

THE “SUSTAINABLE” PLASTIC DILEMMA: AN EXPLORATION OF THE
ENVIRONMENTAL IMPACTS AND SOCIAL PERCEPTIONS OF BIOPLASTICS

by

Lucy S. Pierce

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This Thesis for the Master of Environmental Studies Degree

by

Lucy S. Pierce

has been approved for

The Evergreen State College

by

Shawn Hazboun, Ph.D.
Member of the Faculty

Date

ABSTRACT

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Bioplastics, plastics derived from renewable feedstocks, have grown in popularity since the 1980s. The bioplastics market is largely comprised of packaging for the food and beverage industry. The labeling of bioplastics primarily relies upon a standardization and certification system influenced by industry groups and loosely upon government and academic knowledge. Labels such as bio-based, biodegradable, and compostable convey a variety of meanings to purchasers, distributors, and consumers. A lack of understanding about these products is prevalent. Therefore, this study attempted to address attitudes, knowledge, and the use of bioplastics within local food service businesses in Olympia, Washington through a quantitative survey and qualitative interviews. Additionally, the environmental impacts of bioplastics were examined through a review of the standards, certifications, and Life Cycle Assessments. The survey results demonstrated significant use of bioplastics, with almost half of businesses in downtown Olympia using them. However, the qualitative interviews revealed a lack of knowledge about the standards and certifications. Respondents felt uncertain about whether or not bioplastic’s environmental impacts are less harmful than traditional ones. To inform the bioplastic industry and regulatory policies, this thesis recommends more research on best practices for end-of-life disposal in real life, how and where bioplastics are currently utilized, and environmental assessments that not only employ quantitative data, but merge both quantitative and qualitative methods.

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Introduction

Bioplastics have become popular alongside the increasing awareness of traditional petroleum-based plastic pollution. Historically, plastic was seen as terrestrial litter on city sidewalks and sides of interstates, but now it is polluting our waterways, oceans, and marine life, encompassing all ecosystems. Today, public awareness of the harms of plastics is widespread. Plastic pollution is ubiquitous due to the resiliency and permanence of petroleum-based plastic materials. Plastic has the potential to exist for hundreds, even thousands of years (Wang, Tan, Peng, Qiu, & Li, 2016). The origin of modern polymers, commonly known as plastics, can be traced back to the Second World War. War time spurred research and development of alternative materials to wool, steel, and glass (Mulder, 1998). After World War II the commercial applications of plastic were explored for consumer products and packaging, causing global production of plastics to skyrocket from around one million tons in 1950 to thirty million tons in 1970 (Schouten & Van der Vegt, 1991). As described by Mulder (1998), the world is living in a Plastic Age. Prior ages like the Stone Age, Bronze Age, and Iron Age are distinct stages in history characterized by materials and modernity (Mulder, 1998). The global use of plastics has transformed daily life for billions of people, but with the proliferation of plastics has come severe environmental impacts. Today, many believe petroleum-based plastics are a burden for the environment and their invention unintentionally created further problems (Talon, 2014). Plastic pollution is a global problem; plastic bags and microplastics, plastics under 5 millimeters, are the most prevalent polluters around the world due to their size, thickness, and quantity (Xanthos & Walker, 2017). Physical pollution from plastics is only one factor in the plethora of environmental issues with them, but unlike petroleum-based plastics, the majority of bioplastics are designed to be less permanent. Petroleum-based plastics cause terrestrial and aquatic pollution, exhaust landfill space, emit toxic and greenhouse gas emissions, and are difficult to

fully recover through reuse and recycling (Álvarez-Chávez, Edwards, Moure-Eraso, & Geiser, 2012; Ren, 2003).

Bioplastics, a recent innovation, are broadly defined as plastics derived from biomass and renewable sources. They are used as an alternative material to petroleum-based plastics primarily in the form of consumer goods and packaging (Kinsha, Niesten, Negro, & Hekkert, 2016). Bioplastics are marketed as a solution to the environmental impacts of traditional, petroleum-based plastics because they are manufactured from renewable sources and have the possibility of breaking down in the environment (Mosko, 2012). However, bioplastics' ability to reduce environmental impacts is highly debated.

The bioplastics industry is “green” both in its intentions to create more sustainable plastics, and its burgeoning status on the global market. Bioplastics are a fairly recent innovation, first appearing commercially in the late 1980’s in Europe and the United States (Darby, 2012). Although they are a new addition to the plastics industry and only share about two percent of the global plastics market as of 2015, the projected growth of bioplastics is astonishingly high. The association group, European Bioplastics, predicts a twenty percent increase in the global bioplastic market by 2020, setting the total global market value at 30.8 billion dollars (Bhilare, 2018). The largest sector of bioplastics use is packaging, comprising sixty percent of the total bioplastic market in 2017 (Global Market for Bioplastics to Grow by 20%, 2017). Other sectors where bioplastics are commonly found are in the textile, automotive, consumer goods, and agricultural industries. This study focuses on bioplastic packaging, specifically packaging in food service.

In a nationwide poll of 1,107 people in the United States by SPI: The Plastic Industry Trade Association, twenty-seven percent of the participants said they were somewhat familiar with bioplastics. However, thirty-four percent of participants said they were completely unfamiliar with bioplastics. In addition to an unfamiliarity with bioplastics, eighty-six percent of participants said they had never seen or were unsure if they had seen the U.S. Department of Agriculture Certified Biobased Product logo (Mashek, 2016). These statistics demonstrate the public's low level of knowledge about bioplastics. This lack of knowledge is only one element in the complex bioplastic industry. In a recent report from SPI: The Plastics Industry Trade Association, they highlight some of the other challenges within the bioplastic industry: confusion with terminology, lack of industry cohesiveness, lack of infrastructure for end-of-life disposal other than landfill, limited legislation and regulation, lack of international harmonization of test standards and certification, and limited availability of non-food renewable feed stocks like sawdust, hemp, and byproducts like husks or peels (Mashek, 2016).

In addition to these challenges within the industry, the environmental benefits of bioplastics have not been fully determined. While many believe bioplastics are less harmful than traditional plastics, the negative environmental effects of bioplastics include a wide range of problems. In order to manufacture bioplastics, renewable raw materials are needed. Industrial agriculture practices are typically utilized for the renewable raw materials. These industrial processes have many negative environmental effects including high fossil fuel energy requirements, human and wildlife exposure to pesticides, significant water use, competition with the global food supply, changes in land use, deforestation, loss of biodiversity, and eutrophication, a process where excess nutrients from fertilizers enter waterways and cause the overproduction of plant matter, resulting in the depletion of oxygen (Álvarez-Chávez et al.,

2012). On the production side, it is unclear if the levels of greenhouse gas emissions during bioplastics manufacturing are actually lower than traditional plastics. Finally, for end-of-life environmental problems most are related to a lack of industrial composting infrastructure (Yates and Barlow, 2013).

To address the complexities and problems within the bioplastic industry more research is needed. To add to the literature, this research asks the following questions: 1) Are bioplastics less environmentally harmful than their petroleum-based counterparts? 2) How are bioplastics being perceived and used within the food service industry, their most common application? The goal of this research is to approach these questions holistically, rather than focusing solely on quantifiable environmental impacts, like pounds of greenhouse gas emissions. Three methodological approaches were used, including a review of relevant standards and regulatory measures, quantitative surveying of food service businesses, and qualitative interviews of food service managers.

The theoretical framework used for this study, Ecological Modernization Theory (EMT), provides a contemporary interpretation of macro-level societal- environmental interactions. EMT has evolved over the past 30 years, but at its earliest stages in the 1980's it developed as a new way for thinking about environmental reform, or how society avoids environmental crisis. One of the founders of the theory, Huber (1985), emphasized economic growth and the market as means for environmental reform, where technology and science could provide enough modernization to drive society from environmental crisis, rather than state actors leading the environmental movement.

