetizing elements from the Psychometric paradigm and Technology acceptance model, as well as cultural theory and responsible innovation(McNeeley & Lazrus, 2014). According to these theories, a lack of knowledge about a technology or its exposure can lead to more negative perceptions. Additionally, ease of use is an important factor in shaping perceptions and in contrast technologies that require significant effort, are difficult to control, or incompatible with existing systems can be negatively perceived (Ravetz, 1990). Bioplastic clothing can benefit from understanding customers' knowledge of technology by ensuring that the technology is well understood and visible in use.

- **Scope of technological projects***:* The second item is about how the scope of technological projects influences people perceptions based on cultural and responsible innovation theories and it mentioned that the purpose of a technology is a crucial factor that affects people's perception. Transparent purposes being more positively perceived than vague ones (Macnaghten & Chilvers, 2014). Also, the technology acceptance model emphasizes the importance of usefulness and extrinsic motivation in shaping perception, where technologies that improve performance and have co-benefits are more positively perceived (Tahar et al., 2020). Bioplastic clothing could be seen as an example of a technology that offers greater extrinsic motivation, as it has co-benefits such as reduced carbon footprint and reduced plastic waste.

- **The impacts of technology***:* This item plays a significant role in shaping people's perceptions of its benefits and risks. The psychometric paradigm highlights that technologies with clear benefits are perceived more favorably than those with questionable benefits (Covello et al., 1989). In the context of bioplastic clothing, perceptions of its benefits and risks could be influenced by factors such as environmental impact, durability, access to affordable and sustainable clothing options, perceived quality and clothes appearance.

- **Trust in the control of technology:** One aspect of trust in the control of technology that might be relevant to biobased clothing is the perceived credibility and trustworthiness of the institutions involved in its production and distribution. Consumers may be more likely to trust and support brands that are transparent about their supply chains, production process, and environmental impacts (D'Itria & Colombi, 2022).

Chapter 3: Methodology

This chapter outlines the actions taken to attain the research goal, including the research framework, research strategy, data collection, analysis methods, and analytical framework.

3.1 Research Framework and research strategy

In this study, the research object was bioplastic. On the other hand, the research objective was to enhance knowledge on the various factors affecting the development of biobased and biodegradable plastic in the clothing industry and analyzing its social readiness level. This research analyzed economic and technical drivers and barriers through a qualitative approach and interviews with related stakeholders and literature review. Consumer surveys and quantitative approach are used to assess the social readiness of bioplastic-based clothes and their intention to choose them. This enabled the research to cover the economic, technical and market aspects involved in the production of bioplastic-based clothes and at the same time analyze the level of social readiness by holistic investigation on individual willingness to adopt them. In doing so, both the production and consumption aspects pertaining to bioplastic-based clothes were explicitly addressed in the research.

3.2 Data Collection

For this research, nine semi-structured interviews with bioplastic manufacturer, researchers and experts were carried out. For the interviews in this research an online approach was adopted using Teams software. The interviews lasted between 30 to 40 minutes and the interview questions were carefully designed to address the current economic and technical barriers and the future feasibility and possibility of using bioplastic in the clothing industry. The interview questions are presented in Appendix I. All interviews were recorded, and immediate transcription took place right after each interview concluded. This approach ensured accurate capturing of the interview data for further analysis and interpretation. On the other hand, for reaching more holistic view about technical and economic barriers literature review method was also conducted by reviewing gray literature and scholarly articles on Scopus with ''bioplastic", ''economic barriers'', ''technical barriers'', ''sustainable- clothing'' and ''biodegradable plastic'' search terms. Also, 100 surveys were conducted to analyze the social readiness of sustainable and bioplastic-based clothing with 13 questions that are presented in Appendix III.

3.2.1 Selection of Interviewees

To answer research questions, this study collected data from bioplastic producers, bioplastic researchers, experts, and consumers who play a vital role in the supply chain of clothes from bioplastics. The view of the different bioplastic producers was crucial to broaden the horizons regarding different types of bioplastics, their properties, and their limitation beyond what is found in the literature. Also, interviewing researchers and experts in sustainable innovations could shed light on the current sustainability problem in the clothing industry, the current solutions, and the effectiveness of bioplastic-based clothing.

Table 2 :List of Interviewees, their roles in the study and their affiliations

	Name of interviewee	Role in the study	Affiliation
1	Bas Krins	Bioplastic producer in Netherlands	Technical Director at SENBIS company
2	Pieter Imhof	Researcher in Netherlands	Senior Business Developer Circular Economy & Environment; Cluster Lead Circular Plastics at TNO company

3	Pramod Agrawal	Sustainability expert in Netherlands	Expert in material science and sustainable innovations
4	Interviewee 4	Bioplastic producer in Netherlands	Technical Sales Manager at a Dutch bioplastic producer company
5	Interviewee 5	Bioplastic producer in Netherlands	Strategic Developer at a Dutch biochemical producer company
6	Interviewee 6	Bioplastic producer in Netherlands	Director business development and product innovation at a Dutch bioplastic company
7	Interviewee 7	Bioplastic producer in Netherlands	Project leader at a Dutch bioplastic company
9	Interviewee 8	Bioplastic producer in Netherlands	Technology developer lead at a Dutch bioplastic company

3.2.2 Survey: sampling method and sample size

For analyzing the level of social and customer readiness regarding sustainable and bioplastic-based clothing, this thesis used online surveys designed through Qualtrics online survey software with sample size of 100 people. This sample size was obtained from Slovin's formula which is described below with Leeuwarden young population of 46,428 people (total population of 107,691 people) and margin error of 10% (Urbistat, 2023; ZACH, 2023). To ensure a more representative sample, this study specifically focused on young people who have a higher interest in purchasing clothing (Zhang et al., 2021).

$$n = N / (1+Ne^2)$$

n= sample size N= given the population size e= margin of error

The survey sampling process involved administering the surveys at the NHL University library in Leeuwarden. The surveys were filled out either by scanning the provided QR code or by accessing the survey link shared through various Leeuwarden student WhatsApp groups and Instagram. The data collection phase spanned approximately one month, from May to June 2023. The survey questions are presented in Appendix III.

3.2.3 Data required and accessing method

As shown in Table 3, for better preparation for the interviews, the required data and information as well as their accessing method were identified through the research sub-questions.

Table 3: Data required for the research and accessing methods

Research Sub-Questions	**Data/Information Required**	**Sources**	**Accessing Data**
RQ1: How do significant technical factors in terms of bioplastic properties and the availability of resources and technology affect the development of bioplastics applications in the clothing industry	-Efficiency and resistance of bioplastics - Available resources or technology	Bioplastic manufacturers- Experts- researchers- literature	Interviews Literature review

RQ2: How do significant economic factors in terms of bioplastic production costs and marketing affect the development of bioplastics applications in the clothing industry?	-The production cost and benefit -The available niche markets in clothing industry for bioplastic	-Bioplastic manufacturer -Literature	Interviews Literature review
RQ3: What is the current level of social readiness for sustainable and biobased clothing among different consumers, what are the key factors that affect them, and how it could be increased?	-The current social readiness level of customers to sustainable clothing	Customers	Surveys

3.3 Data Analysis

The first stage of the study comprised a qualitative investigation of the data required from interviews. For analyzing the bioplastic-based or sustainable clothing social readiness level, the quantitative methods and analysis of related graphs and charts were applied.

3.3.1 Validity of findings

Before the interview with the relevant stakeholders, the consent form was sent to them allowing the researcher to record the meeting and use their names as a reference in the report. For the recorded meeting, researcher transcribed the records word by word and made a summary of the session. After each meeting, the prepared summary was sent to the interviewee for their confirmation.

3.3.2 Analytical framework

The schematic representation of analytical framework is presented in figure 2.

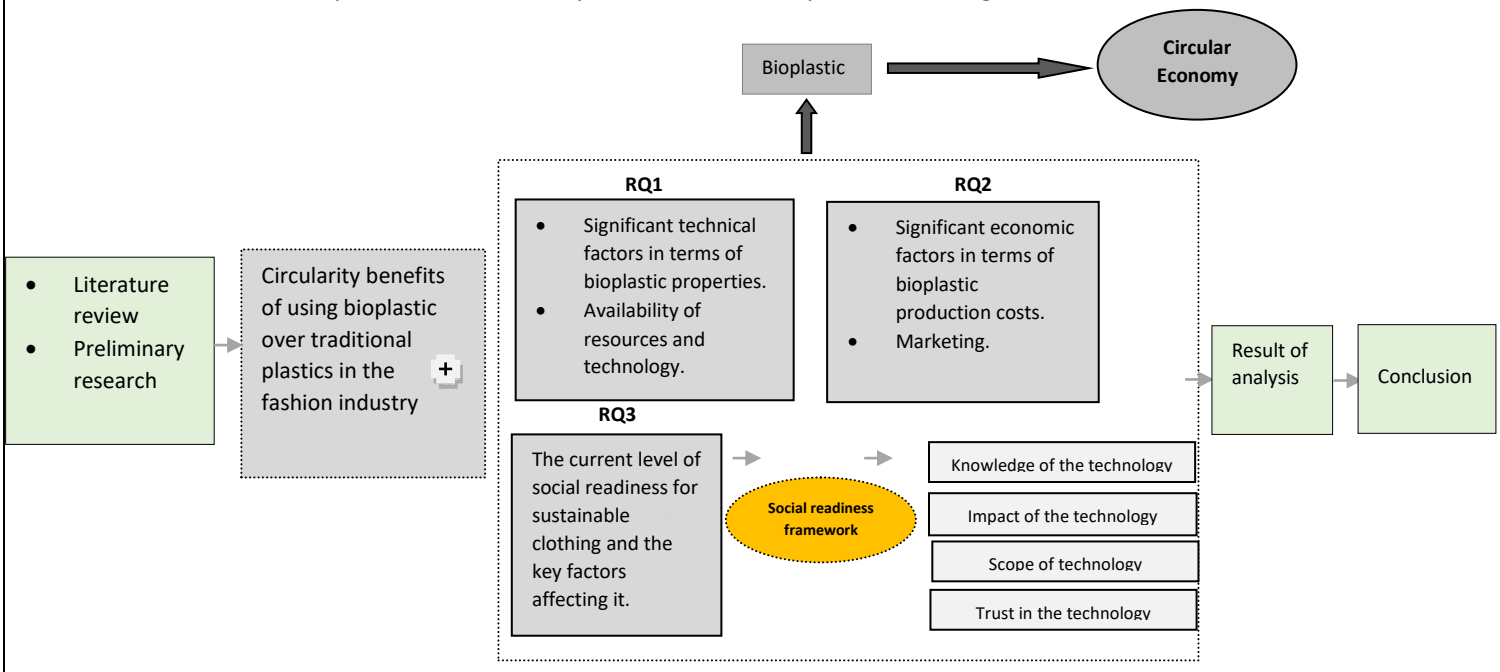

Figure 2: A schematic representation of the analytical framework

3.4 Ethical Considerations

In this study, data were collected through interviews with individuals and surveys. To ensure ethical standards were met, participants were asked for their consent before interviews and in the last questions of the survey. This involved informing them about the voluntary nature of participation, the purpose and scope of the study, their right to withdraw at any time without negative repercussions, and the researcher's identity.

The consent of participants: Participants were allowed to decline or interrupt their involvement in the research process, ensuring that they had control over the participation. A written consent form was provided to the participant before the interview and also the participants willingness and consent for sharing their information through the surveys were also asked in the final question of the survey. The sample of the consent form and the survey questions can be found in Appendix ll.

In terms of confidentiality: if a participant requested that their information be kept private or their identity be kept anonymous, the researcher assured this issue.

Consequences: the researcher ensured that confidentiality was maintained by respecting the privacy and anonymity requests of the participants if they requested it.

Chapter 4: Findings

This chapter presents the research findings by analyzing the data collected from the interviews and the surveys. The profile of the interviewees and the sample size of the surveys have been presented in **c**hapter 3. No discussion or interpretation of results takes place in this chapter. The information needed to answer research sub-questions and, ultimately, the main question is presented sequentially. The first section deals with the economic and technical barriers to the development of bioplastics in the clothing industry, while the next section deals with analyzing the social readiness for this sustainable clothing.

4.1 Technical factors affecting the development of bioplastics applications in the clothing industry

This section presents the findings from interviews with related stakeholders about the technical factors affecting the development of bioplastic application in the clothing industry which are categorized into analyzing the efficiency and durability of bioplastics and the available resources or technology for using of bioplastics in the clothing industry.

4.1.1 Comparing efficiency and durability of bioplastics in the clothing industry in comparison with conventional plastics

During the interview with Bas Krins, technical director at Senbis polymer innovations B.V, it was mentioned that one technical barrier to using bioplastics in clothing is their melting point and that alternatives of polyester in the clothing should not have a melting point much lower than PET, and many biopolymers have a low melting point. He also mentioned that currently, viscose is the most commonly offered sustainable alternative to PET in the clothing industry, with the biobased and biodegradable plastic PHA, as a potential candidate for commercial introduction in the future. On the other hand, Interviewee 4, mentioned that most bioplastics are brittle and unsuitable for making clothes. They stated that PLA, PHA, and cellulose acetate are difficult to process and expensive, with PHA showing potential for use in clothing in the future. It was also mentioned that biobased plastics could be a better option for clothing than biobased and biodegradable plastics since they are more suitable for recycling.

Both Pieter Imhof and interviewee 6 discussed the challenges associated with using biobased and biodegradable plastics in the clothing industry. Pieter Imhof, the business developer, and cluster lead circular Plastics at TNO, mentioned that new bioplastics like PLA and PHA have not yet had their applicability fully understood, and PLA might not be suitable for certain applications since it might degrade during use, which is not ideal.

On the other hand, interviewee 6, the director of business development and product innovation at a bioplastic producer company, stated that while bioplastics such as PLA have been used to produce clothing in the past such as wedding dresses, the main problem with PLA is its lack of temperature resistance. On the other hand, it was mentioned that PHA and PBS have properties suitable for textile purpose such as being flexible and breathable. Both experts agreed that there is a need for further research to make bioplastics applicable to textiles, and natural textiles like wool and silk are also biodegradable but have their own limitations in terms of care and durability.

In the interview with interviewee 7, he discussed the efficiency and resistance of bioplastics, especially PEF and PLA. PEF is a biobased plastic that is not biodegradable and has similarities with PET, making it a potential high-performance material for use in the textile industry and other industries.. Their company is confident that PEF can be converted to fibers without issues and can be used well in the textile industry. Based on an interview with Pramod Agrawal, an expert in material science and sustainable innovations, it was noted the use of biobased materials in textiles is also questioned because they are

often easily disintegrated and are not efficient for recycling since they have less degree of polymerization, which makes them less suitable for multiple reuses and supporting the slow fashion. Also, he mentioned that when these biobased plastics become combined with materials such as elastane, their lifetime could decrease even further.

According to interviewee 8, their company is currently upscaling their production of biobased and biodegradable plastics; PHA, a potential polymer, could be used to create textiles. Their company is involved in a project to work with fashion companies, which aim to find sustainable alternatives for fashion fibers, and are exploring PHA as a potential option. Their position in this project is to supply polymers for fiber spinning, and they believe their polymers have a high chance of success due to the longer chain length they can produce, which is an essential factor for creating fibers. About PHA properties and their competition with other plastics, it was mentioned that PHA could achieve similar properties to other plastics, although it is slightly heavier. It is possible to produce longer-chain PHA and even compound it with other materials to reach optimal solutions in the textile industry. It was also stated that PHA does not have the exact properties as fossil-based plastics, sometimes, it is better, and sometimes, it is worse, but industries and production processes need to adapt to the use of alternative materials.

4.1.2 Available resources or technology for application of bioplastic in the clothing industry

According to Bas Krins, the current percentage of biobased and biodegradable plastic usage in the clothing and textile industry is non-existen. The primary polymer used in clothing is PET, with wholly integrated production units and a scale of hundreds of thousands of tons per site. This makes changing this infrastructure toward a new polymer and usage almost impossible. Additionally, procedures like texturizing and dying are fully developed for PET, making bioplastics usage in the mainstream market difficult. Also, he mentioned scale as an important issue, as no biopolymers are available at a sufficiently large scale.

On the other hand, interviewee 4 mentioned that biobased plastics could be better options rather than biodegradable ones for clothing as they are more suitable for recycling. Currently, polyolefins are sometimes used in textiles but only for rough structures like artificial grass. It is also mentioned that the future of PHA looks promising. Still, research needs to be done to make it suitable for existing production machinery and to increase its availability at a lower price. Additionally, he noted that a possible application for bioplastics in clothing could be to increase the biodegradability of fibers by coating it with PHA.