Fundamentally, EMT “analyzes how contemporary industrialized societies deal with environmental crisis” (Mol & Sonnenfeld, 2000, p. 5). There are five core foundations to Ecological Modernization Theory: 1) science and technology may have caused environmental problems, but conversely they can be used for overcoming and avoiding future environmental crisis; 2) producers, consumers, corporations, and all other market actors have a role in environmental reforms, not just state agents and governments; 3) less command-and-control regulation from state agencies and more collaboration with non-state actors on regulatory issues lead to more environmental reform; 4) social movements have power in environmental decision-making institutions, whether public or private; and 5) for modern society to continue we must not accept a separation between ecology and economics, overlooking the environment is no longer an option (Mol & Sonnenfeld, 2000). Bioplastics are an appropriate example for EMT because of their similar time of emergence in society, along with their development as an alternative to petroleum-based plastics. Characteristically, bioplastics are environmentally reformed plastics and developed from an advancement in technology and science. However, EMT is only one theoretical framework for analyzing the bioplastic industry and gaps are identified later in the study. Nevertheless, this study aims to demonstrate EMT as an applicable way of thinking about the role bioplastics have played and will continue to play in modern environmental reform.

Chapter 1: Overview of Bioplastic Standards and Certifications

This chapter will provide insights into the intricate bioplastic industry regulations. The most common standardizations used to harmonize the bioplastic industry are described in some detail, followed by a demonstration of the similarities and differences between the definitions and testing methods of these standards. In doing so, this study will explain the terms bio-based, biodegradable, compostable, and why this study applies the umbrella term *bioplastic*. Following the descriptions and standards section, the certifications used globally to label and identify bioplastics will be reviewed. This chapter intends to provide a foundation for understanding the intricate industry regulations within the bioplastic market. This study will use the following abbreviations: ISO: International Organization for Standardization, ASTM: American Society for Testing Materials, CEN: European Committee for Standardization, DIN: Deutsches Institute für Normung (German institute for standardizations), DIS: Draft International Standard (Associated with ISO), EC: European Commission (the governing body of the European Union responsible for legislation and regulations), and EN: European Norm.

In the 1980's, bioplastics originally manufactured for applications in agriculture, but over time bioplastics became commercially available to more industries like packaging and consumer goods where they are more commonly seen today (Darby, 2012). Bioplastics are unlike fossil fuel-based polymers, as they are produced using renewable resources (van der Zee, 2005). The decreasing supply of fossil fuels, increasing number of landfills reaching capacity, and the rise of mitigation efforts for greenhouse gas emissions, drove polymer manufacturers to research alternative sources for polymer production (Hermann, Debeer, Wilde, Blok, & Patel, 2011; Kabasci, 2014). In order to replace fossil fuel sources for polymers, a renewable source needed to be identified. This came in the form of bio-based raw materials like starch, lignin, cellulose,

and proteins. These bio-based raw materials are commonly known as agricultural products like corn, soy, sugarcane, and forestry material or biomass (Alvarez-Chavez et al., 2012; Department of Ecology State of WA [USDEWA], 2014; Kabasci, 2014). Polymers derived from agricultural products have inherent properties of biodegradation. Unlike fossil fuel-based polymers, which have no biodegradable properties, polymers derived from bio-based raw materials are designed to be less persistent in the environment and decompose through interactions with living organisms (Lörcks, 1998; Rudnick, 2008). This study uses the term *bioplastics* because of one key problem in the industry of manufacturing polymers from renewable sources. The problem is eloquently stated by Hottle, Bilec, & Landis (2013),

“Biopolymers come in many different forms; they can be derived from renewable resources and may not be defined within the traditional plastics classification numbering system 1-6 like polylactic acid (PLA) or they can be partially made from renewables and synthesized like traditional plastics in the case of bio-based PET” [Polyethylene Terephthalate] (p. 1899).

The key phrase in this statement is “partially made from renewables”. A biopolymer or bioplastic falls under the category of either fully derived from renewable raw materials, or it can also contain petroleum or fossil fuel sources in addition to renewable raw materials (USDEWA, 2014). This study uses the general term bioplastic because bio-based, biodegradable, and compostable inherently have a variety of different meanings and are made from several raw materials or fossil fuels. Talon (2014) makes a similar argument and says,

“In the interests of clarity, it should be noted that the term “bioplastic” is to be understood here in terms of nature, rather than properties. Thus, for our own purposes a bioplastic is a plastic material created, at least partially, from or with renewable resources exclusively” (p. 92).

In order to be general, like Hottle et al. (2013) and Talon (2014), this study will use the term *bioplastic*. This is appropriate within the scope of this study because the data collection

involved interactions with average citizens who typically use the term plastic rather than polymer. In addition to Hottle et al. (2013), Kabasci (2014), and Talon (2014), others like Peelman, Ragaert, Muelenaer, Adons, Peeters, Cardon, Van Impe, and Devlieghere (2013), provide examples of bio-based and fossil fuel-based plastics. Peelman et al. (2013) specifically studied bioplastics in food packaging applications, which is relevant to this study. Table 1.1 describes the most common bioplastics by their technical name and abbreviation, in addition to if they are bio-based or petroleum-based.

Table 1.1: Bioplastics Variations

Material	Abbreviation	Source
Polyhydroxyalkanoates	PHA	Bio-based
Poly Lactic Acid	PLA	Bio-based
Thermoplastic Starch	TPS	Bio-based
Bio-urethanes	BURS	Bio-based
Cellulose and Lignin	-	Bio-based
Bio-polyethylene	Bio-PE	Bio-based
Bio-poly(ethylene-terephthalate)	Bio- PET	Bio-based
Bio-polyamide	Bio-PA	Bio-based
Polyethylene terephthalate	PET	Petroleum-based
Polyethylene	PE	Petroleum-based
Polyamide	PA	Petroleum-based
Polybutylene succinate	PBS	Petroleum-based
Poly trimethylene-terephthalate	PTT	Petroleum-based
Polycaprolactone	PCL	Petroleum-based
Polyethylene succinate	PES	Petroleum-based
Polybutyrate adipate terephthalate	PBAT	Petroleum-based

Table adapted from Álvarez-Chávez et al., (2012); Emadian et al. (2017); Hermann et al., (2011).

Bio-Based

Bio-based is a term used to describe bioplastics that holds little meaning in terms of end-of-life process and mostly refers to the origins of the product. Table 1.2 demonstrates the variability found in the bio-based definition within numerous organizations, including a government agency, an international standardization organization, and a business/ NGO working group.

Table 1.2: Bio-based Definitions in the United States

Business-NGO Working Group for Safer Chemicals and Sustainable Materials (BizNGO)	Plastics in which 100% of the carbon is derived from renewable agricultural and forestry resources such as corn starch, soybean protein, and cellulose.
United States Department of Agriculture (USDA)	Commercial or industrial goods (other than food or feed) composed in whole or in significant part of biological products, forestry material, or renewable domestic agricultural materials, including plant, animal, or marine materials
American Society for Testing Materials (ASTM)	An organic material in which carbon is derived from a renewable resource via biological processes

Adapted from Álvarez-Chávez et al. (2012). This table describes 3 different organizations and their definitions of bio-based plastics.

The U.S. Department of Ecology State of WA (2014) states a bio-based plastic is simply made from renewable raw materials rather than petroleum, but it does not need to be fully bio-based. They distinguish a bio-based plastic might not be biodegradable, or compostable either. Alternatively, Kabasci (2014) notes a definition of bio-based plastic that is simply “plastics derived from biomass” (p. 2). This definition is from EN ISO 472, a norm created by the European Committee for Standardization (CEN) in August of 2009. They further explain and say the EN states,

“Plastics are materials that contain an essential ingredient a high polymer and which at some stage in their processing into a finished product can be shaped by flow. Biomass means non-fossilized and biodegradable organic material originating from plants, animals, and micro-organisms. Biomass is considered a renewable source as long as its exploitation rate does not exceed its replenishment by natural processes” (p. 2).

The European definition of bio-based plastic involves some notion of regrowth and proper management of materials in the last sentence, something missing from the definitions from the United States (De Wilde & Boelens, 1997). Similar to the Department of Ecology State of Washington (2014), Kabasci (2014) describes a difference between bio-based and biodegradable with a few polymer examples. He says, “The process of biodegradation is closely linked to the molecular structure of the polymer, it does not depend on the origin of the material” (p. 2). What this means is that some bioplastics are made mostly or totally from fossil fuel based resources and have the potential to biodegrade, yet some bioplastics made mostly or fully from renewable resources do not have the potential to biodegrade. Kabasci (2014), like Hottle et al. (2013) and Talon (2014) provides some example polymers,

“Some fossil-based polymers, like polycaprolactone (PCL) or poly butylene adipate terephthalate (PBAT) are biodegradable... There are bio-based plastics, like polyethylene (PE) from sugar cane, which are resistant to biodegradation” (p. 2).