On the other hand, according to Pieter Imhof there are not many commercially available biobased, biodegradable plastics being used in the overall consumption of plastics. Moreover, he mentioned that clothes made with PLA might degrade during use, and this is not ideal. Additionally, combining PLA with other materials is needed for clothing, like additives, other textiles, which might reduce the overall sustainability of the product. While there are methods for separating materials from each other, these methods demand a lot of energy or are very difficult. Regarding biobased plastics' availability for the textile industry, Imhof was not aware of any being used on a significant scale and mentioned that the primary materials used in clothing are polyester, cotton, and nylon, none of which is available on a bio-based scale. Moreover, he stated that while there are new materials available, like PEF, that could replace PET, these materials are not yet widely applicable. Pieter Imhof was also asked about the possibility of using PHA in clothing, and he acknowledged that from an environmental perspective, it would be a good opportunity. However, he was curious to know if the material would possess the necessary characteristics for use in clothing. He emphasized the need for more research on the properties of PHA and its adaptation to the textile industry since, currently, PHA is not widely available,

and the market needs to gain knowledge about its properties. Therefore, further research is necessary to make it applicable to textiles.

Interviewee 6 mentioned that PHA could be used to make fibers, although it is an expensive solution compared to natural textiles, and there is the limited global availability of PHA. It was also discussed the issue of textile waste and recycling and the current lack of enough biological treatment of textile waste and their conversion to biogas. While cotton could be perfectly converted into biogas, making it a potentially valuable resource. When asked about the current use of bioplastics in textiles, the interviewee mentioned that they are being used in non-woven materials like masks for COVID-19 but not yet in clothing such as pants or shirts. However, technically, it is possible to make clothing out of bioplastics, and they have properties like elasticity or breathability that could be advantageous over synthetic fibers like PET. Despite this, natural fibers like cotton and wool are still more commonly used in clothing production due to their availability and affordability.

About the availability of PLA, interviewee 7 stated that there are several companies producing PLA commercially which indicates that PLA is currently available, and its availability may even increase in the future. Although the production quantities of PLA are not as high as PET, there is still an adequate supply at a reasonable price of 2 to 4 euros per kilogram. It is also mentioned that their company, a bioplastic producer, is set to open a new plant next year with a capacity of 5000 pounds per year to produce PEF. This quantity is considered sufficient to commercialize the material. The commercialization of PEF is still in the research and development phase, but it is expected to become available in the coming years. It was also stated that there are no evident barriers to the commercialization of PEF, although upscaling the production of PEF is not without risks. Also, since PEF is pretty similar to PET and it is not a biobased plastic, there is no need to build a special recycling facility for PEF because facilities for PET are already available and can be used for recycling PEF. Also, Pramod Agrawal mentioned that If bioplastics are used for clothing, recycling facilities may not need to change because the bioplastics would be thermoplastics and need the same recycling facilities as before.

Regarding the availability of the bioplastics, it was revealed during the interview with interviewee 8 that there are already different grades of PHA available as it is a family of polymers with a large variety and currently, there are several producers with the first commercial facilities not in Europe but in China, Japan, and the United States are producing PHA. To increase the production of PHA and its application in different industries, the company needs funding and time to build new plants and scale up production. Implementing a full-scale plant takes at least three years, and the company expects to have production online by 2027. Currently, the company has the technology for PHA production and only needs to answer some upscaling questions to implement it. He said that there could be a large market for usage of PHA in textiles. However, it was mentioned that if they aim to produce 6,000 tons of PHA and other companies produce between 5,000 tons and 11,000 of that, with a total of approximately 3011,000 tons, this is still quite small for the clothing industry, and more scaling up is needed. Regarding the recycling facilities for PHA, he mentioned PHA is a highly recyclable material that can be mechanically recycled multiple times.

4.2 Economic factors affecting the development of bioplastics applications in the clothing industry

This section presents the findings derived from interviews with related stakeholders about the economic factors affecting the development of bioplastic applications in the clothing industry and discussed them more in detail under the bioplastic production cost and their marketing in the clothing industry.

4.2.1 The bioplastic production cost and their marketing in the clothing industry

According to interviewee 5, in their company's first plant, they plan to sell their products to the industries that are most in need of renewable or biobased chemicals. Although the clothing industry may be interested in their products, there are other industries that are currently requesting more renewable chemicals. However, this could change when consumers may be willing to pay a premium for biobased polyester in their clothing. Therefore, the market demand for biobased clothing may not yet be as high as for other applications at this moment and If people want to pay more for biobased polyesters in their clothing it can be possible to have larger market for usage of bioplastic in the clothing industry. As Bas krins also mentioned about the price of yarns from bioplastics that will become at least five times more expensive than PET, interviewee 5, also mentioned that currently, making clothes from these biobased things would be more expensive but in 10 years it could be cheaper. For example, in the case of their technology, if they build their first plants and then be successful to build five more plants then it is going to be possible to produce for the same price as the fossil-based plastics. It was also mentioned that currently the clothing industry is not a front runner on the topic of renewable chemicals in their products and this can change in the future. It was mentioned as an example that in the automobile industry they are using a lot more plastic than some other industries and for them it is not a problem to pay a bit more for the plastic that they use because a car is more expensive than a T-shirt. However, it was mentioned that in industry you always need the first movers and once it is going to the large scale you can also produce at lower cost and then go to low valuable applications such as clothing but now, we are stocked with a highly valuable application.

According to interviewee 6 the current production cost of PHA is relatively expensive due to the downstream processing needed to isolate pure materials from the bacteria, costing around 4-6 euros per kilogram, which is much higher than the cost of cotton production. It was stated that the price of raw materials is not a determining factor in the final product price as you might use only a small amount of the bioplastic in the pair of jeans for example and other factors such as brand, image, and emotions also play a role. Thus, it was stated that even if the price of PHA doubles, it should not significantly impact the final product price. Interviewee 6 also mentioned that producing textiles from PHA is not a technical issue, but the challenge is setting up a business model and finding a brand that can position it well in the market. It was also stated that while natural fibers and fabrics may still dominate the market in the future, a mix of PHA and cotton with elastic properties can be a game-changer and the key is to find a brand that is interested in providing microplastic-free textiles as a solution to the current problem. It is mentioned that price is not the primary issue; instead, the focus should be on finding a company that cares about sustainability and reducing microplastics. Brands that are sensitive to these issues could promote microplastic-free clothing while maintaining durability, and bioplastics could play a significant role in achieving this.

On the other hand, interviewee 7 mentioned that PLA could be available even more in coming years with price of 2 to 4 euro per kilogram, which is quite a good price, and it is not challenging. It was also mentioned that there are no evident barriers to the commercialization of PEF. However, upscaling the production of PEF is not without risks, for example: the production of 1 million tons per Annum is quite risky as they also must sell these which needs time to create and expand a market and considering the time for this process. Therefore, it was stated that commercializing of the PEF as same as any other types of plastics takes time, and now that they are doing the upscaling, they must deal with price, because lower amount means higher price. On the other hand, when they are doing the upscaling, they should consider where the investment comes from and think where they can sell the products and who are the interested partners, which is a process and not a challenge. And in general, these processes are needed to bring new material such as PEF into the market which needs lots of effort, money, and time.

According to interviewee 8, the prices of PHA are currently quite high due to the first-scale production. The range of prices is between 5 and 10 euros per kilogram, with 10 euros being the most common. However, there is a huge demand for biodegradable solutions, and the production of PHA needs to meet the demand, which is also pushing up the price. It was also stated that, although some companies are expanding and new ones are emerging, the price will likely remain high for some time. Their company goal is to produce polymer from waste, which will lower the price as the feedstock will be free or even have a negative value.

4.3 Role of society in promoting more sustainable clothing

It is mentioned by interviewee 6, producing textiles from bioplastics such as PHA is not a technical issue and the key is to find a brand that is interested in providing microplastic-free textiles as a solution to the current problem and he mentioned that price is not the primary issue; instead, the focus should be on finding a company that cares about sustainability and reducing microplastics. Brands that are sensitive to these issues could promote microplastic-free clothing while maintaining durability, and bioplastics could play a significant role in achieving this.