Bio-based is the worst offender for confusing terminology because it does not include any notion of what potential end-of-life pathway is appropriate. Rather, the term bio-based helps determine the contents of the bioplastic.

USDA BioPreferred

In the 2002 Farm Bill, the U.S. Department of Agriculture (USDA) launched a program with the mission to purchase and utilize more bio-based materials within the federal government to promote U.S. agriculture, create jobs, and reduce fossil fuel reliance. The BioPreferred program has two initiatives: mandatory purchasing agreements among federal agencies and their suppliers and a voluntary labeling scheme for those products purchased (USDEWA, 2014;

BioPreferred, n.d.). This program is not a standard, but it is commonly and mistakenly used in those contexts. The USDA BioPreferred program does use a standard created by the American Society for Testing Materials (ASTM) for determining carbon content, which translates as the bio-based content of a product. The USDA uses ASTM D6866, which is a test method that can be used to determine the bio-based carbon content of a material by analyzing a gas after combusting the material (Narayan, 2014).

The second initiative of the USDA BioPreferred program requires federal agencies to purchase products with a minimum bio-based content. The content percentage is dependent on the product. Items like composite plastic building materials, paints, cleaners, even topical pain ointment are included in the list of 97 products. Topical pain relief products must contain a minimum of 91% bio-based content whereas plastic lumber is only required to contain 23% bio-based content (BioPreferred, n.d.) In addition to federal purchasing requirements, products that meet the USDA's minimum requirement for bio-based content are permitted to use the USDA BioPreferred logo (Narayan, 2014). This logo only indicates the product contains a specific percentage of bio-based resources, not that it is biodegradable or compostable.

Figure 1.1 USDA BioPreferred Logo



Biodegradable

Biodegradable plastics are materials that “can degrade by naturally occurring microorganisms such as bacteria, fungi, and algae to yield water, carbon dioxide, and methane,

biomass and inorganic compounds” according to a 2014 report by the Department of Ecology State of Washington. Biodegradable is a common term for polymers that are designed to decompose, but there is a large discrepancy with the term biodegradable because of the inconsistent application and the lack of temporal distinction (Emadian, Onay, & Demirel, 2016; Rudnik, 2008; van der Zee, 2005).

Many bioplastic related groups and organizations have tried to apply a clear definition for biodegradable. In some context, biodegradable implies hydrolysis, a chemical break down in water. Alternatively, in non-aqueous contexts, biodegradable indicates fragmentation or degradation by living organisms. Occasionally biodegradation can wrongfully be suggested as deterioration, the physical failure of a material (van der Zee, 2005). There are factors inhibiting a common definition for the international community including: the diverse environments where the material will be introduced, differences in scientific communities’ determination of degradation, the variety of consequences on policy, and language barriers (van der Zee, 2005).

In order for biodegradation to have meaning within a standardization context the environment in which it will decompose must be defined in addition to a measurable time must be set preemptively (USDEWA, 2014; Rudnik, 2008). Emadian et al. (2016) argue the conditions of an environment are the key factors for polymer’s degradation including conditions like the pH, temperature, amount of moisture and oxygen in an environment. Furthermore, Hermann et al. (2011), state biodegradation can take place in natural or controlled environments. A natural environment would be in soils or water, where a controlled environment could be a biological waste treatment like a compost pile or anaerobic digester (Hermann et al., 2011). Despite the lack of a homogenized definition for biodegradability, all of the efforts have culminated in a few set elements which van der Zee (2005) outlines,

“Material manufactured to be biodegradable must relate to a specific disposal pathway such as composting, sewage treatment, denitrification, or anaerobic sludge treatment.

The rate of degradation [...] has to be consistent with the disposal method and other components of the pathway into which it is introduced.

The ultimate end products of aerobic biodegradation [...] are carbon dioxide, water, and minerals and that the intermediate products include biomass.

Materials must biodegrade safely and not negatively impact the disposal process of the use of the end product of the disposal” (p.3)

When attempting to define biodegradability it is crucial to understand what it is not. A plastic labeled biodegradable does not mean it is compostable, recyclable, or entirely made from renewable raw materials (USDEWA, 2014). Biodegradability is one of the many terms used in the bioplastic industry to describe a technological advancement in polymer materials. Nevertheless, the national and international standardization community has created numerous standards for the term biodegradable. In Table 1.3, the most popular standards are shown.

Table 1.3: National and International Standards for Biodegradable Plastics

ASTM D5210-92	Standard test method for determining the anaerobic biodegradation of plastic materials in the presence of municipal sewage sludge.
ASTM D5271-02	Standard test method for determining the anaerobic biodegradation of plastic materials in an activated sludge wastewater treatment system.
ASTM D6340-98	Standard test method for determining aerobic biodegradation of radiolabeled plastic materials in an aqueous or compost environment.
ASTM D6692-01	Standard test method for determining the biodegradability of radiolabeled polymeric plastic materials in seawater.
EN 13432-2000	Packaging- Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging.
ISO 14851- 1999	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium. Method by measuring the oxygen demand in a closed respirometer.
ISO 14892-1999	Determination of the ultimate anaerobic biodegradability of plastic materials in an aqueous medium. Method by analysis of evolved carbon dioxide.
ISO/DIS 14853- 1999	Determination of the ultimate anaerobic biodegradability of plastic materials in an aqueous medium. Method by measurement of biogas production.
ISO/DIS 17556-1999	Plastics. Determination of the ultimate aerobic biodegradability in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved.

All of these standards are standard test methods for biodegradable plastics. They vary by environment and y all focus on biodegradation. However, only a few have additional evaluation criteria to determine biodegradability. This is measured by using limits and thresholds. This is not an exhaustive table, but rather a summary of the most common standard test methods from The Handbook of Biodegradable Polymers. Adapted from Müller (2005) and Arikan & Ozsoy (2015).

Table 2.3 is not an expansive list, rather an example to demonstrate the complex and various methods for standardizing test methods for biodegradation. Narayan (2014) and Arikan & Ozsoy (2015), provide their own listing of important and common test method standards from

ASTM and ISO which overlaps with this table. Narayan (2014) critically points out that these test method standards “have no pass/ fail criteria, and so should not be used to claim biodegradability in any environment” (p. 354). Biodegradable standards begin to refer to the end-of- life for a bioplastic and this can cause confusion with the term compostable. The terms are not interchangeable, but it is very common for non-industry members to refer to bioplastics as biodegradable plastics or degradable. When referring to bioplastics, the term compostable implies biodegradation, but there are specific details unlike biodegradable (USDEWA, 2014).

Compostable

One of the main elements that separates a biodegradable test method standard from a compostable test method standard is the requirement of criteria defining pass/fail (Narayan, 2014). Compostable test method standards require the bioplastic to be in a specific environment for a designated amount of time and demonstrate biodegradation. For a bioplastic to be considered compostable it is necessary for it to biodegrade in a composting environment (Pei, Schmidt, & Wei, 2011; USDEWA, 2014). In addition to biodegradation, compostable test method standards have requirements for disintegration and compost quality (De Wilde, 2005). Compost quality relates to a compostable plastic’s effect on the compost; it must not leave harmful residues or impair the compost or subsequent organisms grown in the compost in the future.

The same organizations that provide biodegradation test method standards provide compostable test method standards; these include ASTM, ISO, and CEN (Rudnik, 2008). A bioplastic must meet the three principals of biodegradation, disintegration, and compost quality in order to pass the test method standards. Most of the standard test methods vary slightly at the different organizations, but the overall themes remain consistent (De Wilde, 2005).

International Organization for Standardization (ISO)

The ISO dominant standard for compostable plastics is #17088. This standard relates specifically to the “procedures and requirements for the identification and labelling of plastics, and products made from plastics that are suitable for recovery through aerobic composting” (ISO, n.d.). Again, the three main components of this test method standard are biodegradation, disintegration and compost quality. ISO 17088 goes a bit further and distinguishes between “negative effects on the composting process and facility” and “negative effects on the quality of the resulting composting, including the presence of high levels of regulated metals and other harmful components” (ISO, n.d.).

This test method standard lays out the conditions for labelling plastics with the following three labels:

- Compostable
- Compostable in municipal and industrial facilities
- Biodegradable in compost

ISO considers all three of these labels to be equal in definition and purpose. In Table 1.4, the ISO standards related to compostable plastics are listed. This is not an exhaustive list, but rather it demonstrates the most common and accepted ISO standards by those involved in the bioplastic industry.

Table 1.4: ISO Standards related to Composting

ISO/DIS 17088	Specifications for compostable plastics.
ISO 14021	Environmental labels and declarations. – Self-declared environmental claims.
ISO 14853	Plastics- Determination of the ultimate aerobic biodegradation of plastic materials in an aqueous system. Method by measurement of biogas production.
ISO 14855:1	Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions. Method by analysis of evolved carbon dioxide. – General method.
ISO/DIS 14855: 2	Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions. Method by analysis of evolved carbon dioxide. – Gravimetric measurement of CO ₂ evolved in laboratory-scale test.
ISO 15985	Plastics- Determination of the ultimate anaerobic biodegradation and disintegration under high solids anaerobic digestion conditions. Method by analysis of released biogas.
ISO 16929	Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test.
ISO 17556	Determination of the ultimate aerobic biodegradability in soil by measuring the oxygen demand in a respirometer or the amount of CO ₂ evolved.
ISO 20200	Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test.

This table represents the standard test methods and their titles from ISO related to composting. Adapted from Rudnik (2008) in Compostable Polymer Materials.

American Society for Testing Materials (ASTM)

The most common standardization organization in the United States is the American Society for Testing Materials. Although this organization is recognized outside of the United States, it is commonly thought of as a regional organization, rather than an international one like

ISO (Rudnik, 2008). The ASTM’s most prevalent standard test method for compostable plastics is ASTM D6400. Below is Table 1.5, which describes the majority of the ASTM standards for compostable plastics.

Table 1.5: ASTM Standards related to Compost

ASTM D6400	Standard specific to compostable plastics.
ASTM D6002	Standard guide for assessing the compostability of environmentally degradable plastics.
ASTM D6868	Standard specification for biodegradable plastics used as coatings on paper and other compostable substrates.
ASTM D6340	Standard test methods for determining aerobic biodegradation of radiolabeled plastic materials in an aqueous or compost environment.
ASTM D5929	Standard test method for determining biodegradability of materials exposed to municipal solid waste composting conditions by compost respirometry.
ASTM D5338	Test method for determining aerobic biodegradation of plastic materials under controlled composting conditions.
ASTM D5988	Standard test method for determining aerobic biodegradation in soil of plastic materials or residual plastic materials after composting.
ASTM D5511	Test method for determining anaerobic biodegradation of plastic materials under high solids anaerobic digestion conditions.

This table lists the most common standards related to compostable plastics within the American Society for Testing Materials. Adapted from Rudnik (2008) in Compostable Polymer Materials.

The scope of ASTM D6400 includes “plastics and products made from plastics that are designed to be composted under aerobic conditions in municipal and industrial aerobic composting facilities, where thermophilic conditions are achieved” (ASTM, n.d.). This standard test method also, like ISO 17088, establishes labeling criteria for the label “compostable in aerobic municipal and industrial composting facilities” (ASTM, n.d.). To the ASTM this standard is equivalent to ISO 17088, in that it establishes requirements for satisfactory

composting including biodegradation and disintegration although biodegradation is referred to as mineralization in this standard, but the definitions are parallel.

In addition to biodegradation and disintegration, ASTM D6400 references compost quality and safety like ISO 17088, but in contrast, ASTM D6400 allows for far greater heavy metal content in the final compost. In their analysis of ASTM D6400, Rudnik (2008) repeats the following statement from the standard, “safety of compost must be proved by testing phyto- or ecotoxicity using methods listed in the Standard” (p. 99). ASTM D6400 does establish guidelines for compost safety and quality (Philp et al., 2013). While the ASTM D6400 standard dominates in the United States, the European Union has taken their bioplastic industry a step further beyond standardization organizations and has passed legislation regarding bioplastics and the organic recovery of materials (Rudnik, 2008).

European Norm 13432

In an effort to add rigor to existing environmental policies in Europe, the European Commission (EC) authorized the European Standardization Organization (CEN) to establish European Norm 13432, which is a “tool to prove compliance with European Directive 94/62/EC (Rudnik, 2008, p. 99). This norm is recognized by all European Union members and they must follow this standard, which presents specific criteria and practices for the compostability of packing; similar to ASTM and ISO. However, this norm exists within the confines of EU legislation so requirements and consequences have more political meaning than an industry standard (Lee & Xu, 2005; Pagga, 1998). EN 13432 focuses on packaging, whereas ASTM D6400 and ISO 17088 focus on additional forms of compostable plastics for other sectors like agriculture and not solely packaging (Narayan, 2014; Rudnik, 2008).

Philp et al. (2013), summarize over 25 standards in their research paper “Bioplastics science from a policy vantage point” and reiterate EN 13432 as the “Requirements for packaging recoverable through composting and biodegradation -test scheme and evaluation criteria for the final acceptance of packaging” (p. 641). Similar to the variety of ASTM and ISO standards detailing test methods in various environments, European Norms’ 14045, 14046, 14047, 14048, and 14806 all include specific tests about biodegradation, disintegration, and use methods like measuring oxygen and carbon dioxide to determine passing criteria (Philp et al., 2013).

Table 1.6 below demonstrates the key differences and similarities between the three most common compostable plastic standards of ISO, ASTM, and EN. This table, adapted from Rudnik (2008) provides an overview of the standards used to normalize bioplastics labeled as compostable plastics. ASTM and ISO are standardization organizations while EN is a European Norm published from the European Commission.

Table 1.6: Compostable Plastic Standards: a Comparison

Standard	Biodegradation	Disintegration	Safety
ASTM D6400	<p>Single Polymer Products</p> <ul style="list-style-type: none"> 60% of the organic carbon must be converted to CO₂ within 180 days <p>Multiple Polymer Products</p> <ul style="list-style-type: none"> 90% of the organic carbon must be converted to CO₂ within 180 days 	<p>No more than 10% of its original dry weight remains after sifting on a 2.0 mm sieve after controlled laboratory scale composting</p>	<ul style="list-style-type: none"> No adverse effects on ability of compost to support plant growth Low levels of heavy metals
ISO 17088	<p>Single Polymer Products</p> <ul style="list-style-type: none"> 60% of organic carbon must be converted to CO₂ within 180 days <p>Multiple Polymer Products</p> <ul style="list-style-type: none"> 90% of the organic carbon must be converted to CO₂ within 180 days 	<p>No more than 10% of its original dry mass remains after sifting on a 2.0 mm sieve after 84 days in a controlled composting test</p>	<ul style="list-style-type: none"> Low levels of heavy metals A minimum of 50% of volatile solids Ecotoxicity assessment (plant growth test on 2 different species)
EN 13432	<p>At minimum 90% of biodegradation within 6 months</p>	<p>No more than 10% of the residues from the packaging waste should be larger than 2 mm</p>	<ul style="list-style-type: none"> Low levels of heavy metals Physical/chemical analysis of resulting compost Ecotoxicity assessment (plant growth test on 2 different species)

This table demonstrates the key components of the most common test method standards from ASTM, ISO, and EN. There are similarities among the 3 categories, like percentages of biodegradation and disintegration, in addition to low levels of heavy metals. The differences also lie within percentages of biodegradation and ISO/EN have further safety measures. Adapted from Rudnik (2008).

In a fact sheet published by European Bioplastics, an association of bioplastic industry members, they describe the difference between test method standards and the pass/fail criteria.

“There are two different types of evaluation systems, which are both commonly called standards: On the one hand, test methods describe methodological criteria and typically lay out the procedures that need to be followed. On the other hand, there are specifications, which have a normative function and define a set of pass and fail criteria as the requirements that need to be met in order for a product or material to be compliant with the standard.” (European Bioplastic Fact Sheet, 2016).