At the same time, Pieter Imhof also stated that besides the material change, there should be some changes in people's behavior such as using their clothes for longer time or recycling them. And of course, the main factor reducing the impact of clothing is just buying less and wearing longer. He believed that people only change their behavior when they receive incentives, such as the introduction of a deposit system in the Netherlands that led to a 70% reduction in waste production from bottles. However, with clothing, it is more challenging because it is a fashion item, and people are more concerned about their image and reputation. He thought that people would be more likely to adopt sustainable clothing if they are more beautiful or cheaper, rather than only because it is more sustainable, as only a small percentage of people currently care about circularity and sustainable clothing. Additionally, Pramod Agrawal argued about the trend of "slow fashion" in the Netherlands and Europe, where people are encouraged to use clothing for long periods. However, fast fashion is becoming a big problem as people buy cheap, low-quality clothing and discard it after a short period of use, making it difficult for some collection agencies currently working in the Netherlands for collecting clothes waste or used waste, to resell or repurpose the clothing. He also mentioned the problem of fast fashion and its impact on sustainability, "Many brands these days offer up to 12 collections per year, with each collection only available for 30 days". This creates a sense of urgency to buy, leading to overproduction and excess waste. The speaker also discussed the concept of "green washing," where brands pretend to care about sustainability by using terms like "bio cotton" and "sustainable materials" while still adding non-biodegradable materials like elastane to their products. Also, he pointed out that the problem of overproduction is leading to excess clothing being thrown away.

4.3.1 Analyzing the social readiness to move toward more sustainable clothing

As mentioned by experts, moving toward more sustainable clothing is not only a technical issue but it is also important to consider the social readiness for having biobased or more sustainable clothing and the way that society could help to accelerate this transition. For answering the research question about the social readiness to move toward more sustainable and bioplastic-based clothing, this research conducted an online survey with sample size of 100 people, constituting 51 male and 49 female who lived in Leeuwarden. 50.49% of the population aged between 18 to 30 years old, 46.60% aged 31 to 45 years old and only less than 2 % aged more than 45 years old since this research aimed to analyze the young generation readiness for this transition. According to the data derived from the survey, women were more knowledgeable about sustainable clothing and less interested to choose sustainability over

being more fashionable when buying clothes. This difference between men and women idea was approximately 10% .On the other hand, 45% of men did not trust in sustainability brands while this percentage for women was 30%. According to the social readiness framework the collected data from the survey could be categorized as below:

knowledge of technology:

In order to answer the research question number three of this thesis that is about social readiness level for introducing bioplastic- based clothing, it is important to investigate social awareness and knowledge about these more sustainable clothing options. According to survey, society's knowledge about sustainable clothing and bioplastic-based clothing is presented in figures 2 and 3, respectively. As it is shown, most people with 44% were not knowledgeable of environmental impacts of clothing production. At the same time, 43% of the respondents were totally unfamiliar with the bioplastic-based clothing.

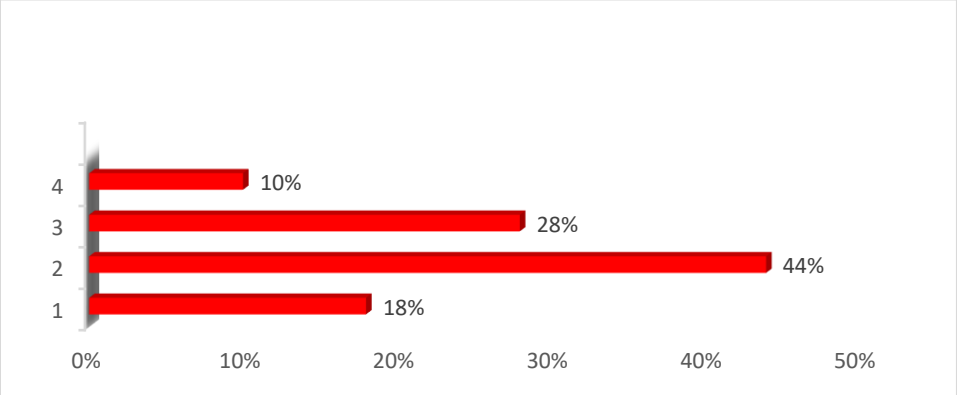

Figure 3: Analyzing the social Knowledge of environmental impacts of traditional clothing production (1 being not knowledgeable at all, 2 slightly knowledgeable , 3 knowledgeable and 4 very knowledgeable)

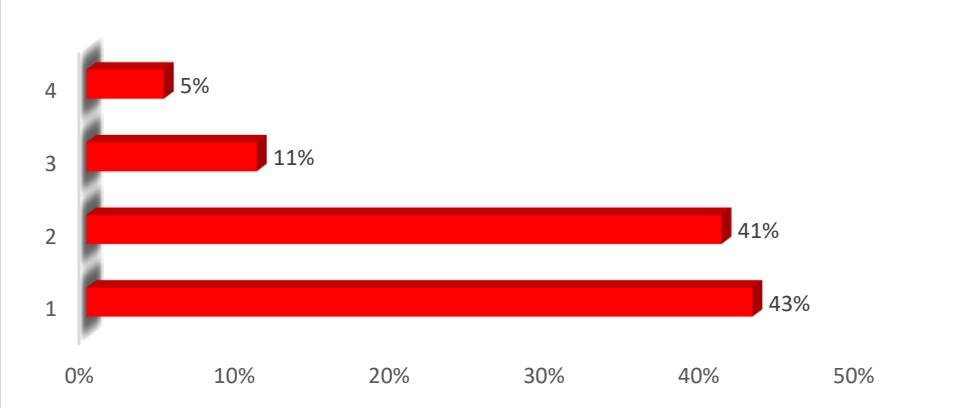

Figure 4:Analyzing social familiarity with bioplastic concept in the clothing (1 being not familiar at all, 2 slightly familiar , 3 familiar and 4 very familiar)

Scope of technological projects*:*

Another factor that could lead to response to the research question about social readiness level of bioplastic-based clothing is to investigate if people consider sustainable clothing useful or whether they priorities using them in their daily lifestyle. According to survey results, figure 4 shows that most of the respondents with 45% did not consider the sustainability of the clothes as their priority when deciding to buy new clothes while according to figure 5 near half of the respondents were agree that the bioplastic-based clothing could be a useful innovation.

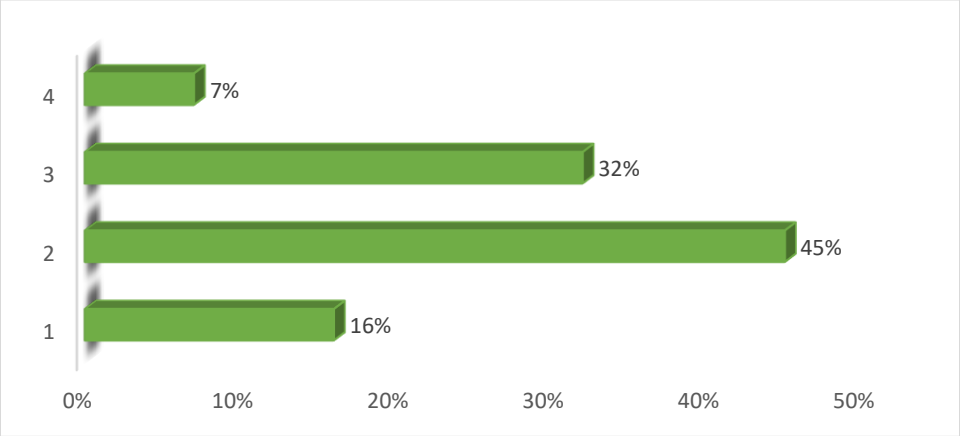

Figure 5: Analyzing social priority in wearing sustainable clothes(1 being not important at all, 2 slightly important , 3 important and 4 very important)

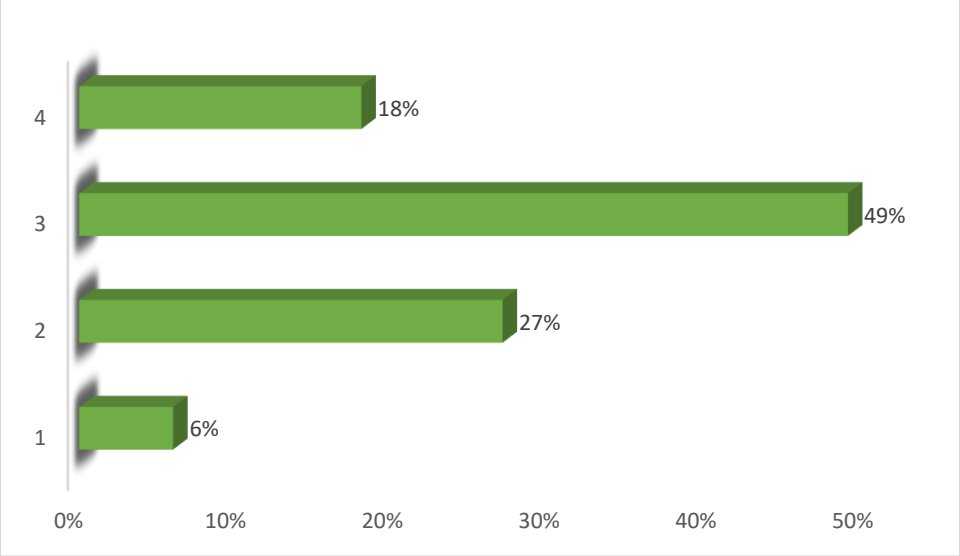

Figure 6: Analyzing the degree that society agree with the usefulness of bioplastic based clothing(1 being very disagree, 2 disagree, 3 agree and 4 very agree)