It is important to note this distinction because this applies to ISO and ASTM standards, as well as related European Norms. The labeling of bio-based, biodegradable, and compostable plastics depends upon the second clause in the above quotation; the specifications and pass/fail criteria is what determines how products are labeled. Additionally, in the United States, labeling claims fall under Federal Trade Commission jurisdiction, in addition to the standardization organizations (Susan Tohman, personal correspondence).

Federal Trade Commission Green Guide (FTC)

The FTC Green Guide is a document which provides examples and is a manual for making environmental marketing claims about products, packaging, or services in the United States (Federal Trade Commission (FTC), 2012). This guide is relevant to the bioplastics industry because it includes information about compostable and degradable claims. The Green Guides are used to prevent misinformation and false marketing to individuals, businesses, and groups. According to the first section on the purpose, scope, and structure, “The guides consist of general principles, specific guidance on the use of particular environmental claims, and examples” (FTC, 2012). The FTC Green Guides do not have rigorous test standards, but a large part of the principles includes scientific evidence for compostability and degradability; this comes in the form of the ASTM and ISO standard test methods.

The compostable claim section in the Green Guide outlines the ways in which marketing claims using the term “compostable” are able to properly advertise. The first principle states “It is deceptive to misrepresent, directly or by implication, that a product or package is

compostable.” (FTC, 2012, p. 15). The second principal is related to demonstrating proof of the compostable claim. The guide states,

“A marketer claiming that an item is compostable should have competent and reliable scientific evidence that all the materials in the item will break down into, or otherwise become part of, usable compost (e.g., soil-conditioning material, mulch) in a safe and timely manner (i.e., in approximately the same time as the materials with which it is composted) in an appropriate composting facility, or in a home compost pile or device” (p. 16).

The second principle implies a connection to the standardization organizations, but it does not explicitly state a requirement to use ASTM, ISO, or other standard test methods. Principle two requires evidence to exist, whereas principle three specifically stipulates that a compostable claim must include information if the product does not compost without harm or within an appropriate amount of time in a home compost environment. In addition, the claim must not be deceptive about the scenario if the product ends up in a landfill that it has comparable environmental benefits (FTC, 2012). Lastly, the fourth principle relates to compostable claims and inadequate, industrial or municipal composting facilities. The principle says a claim must openly state adequate facilities for composting may not necessarily exist where the compostable product is being sold (FTC, 2012). These principles exist to ensure products labeled compostable are not deceptive to consumers and the FTC Green Guide provides examples of claims that are either acceptable or deceptive. An example of an acceptable claim is,

“A manufacturer markets yard trimmings bags only to consumers residing in particular geographic areas served by county yard trimmings composting programs. The bags meet specifications for these programs and are labeled, “Compostable Yard Trimmings Bag for County Composting Programs.” The claim is not deceptive. Because the bags are compostable where they are sold, a qualification is not needed to indicate the limited availability of composting facilities” (p. 17).

In addition to compostable claims, the FTC Green Guide outlines degradable claims. The principles for degradable are similar to those for compostable and includes all claims for the

following terms, biodegradable, oxo-degradable, oxo-biodegradable, and photodegradable (FTC, 2012). The second and third principles for degradable claims are similar to the compostable principles given that they include the requirement of evidence for degradation with temporal and environmental distinction. A degradable claim made about a product intended for a landfill, incinerator, or recycling center is deceptive and the FTC Green Guide provides the example of

“A marketer advertises its trash bags using an unqualified “degradable” claim. The marketer relies on soil burial tests to show that the product will decompose in the presence of water and oxygen. Consumers, however, place trash bags into the solid waste stream, which customarily terminates in incineration facilities or landfills where they will not degrade within one year. The claim is, therefore, deceptive” (p. 18).

The degradable principles in the FTC Green Guide do not intend to establish standards or test methods, like the ASTM or ISO, but rather they are written guides and principles to prevent deception for consumers and work alongside standardization organizations to ensure proper use of the products. In addition to the FTC Green Guide, ASTM and ISO standards there are certifications for bioplastics which designates approval by a third-party organization.

Overall, these standard test methods and federal guidelines are not influential enough to be considered regulations and do not provide a great deal of international harmonization. The varying definitions of bio-based, biodegradable, and compostable remain confusing; however, certifications and their logos can support the divisions between terms.

Certifications

Certifications play a significant role in the development of bioplastics due to the industry’s complex, international standards and multitude of stakeholders from manufacturers to composters. Certifications provide clarity and communicate with consumers about bioplastics by providing a label or logo that contains meaning about the compostability of a bioplastic (de

Wilde, 2005). Along with the ASTM, ISO, and EN standards, there are separate certification organizations that provide the bioplastic industry with certification schemes. The majority of the certification organizations utilize ASTM, ISO, and EN standards.

European Certifications

In Europe, the major bioplastic certification organizations are DIN-Certco in Germany and AIB-Vinçotte International in Belgium (de Wilde, 2005; Lörcks, 1997). In order to have a product be certified and printed with the certification label, bioplastic manufacturers must submit records of evaluations from the standardization organizations in approved laboratories. These certification organizations in Europe typically base their certification acceptance from EN 13432, ISO, and ASTM standards. Once DIN-Certco or AIB-Vinçotte International deliberate and approve the application, the product receives certification and can bear their logos (de Wilde, 2005; European Bioplastic Factsheet, 2016). These labels are for industrial composting only. Figure 1.2 from left to right demonstrates the Seedling Logo from DIN-Certco, OK Compost from AIB-Vinçotte International, and another DIN-Certco certification DIN-Geprüft Industrial Compostable.

Figure 1.2: European Certification Logos



Reproduced from European Bioplastic Factsheet www.european-bioplastic.org

United States Certifications

In the United States, the largest certification organization is the Biodegradable Products Institute (BPI). This institute began its certification and logo program by combining efforts with The United States Composting Council (USCC) in 2000 (Darby, 2012; de Wilde, 2005; USDEWA 2014). Like its European counterparts, BPI's certification and logo approval begins with a submission by a bioplastic manufacturer, the records from ASTM are reviewed, and if approved, the bioplastic product is certified and able to bear their logo. Figure 1.3 is the BPI approved logo.

Figure 1.3: United States Certification Logo



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Conclusion

Generally, the test method standards, marketing claims, and certifications attempt to harmonize and regulate the dizzying variety of bioplastics in the free market, but they lack global cohesiveness and political clout to truly regulate the industry. This chapter attempted to describe and explain the most widespread measures for standardizing the bioplastics industry and is a reference point for the remaining study.

Chapter 2: Literature Review

The previous section introduced the standardizations and certifications of the bioplastic industry. In this literature review, the sections weave together to provide contextual information on perceptions and knowledge of bioplastics from a consumer perspective and the current identified environmental challenges of bioplastics. The use of bioplastics began growing in popularity in the 1980's when they first appeared on the global market. When first created, they were marketed for use in the agricultural sector as ground covers or mulch and really became popular as disposable packaging in the food service industry (Ren, 2003). Around the same time bioplastics first appeared commercially, awareness of global environmental problems had intensified and many sociologists argued there was a need to include the environment in social theory. In the 1980's, a new theory, Ecological Modernization Theory (EMT), developed out of earlier European social theory. This study uses EMT to explain the growth of bioplastics and subsequently the environmental problems of bioplastics within society.

Ecological Modernization Theory (EMT)

In order to understand Ecological Modernization Theory, it is important to acknowledge environmental sociology as a subset of the sociology discipline and its focus on studying the relationships between society and the environment. To some extent, environmental sociology began with a critique from American sociologists William Catton and Riley Dunlap, who critiqued what they called the Human Exemptionalist Paradigm (HEP). This paradigm claimed human beings were acting as if they were free of environmental or natural resource limitations because of their use of technology (Catton & Dunlap, 1978). To Catton and Dunlap (1978), this paradigm was a dangerous way of thinking about the relationship between society and the environment because it ignores the interactions of humans and the environment; it

separated ecology and the economy. They theorized a paradigm shift was necessary to change this and they developed the New Ecological Paradigm (NEP). The New Ecological Paradigm argues for a paradigm shift that creates a “sustainable management of nature” and “according to this new exemptionalism, what is needed in the human relationship to the environment is mainly fine-tuning of the productive apparatus” (Foster, 2012, p. 212).

A few years after Catton and Dunlap published the New Ecological Paradigm, a new environmental social theory emerged from Dutch scholars Gert Spaargaren and Arthur P.J. Mol in 1992. Spaargaren and Mol (1992) propose,

“The ecological modernization approach diverges from neo-Marxist social theories in paying little attention to changing relations of production or altering the capitalistic mode of production altogether” (p. 336).

Capitalistic modes of production and the environment have been extensively critiqued by many like Karl Marx, Max Weber, and Justus von Liebig (Foster, 2012). Among the modern arguments for understanding the foundations of society’s environmental problems is Schnaiberg’s Treadmill of Production (Spaargaren & Mol, 1992). The treadmill of production theory focuses its critiques on modernization theory from a post-World War II perspective. Foster (2012) argues,

“Post-Second World War modernization theory transformed these [capitalism and Western liberalism] in the process of constructing a rigid, unilinear development model at sharp variance with the deeper, more probing traditions of classical sociological analysis. This was particularly evident in its promotion of crude, human exemptionalist notions of the conquest of nature, in contrast to the most historically mediated, environmentally conscious views of classical sociology.” (p. 214).

Foster (2012) explains, post-World War II modernization theory led to society’s ignorance of the environment and its protection, as pointed out by Catton and Dunlap’s (1978) Human Exemptionalist Paradigm.

The Treadmill of Production theory is a “perspective, representing a diametrically opposite frame [of EMT], rooted in neo-Marxian theory” (Foster, 2012, p. 213). In other words, Ecological Modernization Theory and the Treadmill of Production are inherently opposite theories. Given that, Schnaiberg (1980) argues production, as a mode of capitalism, creates and perpetuates environmental problems because of its fundamental desire to continue economic and productive expansion. The treadmill model represents modernity circling in place rather than moving forward, and the only means of moving forward [modernity] and stopping or preventing environmental problems are slowing or ending the treadmill, also known as deindustrialization (Schnaiberg, 1980). Overall, Schnaiberg’s (1980) Treadmill of Production theory uses a modern, post- World War II, Marxist critique of capitalism and production expansion to demonstrate how these social institutions are the source of environmental destruction and crises.

Spaargaren and Mol are not interested in dismantling the capitalistic relationships between production and the environment like in the Treadmill of Production theory, but rather the approach they are interested in modernizes the relationship between the environment and society. They say,

“environmental problems are not just the unintended consequences of an otherwise fortuitous trajectory of modernity... their solution is bound up with altering the major cultural, political, and economic institutions of contemporary society” (Spaargaren & Mol, 1992, p. 324).

Spaargaren and Mol (1992) disagree with Schnaiberg’s (1980) stance that a single factor explains society’s overloading of the finite natural resources. Spaargaren and Mol allege that Schnaiberg focuses on the “monopoly-capitalist character of modern society” and largely ignores a third characteristic – industrialization- when discussing the environmental crisis (Spaargaren & Mol, 1992, p.336).

Their subsequent Ecological Modernization Theory claims that the “possibility of overcoming the environmental crisis without leaving the path of modernity” is feasible (Spaargaren and Mol, 1992, p.334). This implies the path or way of solving environmental problems is continuing to modernize and grow industrially. The authors agree with Joseph Huber (1985), whose work founded EMT, and argue that Ecological Modernization is best understood as a new ecological configuration of production and consumption. Modernizing these two capitalistic processes through increased technologies aimed at restoring environmental conditions is the key to change (Spaargaren & Mol, 1992).

EMT is a theoretical framework concerned with the “shift toward technologies that establish clean production processes”; this means more support for innovations that provide the environment with advantages rather than damages (Spaargaren & Mol, 1992, p.335). The introduction of bioplastics as alternatives to traditional petroleum-based plastics can be considered an example of social change within the Ecological Modernization theoretical framework. The revolution of industrial processes to produce a consumer product with less environmental impacts, like reduced natural resource consumption and emissions, is an example of improved, ecological technologies that work within the existing system’s capitalist market production.

In this study, EMT is a model for examining and comprehending how society manages and prevents environmental crisis. In general, theory offers individuals a lens for understanding the world around them, furthermore this lens influences how and what individuals perceive. This study is testing Ecological Modernization Theory by analyzing bioplastic use, knowledge, and perceptions of individuals in Olympia, Washington. Case studies, like this study, are difficult to generalize. However, the data collected provides insights into the way individuals think about,

feel, and experience bioplastics in the environment. By asking about bioplastic use, knowledge, and perceptions this study challenges the foundations of Ecological Modernization to explain society's current attempts to mitigate environmental crisis.

Consumer Awareness and Perceptions of Bioplastics

With any technological innovation, there is concern about the transition from old to new and bioplastics are no exception. Perceptions about the environmental benefits from bioplastics are mixed and few scholars have studied reactions to bioplastics entering the market from a consumer perspective. In a study of 57 Dutch citizens' perspectives on the bioeconomy, specifically looking at bioplastics, bio-jetfuels, and bio-refineries, the results were very diverse (Lynch, Klassen, & Broerse, 2017). The focus group of participants were provided with two bioplastics products, a bio-based PET bottle and a bioplastic shopping bag with written information on the location of plastic origin, possible uses, and the end-of life options (Lynch et al., 2017). The participants offered arguments both in favor and against buying the products. The authors summarized the arguments in favor of purchasing bioplastics as *economic growth* for the country who produces the material, a perceived *positive environmental impact*, and support of a *green lifestyle* (Lynch et al., 2017). Arguments against the bioplastic products included participants not being convinced of its positive environmental impacts, participants being confused about how to dispose of the product, the perception that the product was low quality, the percentage of actual biomass in the bioplastic being low, and an overall concern of greenwashing and higher prices (Lynch et al., 2017). This study demonstrates the mixed and highly dichotomous views on bioplastics. The variety of interpretations that exist around bioplastic's impacts on the environment and the economy are important to this study because labeling of these products is directly linked to usage by consumers. Confusion and

undistinguishable differences between types of plastics are notable problems within the bioplastics life cycle.

Sijtsema, Onwezen, Reinders, Dagevos, Partanen, and Meeusen (2016) completed a similar study to Lynch et al. (2017), but explored a larger sample size. The study looked at five European countries and the perceptions of 89 participants from Germany, the Netherlands, Czech Republic, Denmark, and Italy. This study focused on bio-based products and demonstrated the diversity of perceptions shared by consumers. Sijtsema et al. (2016), provided participants with seven bio-based products and they were asked to share positive or negative associations. Again, like Lynch et al. (2017), the results of the study showed strong feelings of uncertainty and many questions about bio-based products. Sijtsema et al. (2016) concluded that bio-based is a term not ubiquitous with consumers, so in order to successfully introduce bio-based products in the market associations with the term should be explored further.

Another study exploring perceptions of bioplastics with Dutch university students and staff, focused on the characterizations of “natural” and “high quality” materials (Karana, 2012). This study focused on how perceptions of bioplastics could support product designers and developers, who are able to facilitate the use of bioplastics rather than petroleum-based plastics. The results emphasized how materials convey meaning through properties like hardness, glossiness, elasticity, toughness, strength, weight, opaqueness, warmth, reflectiveness, and smoothness. These properties are important to the growth of bioplastics because the perceptions surrounding bioplastics can undermine their effectiveness and contribute to environmental impacts, especially during the end-of-life stage, explained later by Life Cycle Assessments. Karana (2012), summarized a few strategies to assist developers and designers in their use of bioplastics including: introduce bioplastics with a unique look to extrapolate on their differences

from petroleum-based plastics; do not use bioplastics as a replacement to conventional plastic, but utilize their bio-properties in a more holistic design; and move away from purely disposable bioplastic products to more durable goods to ensure acceptance of the longevity of these plastics. This is relevant to the present research because perceptions of these products are key to ensuring they are utilized in the most efficient manner.