The impacts of technology

Investigating the factors affecting the social readiness of bioplastic-based clothing, it is also important to consider the level people readiness to accept the impacts of these sustainable clothing such as paying more money, composting biobased clothes at their end-of-life span and putting clothes sustainability above its style and being fashionable. Additionally, as it was also mentioned by interviewee, it is also important to investigate people readiness to wear their clothes for the longer period of time to encourage slow fashion. According to figure 6 and survey results, 41% of the respondents were willing to pay more for sustainable clothing while as it is presented in figure 7, 36% were not interested in choosing sustainability over more fashionable options in their clothing. The willingness of customers to pay extra about the bioplastic-based clothing and their preference between being more sustainable or more fashionable was investigated to understand social readiness to move toward more sustainable clothing and accepting its following impact, since it was also mentioned by interviewees that these two issues could play a vital role in promoting the existence of bioplastic-based clothing in the market.

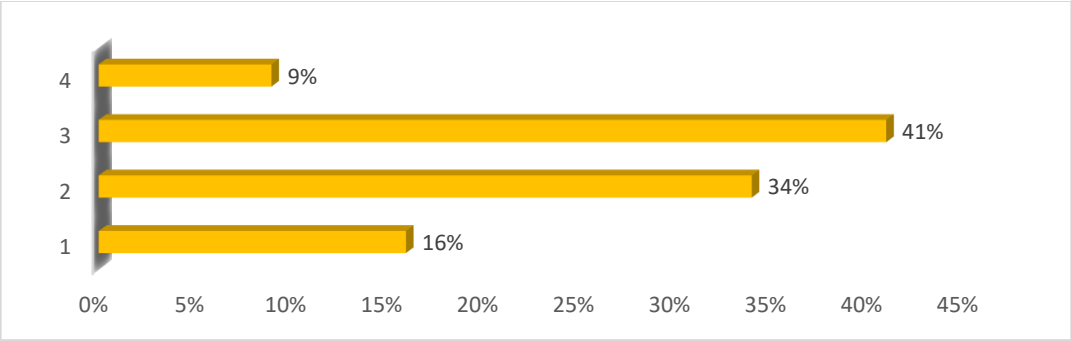

Figure 7: Analyzing social willingness to pay more for more sustainable clothing(1 being not willing, 2 slightly willing, 3 willing, and 4 very willing)

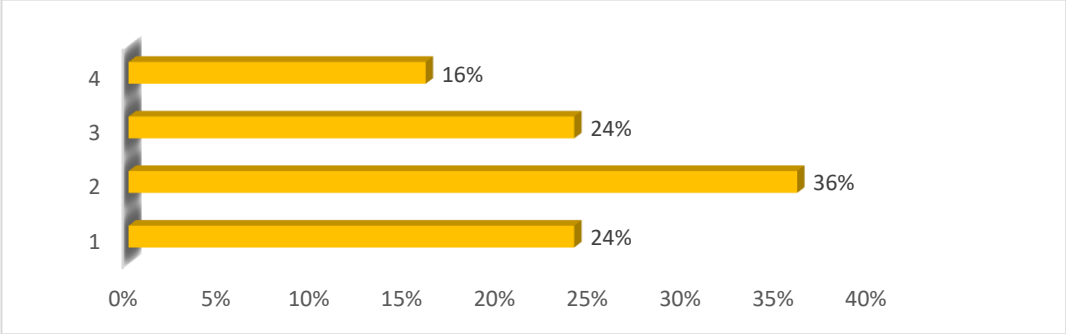

Figure 8: : Analyzing social willingness to wear clothing that are more sustainable but less fashionable (1 being not willing, 2 slightly willing, 3 willing, and 4 very willing)

As it is shown in figure 8, the majority of the respondents with 42% were highly interested to wear their clothing longer in order to reduce waste and also 35% were willing to dispose their bioplastic-based clothes in composting bins at its end life (figure 9).

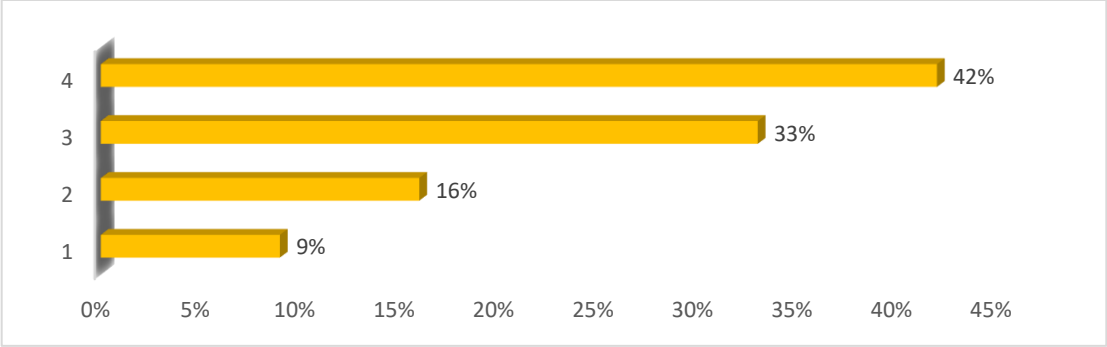

Figure 9: Analyzing social willingness to wear clothing for longer period to reduce waste (1 being not willing, 2 slightly willing, 3 willing, and 4 very willing)

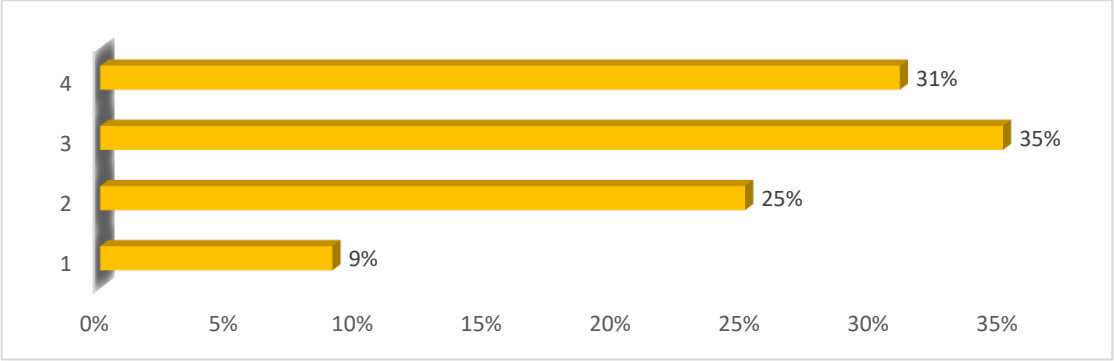

Figure 10: Analyzing the possibility of respondents to dispose their bioplastic clothing in composting bin in the clothing end of lifespan (1 being not likely, 2 slightly unlikely, 3 likely , and 4 very likely)

Trust in the control of technology

Another factor could highly determine the bioplastic-based social readiness level is the degree that society trust in the brands and companies claim using sustainable materials on the clothes. According to survey results and figure 10, 42% of respondents did not trust brands claiming that they use sustainable materials in their clothing.

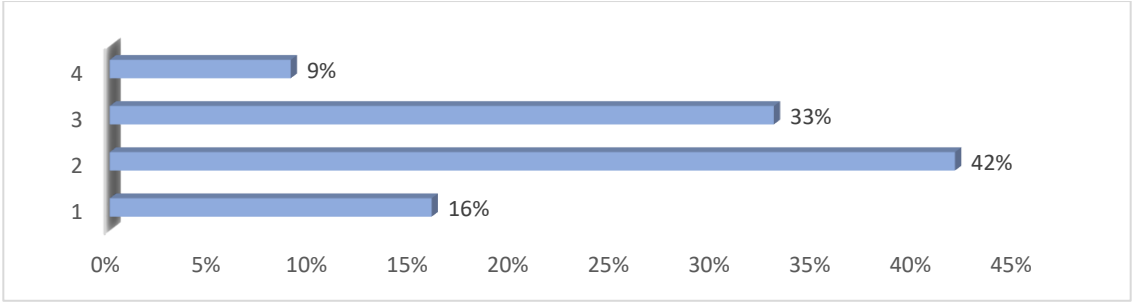

Figure 11: Analyzing the degree that people trust the brands claiming that use sustainable materials in their clothing (1 not trusting, 2 slightly trusting, 3 trusting and 4 very trusting)

Chapter 5: Discussion

This chapter concentrates on responding to the main research question based on the analysis of the findings from the interviews and surveys which were presented in chapter 4. Each of the research sub-questions are discussed in different sections.

5.1 Technical factors affecting the development of bioplastics in the clothing industry

The development of bioplastics in the clothing industry is facing technological barriers and the main ones are related to the infrastructure and scale of the current production process for PET, the most common polymer used in clothing, and the fact that the procedures like texturizing and dying are fully developed for PET but would have to be developed for other polymers.

Promising bioplastics suitable to be used in fashion industry could be PLA, PEF and PHA. PLA fibers have properties such as good moisture management, elastic recovery, crease resistance, controlled fabric stability and positive after-care properties that could make PLA fibers suitable for next-to-skin garment, sportswear, ski jackets, and children's sleepwear(Farrington et al., 2005). Independent laboratory testing showed that PLA fibers outperformed cotton and PET fibers in terms of comfort under normal and active wear conditions(Farrington et al., 2005). While PLA has many positive properties, such as good moisture management, there are some issues to consider. For example, the melting point of PLA is relatively low, which can limit downstream processing and cause problems for consumers who may use high temperatures to press or iron their clothes (Dugan, 2004). Additionally, hydrolysis degradation of the polymer can occur during dyeing and finishing process if appropriate conditions are not observed. However, existing machinery can be used for processing PLA, and it can be compared to PET in terms of processing and product characteristics. It is important for processors to understand the differences between different fibers and adjust operating details accordingly (Lunt & Shafer, 2000).

Additionally, another technical barrier regarding the usage of bioplastics in the clothing industry is their current low availability which is expected to be increased in the future. Currently, as also mentioned through interviews, among the bioplastics, PEF and PHA could be the most suitable candidates for application in clothing and as a substitute of polyester. PEF is a biobased and non-biodegradable plastic that has similarities with PET, making it a potential high-performance material for use in the textile and other industries. Also, there is no need to build a special recycling facility for PEF because facilities for PET are already available and can be used for recycling PEF. On the other hand, PHA is biobased and biodegradable polymer that could be used to create textiles. PHA could be broken down by natural processes and have various chemical, thermal and mechanical features. These properties can be modified to match those of traditional synthetic commonly used in clothing. This bioplastic is resistant to hydrolysis, with excellent ultraviolet resistance and can exhibit a diverse range of mechanical properties from tough and crystalline to flexible and is biodegradable (Creative Mechanisms, 2017; Samrot et al., 2021). PHA is a promising biodegradable polymer with several characteristics such as flexibility and breathability that make it ideal for use in clothing and fashion application (Fashion for Good, 2021). As it mentioned by interviewee 8, their company has involved in a project to work with fashion companies aimed at finding sustainable alternatives for fashion fibers and as it is mentioned by them, PHA could achieve similar properties to other plastics, although it is slightly heavier. It is possible to produce longer-chain PHA and even compound it with other materials and fibers such as cotton to could have more flexible textile and clothing. Although PHA showing potential for use in clothing in the future and there is a need for further research to make bioplastics applicable to textiles. Additionally, PHA can be put into compost and easily degraded by bacteria, so there is no need for further recycling

technology and there would be no microplastic issue. In contrast, other polymers like PLA are not natural and must be synthesized by a chemical process, and currently there is not enough machinery that could degrade PLA left-over very fast and that makes PHA a more advantageous option. The key finding and issues about the technical barriers and availability of resources and technology in development of bioplastic-based clothing, are presented in table 4.

Table 4: Technical barriers to promote bioplastic-based clothing

Technical factors	Issues/ Findings
Efficiency and durability	• While PLA has many positive properties, such as good moisture management, the melting point of PLA is relatively low, which can cause problems when using high temperature to press or iron their clothes. • PLA fibers have properties such as good moisture management, elastic recovery and controlled fabric stability that could make PLA fibers suitable for next-to-skin garment, sportswear, ski jackets, and children's sleepwear. • Most bioplastics, including PLA and cellulose acetate, are considered brittle and unsuitable for making clothes are not efficient for recycling since they have less degree of polymerization, which makes them less suitable for clothing. • Biobased plastics may be a better option for clothing than biobased and biodegradable plastics due to their suitability for recycling. • PEF, a biobased and non-biodegradable plastic similar to PET, shows potential as a high-performance material for textiles. • PHA has properties suitable for textile purposes, such as flexibility and breathability and has excellent ultraviolet resistance and can exhibit a diverse range of mechanical properties from tough and crystalline to flexible that makes it suitable for clothing. • It is possible to produce longer-chain PHA and even compound it with other materials and fibers such as cotton could have more flexible textile and clothing. • Further research is needed to make bioplastics such as PHA applicable to textiles.
Available resources/ technology	• PET is widely used in clothing and has fully developed procedures for texturizing and dyeing and make it hard for switching to use biopolymers. • Scale is an important issue, as biopolymers are not available at a sufficiently large scale. • The same recycling facilities could be used for PEF, since it has similar properties as PET. • PHA can be put into compost and easily degraded by bacteria, so there is no need for further recycling technology and there would be no microplastic issue. • Other polymers like PLA must be synthesized by a chemical process, and currently there is not enough machinery that could degrade PLA left-over very fast and that makes PHA a more advantageous option.

Therefore, based on the research findings and experiences and considering the mentioned technical barriers, maybe it would be better to propose a framework considering the below items to facilitate the successful integration of bioplastics into the clothing industry:

1. **Collaborative research and development**: encourage collaborations between academic institutions, bioplastics manufacturers, and textile companies. Joint efforts can lead to innovative solutions for processing and incorporating bioplastics into textile production.
2. **Education and awareness**: raise awareness among consumers, designers and manufacturers about the benefits and challenges of bioplastics. Education can foster responsible usage and ensure proper care for bioplastic-based clothing.
3. **Sustainable supply chains:** develop sustainable supply chains for bioplastics, ensuring a consistent and sufficient availability of raw materials. This will drive market growth and motivates further research and development.
4. **Regulatory support:** Advocate for supportive policies and regulations that promote the use of bioplastics in the clothing industry.
5. **Continuous Innovation:** promote ongoing research and development to improve bioplastic properties, address technical challenges, and explore new applications. This will accelerate the overall sustainability of fashion industry.

5.2 Economic factors affecting the development of bioplastics in the clothing industry

According to the interviews, the development of bioplastics applications in the clothing industry has been affected by several economic factors, including bioplastic production cost, marketing demand from consumers and clothing and textile companies. One of the main concerns regarding the use of bioplastics in the clothing industry is the production cost. Although the cost of production might be decreasing over time, it is still higher than traditional plastics such as PET. However, according to interviewee 5, the cost of producing bioplastics could become competitive with fossil-based plastics in the next decade, especially if the demand for renewable chemicals continues to increase. Currently, the production cost of PHA is relatively expensive due to the downstream processing needed to isolate pure materials from bacteria, costing around 4-6 euros per kilogram. However, the price of PLA is expected to decrease in the coming years making it a more cost- effective option for clothing manufacturers.

Another economic factor that affects the development of bioplastics in the clothing industry is market demand. While the demand for biobased products is increasing, other industries, such as automobile industry are currently more interested in using renewable chemicals in their products. However, the demand for biobased clothing could increase if consumers are willing to pay a premium for sustainable materials. Interviewee 6 stated that even if the price of PHA doubles, it should not significantly impact the final product price as only a small volume of PHA or other bioplastics would be applied in the clothing such as jeans and believed that other factors such as brand, image and emotions play a more significant role in the pricing of clothing items.