Similar to the studies previously mentioned, Magnier, Schoormans, and Mugge (2016) and Steenis, Herpen, Lans, Ligthart, and Trijp (2017) conducted research related to packaging and sustainability. In both studies, the researchers were interested in consumers' perceptions about the sustainability of product packaging and how consumers reacted to various packages. They did not predetermine responses for the participants in order to prevent misleading consumers' perceptions. Overall, both of the studies came to similar conclusions. Magnier et al. (2016) discovered that "packaging sustainability positively influences the perceived quality of a food product" and "individuals make inference about the quality of food products when assessing a noticeably sustainable packaging" (p. 138). The original question of their study asked to what degree does packaging sustainability influences consumers' perceptions of products' quality and sustainability. Their question relates to this study of bioplastics because bioplastics are perceived as a sustainable packaging option and if there is evidence of sustainable packaging influencing perceived quality, it may be in business owners' best interest to utilize bioplastics or sustainable packaging to sell their products. Magnier et al. (2016) did not explicitly use bioplastics, however bioplastics are inherently a part of their study because they defined product sustainability as,

"the endeavor to reduce the environmental footprint through altering the intrinsic attributes and thus the composition of the product... In this respect packaging sustainability is defined as the endeavor to reduce the product's footprint through altering

the products' packaging, for example by using more environmentally friendly materials" (p. 132).

This definition is important to this study because bioplastics have been marketed to consumers as more environmentally beneficial than traditional, petroleum-based plastics. The environmental benefits of bioplastics are debated and in a study by Steenis et al. (2017) the intersection of perceived environmental benefits and actual environmental impacts is explored further.

Steenis et al. (2017), argue one of the strongest influences on modern consumption is packaging. They argue there is a great deal of effort from packaging companies, lobbyists, environmental groups, and policy makers to create more sustainable packaging. However, the most common method for understanding environmental impacts of materials, the life cycle assessment (LCA), is the least advertised or publicized aspect of packaging, especially to consumers (Steenis et al., 2017). Life Cycle Assessment measures the environmental effects of a product. The research investigates the "influences of both the structural elements (materials) and graphical design of packaging on consumer perceptions of sustainability... Additionally, consumers' sustainability perceptions are compared with life cycle assessment outcomes" (p. 287). This study is unique in its application of LCA data because the authors compared consumer perceptions of packaging, including bioplastics, with the LCA data. This comparison led to inferences about consumer packaging perceptions and the environmental benefits of the packaging material. For example, the consumers ranked a bioplastic pot as the most sustainable of the following seven materials: glass jar, liquid carton, can, plastic pouch, mixed material pouch, and dry carton sachet. While the consumers perceived the bioplastic pot to be the most sustainable (ranked first), in terms of the LCA the bioplastic pot ranked fifth, much less sustainable than perceived by consumers. There are hundreds of LCA's examining bioplastics in

the literature, so this is just one example, but the intersection of LCA and consumer perceptions is a unique perspective. In general, the authors. Steenis et al. (2017) concluded that consumer perceptions do not necessarily match with life cycle assessments of products. Therefore, most consumers use their own beliefs to make decisions about sustainable packaging.

Overall, these studies demonstrate the diverse and often dichotomous attitudes consumers have related to bioplastics and sustainable packaging. These studies are important to this research because it makes evident a gap in the literature. In contrast to the studies mentioned, this research addresses the redistributors of bioplastics, identified as business owners or employees of businesses who sell their products in or with bioplastics, thus redistributing them from the manufacturer. Conflicting perceptions of bioplastics environmental benefits become even more chaotic when the quantitative method for establishing environmental impacts, Life Cycle Assessment, enters the discussion.

Life Cycle Assessment (LCA)

Life Cycle Assessment is an internationally recognized method for measuring the environmental effects of a product. Each step in the series of changes that a product goes through during its entire existence is analyzed. Life Cycle Assessment is one of many life cycle centered evaluations used by the international manufacturing industry. From the first stages of resource extraction to the final disposal, or end-of-life, Life Cycle Assessment includes everything a product experiences (Crisóbal, Matos, Aurambout, Manfredi, & Kavalov, 2016).

Most prevalent literature on bioplastics comes in the form of articles analyzing, reviewing, or criticizing LCAs of various bioplastics. According to Dietrich, Dumont, Del Rio, and Orsat (2017), there are other sustainability assessment tools including “carbon footprint, carbon efficiency, Sustainable Process Index, health and safety score cards, and the Biomass

Utilization Efficiency (BUE)” (p. 63). However, Life Cycle Assessment is the most widely accepted. Here, a Life Cycle Assessment is defined as a tool, which “quantifies the environmental impact of the entire production chain from biomass collection to either factory gate or disposal in defined impact categories” (Dietrich et al., 2017, p. 63). Yates and Barlow (2013) have a bit different definition, and classify LCA as a

“framework which can be used to assess the environmental impacts of a product throughout its life starting from the extraction of raw materials from the earth and ending at the waste products being returned to the earth” (p. 55).

Both of these definitions include the notion that a LCA works from earliest beginnings to the very end-of-life of a material, but Yates and Barlow (2013) include the idea that a LCA assembles data about both the environmental inputs and outputs, like emissions, waste, resource consumption and then utilizes this data to transform into widespread environmental impacts. The outcome of the data assembly and assessment is understood as environmental impacts or consequences, which translates into anthropocentric concepts like climate change, air quality, toxicity of humans and ecosystems, eutrophication, and acidification (Yates & Barlow, 2013). In the 2013 review article *Sustainability Assessments of Bio-Based Polymers* by Hottle, Bilec, and Landis, they demonstrate there are LCA guidelines established by the International Organization for Standardization (ISO). In Table 2.1 below the ISO guidelines are further defined.

Table 2.1: ISO LCA Steps

Goal and Scope Definition	Defines the extent of the analysis including goals and system boundaries. The functional unit is defined. It describes what is being studied, how much, and the time frame.
Inventory Analysis (LCI)	Documents material and energy flows within established system boundaries. (Inputs and outputs)
Impact Analysis (LCIA)	Characterizes and assesses environmental effects of data obtained in the LCI. Expresses the data in common terms like global warming potential (GWP), eutrophication, smog formation, non-renewable resource depletion, ecotoxicity, acidification, ozone depletion, and human health.
Interpretation	Reviews results of LCA, provides conclusions, recommendations, and identifies areas of improvement.

This table, adapted from Hottle et al. (2013) describes the four steps involved in the ISO LCA guidelines.

Hottle et al. (2013) point out in addition to ISO’s guidelines, other organizations like the Environmental Protection Agency (EPA) and the Society for Environmental Toxicology and Chemistry (SETAC) have adopted guidelines for LCA, but they all contain the same main themes and are a quantitative analysis. For example, Häkkinen and Vares (2010) interpreted the four stages of ISO LCA guidelines as

“compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study” (p.1458).

Although they are quantitative in nature, LCAs are open to interpretation of the researcher and many LCA studies of bioplastics have varying results and analysis (Häkkinen & Vares, 2010; Hottle et al., 2013; Yates & Barlow, 2013). Beyond the four steps of an LCA, there are two types: attributional and consequential (Häkkinen & Vares, 2010; Pawelzik et al., 2013). The attributional LCA, described by Pawelzik et al. (2010) is considered a “cause-oriented, descriptive, or retrospective LCA” (p. 224). The attributional LCA utilizes standard and

current data to determine environmental impacts; it is specifically looking at the immediate impacts connected to the life cycle of the material and the system boundaries are restricted. Häkkinen & Vares (2010) agree and argue “the attributional LCA model does not include processes outside the life cycle to investigate” (p. 1459).

In contrast to the attributional LCA, the consequential LCA incorporates any process that is affected by the material’s life cycle (Häkkinen & Vares, 2010). The consequential LCA according to Pawelzik et al., (2013), “analyzes the environmental impacts based on the consequences that occur as a result of production, use, and disposal of products” (p. 224). These LCA’s are aimed more at the effects, change, or potential of a material. The difference in LCAs is an important distinction for bioplastics because the outcomes of an LCA is highly dependent on the system boundaries and data collected. For example, Yates and Barlow (2013) review and analyze nine bioplastic LCAs and four petroleum-based plastic LCAs and found starkly contrasted viewpoints on the environmental impacts of bioplastics compared to their petroleum based counterparts,

“Piemonte (2010) found that PLA products had a lower nonrenewable energy use (NREU) and global warming potential (GWP) than the petrochemical polymer products they were compared with... In contrast to these results, Hermann et al., (2010) found that PLA used for both inner and outer food packaging had a greater environmental impact than polypropylene, the reference material, based on NREU, GW, eutrophication and acidification potential and ozone creation” (Yates & Barlow, 2013, p. 57).