A study by Friedrich investigated the impact of economic factors on the development of bioplastic in the textile industry and it showed that the food industry is more advanced in the transition to bioplastics and has more favorable market condition, while the textile industry has less optimal sales-related frameworks (Friedrich, 2021b). According to Guo et al, any increase in the prices should be achieved through strategic cartelization of the market to facilitate competition and increase the sustainability in apparel industry (Guo et al., 2020). Also, it is mentioned by Dai et al, that price contracting is the most impressive way for clothing producers and their retailers in the green supply chain (Dai et al., 2017).

The study by Friedrich also outlined theoretical implications for the successful substitution of bioplastics in the textile industry, highlighting the importance of market-related criteria and models based on the

monopoly market (Friedrich, 2021a). To practically implement the transition to bioplastics in the textile industry, the study recommended strategic concentration on fewer but more effective market-allocating key activities, focusing on innovations and implementing them in as many products as possible, distinguishing products make out of bioplastics by proper labeling and the creation of incentives by public authorities (Friedrich, 2021a).

Moreover, as mentioned by interviewee 6, companies that are sensitive to environmental issues and microplastic pollution could play a crucial role in promoting microplastic- free clothing while maintaining durability. Based on his opinion, finding a brand that is interested in providing microplastic-free textiles as a solution to the current problem could be the key to successful commercialization of bioplastics in the clothing industry. Furthermore, the upscaling of production of bioplastics is also a significant factor affecting the development of bioplastics in the clothing industry. According to interviewee 7, Upscaling the production of new materials such as PEF is not without risks and takes lots of energy, time and money. However, once production is upscaled and a market is created, the price of bioplastics could become more competitive with traditional plastics. The key finding and issues about the economic barriers affecting the development of bioplastic-based clothing is presented in table 5.

Table 5:Economic barriers to development of bioplastic-based clothing

Economic factors	Findings
production cost	• Downstream processing required for pure material isolation from bacteria for producing PHA makes it relatively expensive, 4-6 euros per kilogram, which is much higher than the cost of cotton production. • Large-scale production can lead to lower costs, enabling bioplastic usage in low-value applications like clothing. • Commercializing of the bioplastics in the clothing industry takes time, money and effort.
Marketing	• The market demand for biobased clothing may not yet be as high as for other applications at this moment. • Making clothes from biobased materials is currently more expensive, but costs could decrease in the future with successful plant construction and scaling. • Consumer willingness to pay a premium for biobased polyester in clothing could drive market demand in the future. • Increase in the prices of sustainable clothes should be achieved through strategic cartelization of the market and price contracting to facilitate competition and increase the sustainability in apparel industry. • Successful substitution of bioplastics in the textile industry could be achieved through market-related criteria and models based on the monopoly market. • Distinguishing products make out of bioplastics by proper labeling and the creation of incentives by public authorities could help developing sustainable clothes in the market. • Finding first-mover companies and large-scale production can lead to cost reduction and broader adoption of biobased textiles. • Brand positioning, sustainability, reducing microplastics, and image play crucial roles in marketing bioplastic textiles.

Therefore, based on the research findings and experiences and considering the mentioned economic barriers, maybe it would be better to propose a framework considering the below items to facilitate the successful integration of bioplastics into the clothing industry:

1. **Market demand cultivation**: collaborate with environmentally conscious brand and communicate the benefits of microplastic-free textiles to consumers. Educate and engage about the environmental impacts of their choices to stimulate demand for sustainable fashion.
2. **Innovation and cost optimization**: encourage research and development to enhance the cost-effectiveness of bioplastics, innovate in downstream processing methods to reduce production costs and explore new bioplastic materials with desirable properties for various clothing applications.
3. **Strategic partnerships:** foster collaborations between bioplastics manufacturers clothing companies, and public authorities.
4. **Regulatory support:** advocate for policies and regulations that promote the use of bioplastics in the fashion industry.
5. **Consumer awareness and transparency**: emphasize transparent labeling and clear communication about the environmental benefits of bioplastic textiles. Empower consumers to make informed choices and support sustainable fashion initiatives.

5.3 Evaluating the social readiness for moving toward more sustainable clothing

As mentioned before, society has a critical role in promoting more sustainable clothing as a shifting consumer behavior towards more sustainable fashion choices requires a collective effort from various stakeholders, including brands and customers as end- users. As Pieter Imhof suggested, the introduction of a deposit system for clothing could be a possible solution, similar what has been implemented for bottles in the Netherlands, which led to a significant reduction in waste production. However, it is also essential to acknowledge that incentives alone might not be sufficient to promote sustainable fashion choices, particularly in a context where fashion is often seen as a means of self-expression and social status. Therefore, it is crucial to consider other strategies that can address the psychological and cultural factors that influence fashion choices, and it is necessary to promote sustainable fashion alternatives that are not only durable but also fashionable and affordable. Additionally, brands that are sensitive to sustainability issues can play a crucial role in this regard by promoting microplastic-free textiles and using bioplastics as a viable alternative to traditional materials.

5.4 The social readiness to move toward more sustainable clothing

According to the survey data and social readiness framework, the score of knowledge of technology term could be considered low because only 28% of respondents were knowledgeable about environmental impact of traditional clothing production and 43% were totally unfamiliar with the bioplastic-based clothing. This indicates that there is still a significant knowledge gap regarding the environmental impacts of our clothing and the sustainable clothing options. Increasing social awareness could be done through educating campaign, workshops, media, and universities. The scope of technology term scored medium with 49% and 18% of respondents were agree and strongly agree respectively that bioplastic-based clothing would be a useful innovation.

Interestingly, the score of the impact of technology term was medium with 41% of respondents were willing to pay more for sustainable clothing, and 42% were fully willing to wear their clothes for a longer

period to reduce waste, and 66% were likely to compost biobased and biodegradable clothes at the end of clothes life. As it also mentioned by interviewees that people willingness to pay extra for the clothes could increase the market opportunities for bioplastic-based clothing in the future. However, 36% were not willing to sacrifice fashion for sustainability, highlighting the need for more affordable and fashionable sustainable clothing options.

The score of trust in technology term was low as 42% of respondents did not trust brands claiming they use sustainable materials. This shows that the costumers are somehow skeptical of sustainable clothing technologies and to level up trust among people, companies and brands can provide open-source access to life cycle assessment reports of their apparels and allow consumers to track the clothing's life and environmental impact.

Overall, the medium level of social readiness for sustainable and bioplastic-based clothing indicates that we could be optimistic about the future integration of these sustainable clothing into the society though it is essential to increase social awareness of the environmental impacts of the clothing industry and build trust among people and clothing company for further social readiness for adopting bioplastic-based clothing in the community.

Chapter 6: Conclusion and recommendations

6.1 Conclusion

This research aimed to answer the main question of how the application of bioplastics in the clothing industry contributes to circularity and what factors enable or prohibit its development in the clothing market. Through the analysis of various technological and economic factors, it is clear that bioplastics that comes from renewables or agri-food wastes have the potential to promote sustainability and circularity in the clothing industry. Bioplastics such as PHA offer promising solutions especially that they are biobased and biodegradable plastics could degrade in marine locations, which could solve microplastic problems. However, the development of bioplastics is facing several technological barriers, including the infrastructure and scale of the current production process, the need to develop procedures for other polymers, and the difficulty of processing and future research is needed to make bioplastic more applicable to textiles and overcome the technological barriers. Considering technical barriers, it would be better to propose a framework considering collaborative research and development, education and awareness, sustainable supply chains , regulatory support and continuous innovation to facilitate the successful integration of bioplastics into the clothing industry.

At the same time, the development of bioplastics applications in the clothing industry is affected by various economic factors, including production cost and market demand. Although the cost of production is currently higher than traditional plastics, it is expected to decrease over time. The demand for biobased clothing could increase if consumers are willing to pay a premium for sustainable materials. Strategies such as price contracting and creating incentives by public authorities are recommended for successful commercialization of bioplastics in the clothing industry. Additionally, upscaling production could make the price of bioplastics more competitive with traditional plastics. Considering economic barriers, it would be better to propose a framework considering market demand cultivation, innovation and cost optimization, strategic partnerships, regulatory support and consumer awareness and transparency to facilitate the successful integration of bioplastics into the clothing industry.

The data collected throughout the survey in this study showed that while there is a knowledge gap regarding environmental impacts of our clothing and sustainable clothing options. Increasing social awareness could be done through educating campaign, workshops, media and universities. More than half of the population surveyed agreed that bioplastic-based clothing would be a useful innovation. Consumers are also willing to pay more for sustainable clothing, wear their clothes for a longer period to reduce waste, and compost biobased and biodegradable clothes at the end of clothes life. However, the majority of people were not willing to sacrifice fashion for sustainability, highlighting the need for more affordable and fashionable sustainable clothing options. In terms of trust in technology consumers were somehow skeptical of sustainable clothing technologies. To level up trust among people, companies and brands can provide open-source access to life cycle assessment reports of their apparels and allow consumers to track the clothing's life and environmental impact. Overall, the medium level of social readiness for sustainable and bioplastic-based clothing indicates that we could be optimistic about the future integration of these sustainable clothing into the society though it is essential to increase social awareness of the environmental impacts of the clothing industry and build trust among people and clothing company for further social readiness for adopting bioplastic-based clothing in the community.

In summary, bioplastics have the potential to contribute to circularity in the clothing industry, but further research and development are needed to overcome technological barriers. Consumer willingness to adopt sustainable clothing options and pay a premium for sustainable materials presents a promising opportunity for the commercialization of bioplastics in the clothing industry. Ultimately, the market should focus on developing more affordable and fashionable sustainable clothing options while promoting longer wearing of clothing and end-of-life treatments that minimize waste and negative environmental impacts.

6.2 Recommendations for future research

Based on the findings of the thesis, it is recommended that future research in the field of bioplastics and circularity in the clothing industry should involve a larger sample size of participants could provide more comprehensive insights into consumers attitudes towards sustainable clothing options and the use of bioplastics. Additionally, though it was hard to contact brands and clothing manufacturer willing to participate in this research, it would be beneficial to conduct interviews with these group of people in the future research to understand their perspective and insights in adopting the bioplastics. Furthermore, future research should focus on developing and testing new bioplastics that are more applicable to textiles, and exploring the potential to other sustainable materials that have a lower environmental impact. Furthermore, it should be European Environmental Agency. In addition to technological advancements, future research should emphasize the creation of collaborative actions among bioplastic manufacturers, textile companies, and regulatory parties. Facilitating integration between these stakeholders will promote the adoption of bioplastics on a larger scale. It is essential to explore potential barriers to collaboration and develop strategies to overcome them, ensuring a smooth transition toward sustainable clothing. Also, there are opportunities for future research to enhance the data analysis process and draw more comprehensive conclusions. Here are some suggestions for future research:

1. **Longitudinal studies**: consider conducting longitudinal studies to track changes in consumer behavior and attitudes over time. This will provide a better understanding of the long-term trends in sustainable clothing adoption and the role of bioplastics in the industry .
2. **Cross-Cultural analysis**: extend the research to different regions and cultures to explore how attitudes towards sustainable clothing and bioplastics vary across different populations.
3. **Life cycle assessment**: conduct a life cycle assessment of bioplastics in the clothing industry to compare their environmental impact with conventional plastics and other sustainable materials.
4. **Regulatory analysis**: examine the existing regulations and policies concerning the use of bioplastics in the clothing industry. Identify gaps and opportunities for policy interventions that can encourage the adoption of sustainable materials.
5. **Consumer education**: Investigate the role of consumer education and awareness campaigns in influencing attitudes towards sustainable clothing and bioplastics. Understanding the effectiveness of such initiatives can guide future educational efforts.

Overall, continued research and innovation in this area is essential for the sustainable development of the clothing industry and promotion of circularity.

6.3 Limitation

The limitations of this study were the lack of interest of clothing manufacturers to participate in the research and lack of time to reach more respondents to fill the survey in order to have a bigger sample size. A larger sample size would have provided more representative data. Despite these limitations, this study provides valuable insights into the current landscape of bioplastics and circularity in the clothing industry. Additionally, there were not much life cycle analysis studies and research considering the sustainability of the bioplastics from the different aspects such as land use or water consumption. With more accurate sustainability data of the bioplastics, the share of bioplastic-based in the circularity of fashion industry were more noticeable. On the other hand, this study focused on consumer attitudes towards sustainable clothing and bioplastics, but other relevant factors such as cultural influences and socio-economic factors that could impact consumer behavior were not extensively analyzed a broader scope could provide a more holistic understanding of the subject.

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Appendixes

Appendix I - Questions from bioplastic producers, researchers, and experts

1. What is the current production percentage of biobased and biodegradable and biobased plastics suitable for using in clothing? How could it be increased?

2.What are the technical barriers to using this type of plastic in clothing? How can we overcome barriers?

3.What is the status of bioplastic properties and their competition with other plastics in terms of their application in clothing? How it could be improved?

4. What is the current situation of required technology, facilities, and research, for providing the opportunity for usage of bioplastics in the clothing industry? How could it be improved?

5. What are the economic factors such as production costs, competition with other bioplastics and other items that are involved in adoption of bioplastics in clothing? How can we overcome obstacles?

6.What are the market barriers to adopting bioplastics in the clothing industry? How can we overcome barriers?

7. What is the current market for bioplastic clothing and what are its trends for the future?

8. How could consumer demand drive the market toward using more bioplastics in clothing?

9. How could we increase production and commercialize the usage of a kind of bioplastic which may be the best substitute for plastic in clothing?

Appendix ll -Consent form

CONSENT FORM TO TAKE PART IN A RESEARCH INTERVIEW

Research Topic: Exploration of the feasibility and implication of introducing bioplastic to the clothing industry: Towards circular fashion

Taking part in the study

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

I understand that taking part in the study involves answering questions from a semi-structured questionnaire, note-taking by the researcher, audio recording of interview session which will be transcribed as text for effective data analysis (this will be destroyed once the research is completed)

I understand that in any report on the results of the research, my identity will remain anonymous if preferred to be so.

I understand that I am entitled to access the information I have provided after the interview and I have the right to request for modification, clarification, or changes where applicable.

I understand that I am free to contact the researcher for further clarification and information.

Use of the information in the study

I understand that the information I provide will be treated confidentially and used strictly for research purpose/master thesis report writing.

Consent to be Audio Recorded

I agree to be audio recorded.

Signatures

The participant	**Signature**	**Date**

Saba Shadkam

Researcher	**Signature**	**Date**

s.shadkam@student.utwente.nl

Dr. Steven Mcgreevy

Study Supervisor

Appendix lll- Survey questions

Your willingness to participate in the survey
1.Are you willing to participate in this research? ☐Yes ☐ No

General questions
2.What is your gender?
a. Female b. Male c. non-binary / third gender d. Prefer not to say

3.What is your age range?
a. 18 - 30 years old b. 31 - 45 years old c. 45-65 years old d. more than 65

Sustainable clothing and your clothing practices

4.On a scale of 1 to 4, how much do you know about the environmental impacts of traditional clothing production? (1 being "not knowledgeable" and 4 being "very knowledgeable") a.1 b.2 c.3 d.4

5.On a scale of 1 to 4, how much of a priority is it for you to wear clothing made from sustainable materials? (1 being "not a priority" and 4 being "very important") a.1 b.2 c.3 d.4

6. On a scale of 1 to 4, how willing are you to pay more for clothing that is made sustainably? ("not willing " and 4being "very willing ") a.1 b.2 c.3 d.4

7.On a scale of 1 to 4, how willing are you to wear clothing that is more environmentally sustainable but less fashionable? (1 being "not willing "and 4 being "very willing") a.1 b.2 c.3 d.4

8.On a scale of 1 to 4, how willing are you to wear your clothes for a longer period of time to reduce waste? (1 being "not willing" and 4 being "very willing") a.1 b.2 c.3 d.4

9. On a scale of 1 to 4, how much do you trust brands that claim to use sustainable materials in their products? (1being "not trusting at all" and 4 being "completely trusting") a.1 b.2 c.3 d.4

Bioplastics in clothing

10.On a scale of 1 to 4, how familiar are you with the concept of bioplastics in clothing production? (1 being "not familiar at all" and 4 being "very familiar") a.1 b.2 c.3 d.4

11.On a scale of 1 to 4, how much do you agree or disagree that bioplastic clothing is a useful innovation? (1 being "strongly disagree" and 4 being "strongly agree") a.1 b.2 c.3 d.4

12. On a scale of 1 to 4, how likely are you to dispose of your bioplastic clothing in a composting bin once it has reached the end of its lifespan? (1 being "not likely at all" and 4being "very likely")

a.1 b.2 c.3 d.4

13.Can I use your responses and data for my research? ☐Yes ☐ No