GWP, NREU, ozone depletion, and the other environmental harms in the above quote are only a portion of the overall impacts of bioplastics. It is significant to point out the lack of qualitative and non-numerical data within the LCA framework. This is reiterated by Talon (2014), who states “LCAs are quantitative studies” (p. 98), and calls for a more holistic analysis of bioplastics to include qualitative studies and principles alongside LCA’s to account for aspects of bioplastics that are hidden when examining with a quantitative lens.

Environmental Impacts of Bioplastics Determined from Life Cycle Assessment

Overall, the environmental impacts of bioplastics understood from LCA's can be categorized by steps in the life cycle, feedstocks, manufacturing & processing, and end-of-life (Iles & Martin, 2013). Others, like Häkkinen and Vares (2010), explain in terms of inputs and outputs; inputs are “raw materials, auxiliaries, fuels, electricity, transportation” and outputs are “products, emissions, wastes, and transportation” (p. 1460). Despite differences in LCA scopes and system boundaries, there is a general consensus about the major environmental impacts of bioplastics.

For feedstocks or the renewable natural resources used in bioplastic manufacturing, the main concerns are based on industrial agriculture issues: land use change, deforestation, genetically modified organism use, fossil fuel consumption, fertilizer and pesticide application, eutrophication, acidification, and water scarcity (Álvarez-Chávez et al., 2012; Iles & Martin, 2013). In the manufacturing and processing category the concerning environmental impacts are focused on fossil fuel consumption, toxic chemical agents used in processing, water use, ozone depletion, smog formation, and greenhouse gas emissions (Álvarez-Chávez et al., 2012; Hottle et al., 2013). End-of-life environmental concerns include contamination of recycling facilities, diversity of environmental conditions at industrial composting facilities which causes ineffective decomposition, methane release at landfills, and litter, including marine and terrestrial (Hottle et al., 2013; Iles & Martin, 2013; Yates & Barlow, 2013).

Ecological Modernization Theory (EMT) argues the best pathway out of environmental crisis is to continue modernizing through technological and industrial growth. With this interpretation in mind, the environmental impacts of bioplastics can be overcome, and are current consequences of the attempts to modernize further. This is highlighted in Yates & Barlow's

(2013) critical review of bioplastics LCAs. In their conclusion they say following about the environmental impacts of bioplastics,

“The current picture is confusing and definitive conclusions are difficult to draw although the studies reviewed suggest that these biopolymers may not necessarily be more environmentally friendly than the petrochemical polymers they could replace at this time. However, trends in studies show that the environmental profile of these biopolymers is improving and may continue to do so in the future” (p. 65).

The growing demand for bioplastics is a direct call for increased efforts to reduce environmental impacts, and using EMT to understand the social impacts can be an effective process for seeing bioplastics as a potential pathway towards ecological modernization.

Conclusion

The literature on Ecological Modernization Theory, perceptions of bioplastics, and their environmental impacts collectively offer unique, but complementary approaches for investigating the first research question posed by this study: Are bioplastics less environmentally harmful than their petroleum-based counterparts? Ecological Modernization Theory provides a theoretical framework for analyzing the role of bioplastics in economic and social development toward sustainable modernity. The variety of standards and certifications do not simplify this and little research has been done concerning standards and perceptions. It is also clear that missing from the conversation about LCAs is a qualitative perspective. One might draw the connection that qualitative data absent from LCAs and the various perspectives on bioplastics demonstrates a need for more research about the role the public’s knowledge and awareness of bioplastics has in their environmental impacts. This study provides a lens for investigating perspectives, knowledge, and use of bioplastics and contributes to answering the second research question: How are bioplastics being perceived and used within the food service industry, their most common application?

Chapter 3: Methods

Research Objectives

The objective of this research is to provide new insights into the attitudes about and the environmental impacts of bioplastics. This research uses a case study approach, focusing on the downtown area of Olympia, Washington, using a mixed method exploration of the usage and knowledge of commercially available bioplastic serveware amongst food service businesses. Preceding chapters described the complexities of labeling and certifying bioplastics, their environmental impacts through Life Cycle Assessment, and attitudes of consumers using bioplastic products on an international scale. This chapter outlines the methods used in the empirical research component of this thesis – a study of public perceptions of bioplastics from the perspectives of the business owners and employees of food service businesses, who are the main redistributors of bioplastics.

This study fills a gap in the academic knowledge of bioplastics by addressing an underrepresented population. Most studies exploring perceptions and awareness of bioplastics focus on consumers. In this context, the term consumer signifies an ordinary citizen who purchases goods and services (Sijtsema et al., 2016; Steenis et al., 2017). This study differs from most previous research by focusing on a different part of the supply chain: business owners and general or purchasing managers. Typically, these individuals purchase bioplastics from a distributor or wholesaler and then redistribute bioplastics to consumers. This study's distinctive method is significant because consumers do not necessarily make the decision to purchase a bioplastic at food service businesses. The business owner or purchasing manager makes the decision to procure bioplastic serveware and redistribute it to customers who purchase food or beverages at the business. As the literature reviewed in the previous chapters describes, there is a lack of understanding about how these redistributors perceive bioplastics. The empirical research

component of this thesis provides research about a specific population in order to increase understanding regarding the environmental impacts and perceptions of bioplastics.

Site Description

The city of Olympia, with roughly 50,000 residents in 2014, is located at the southernmost point of the Puget Sound in western Washington and is the state capital. Olympia was an appropriate sampling site for this research due to the culture of environmentalism and progressivism prominent through the city and greater region. It is home to The Evergreen State College, a self-identified progressive public liberal arts and sciences college. The culture of environmentalism and progressivism in Olympia is important to this study because residents were willing and able to speak about environmental issues and express their perspectives on bioplastics. The culture of Olympia fosters free thinking and encourages residents to be passionate about reducing environmental impacts. For example, the City of Olympia's website includes information regarding sea level rise, resource conservation, zero waste event planning, environmental education, natural lawn care, and more. Many of the respondents in the interview portion of this study remarked on the progressive environmental culture of this town. For example, Respondent #9 said, "I'd definitely say living here, in Olympia, versus many other places we are way ahead of what other municipalities are offering". In addition, Respondent #8 spoke of the culture of Olympia and their use of bioplastics. They said, "the motivation for that [bioplastics] is two-pronged. It's obviously your market... that's going to sell here".

The geographic boundary for the present study was Olympia's downtown area. Due to the walkability, and high density of neighborhood restaurants, cafes, and food service operations, downtown Olympia is an ideal location for this research. The majority of food service operations

are locally owned, rather than chains or corporate franchises, providing a unique opportunity to research the role of bioplastics with local owners, managers, and purchasers.

Sampling and Data Collection Methods

The study used a mixed methods approach comprised of a quantitative survey, as well as qualitative interviews. The purpose of the survey was to collect baseline data about how and if food service businesses in downtown Olympia are using bioplastics. Follow-up interviews were then conducted to garner in-depth answers to open-ended questions connecting environmental attitudes and Ecological Modernization theory; knowledge of bioplastic products and regulation; and business decision making regarding bioplastics. The methods for both the survey and interview process are described below.

Survey

To understand the purchasing and distribution of bioplastics among food service businesses in downtown Olympia, a survey instrument was developed and included items about business operations, composting practices, and bioplastics usage. This survey was designed to collect descriptive statistics about the businesses in downtown Olympia with regard to bioplastics. Questions on composting practices were included on the survey because the environmental impacts of bioplastics highly depend on their end-of-life locations. Other measures included number of employees at the business; whether customers order from a counter or a server at a table; if the business uses bioplastic serviceware, and if they do use bioplastic serviceware, what forms and brand names of bioplastics. The number of employees at the business was included as a reference to the size of the business. The type of food service business, table service or counter service, was included in the survey instrument because traditionally, table service businesses have durable or reusable serviceware, whereas counter

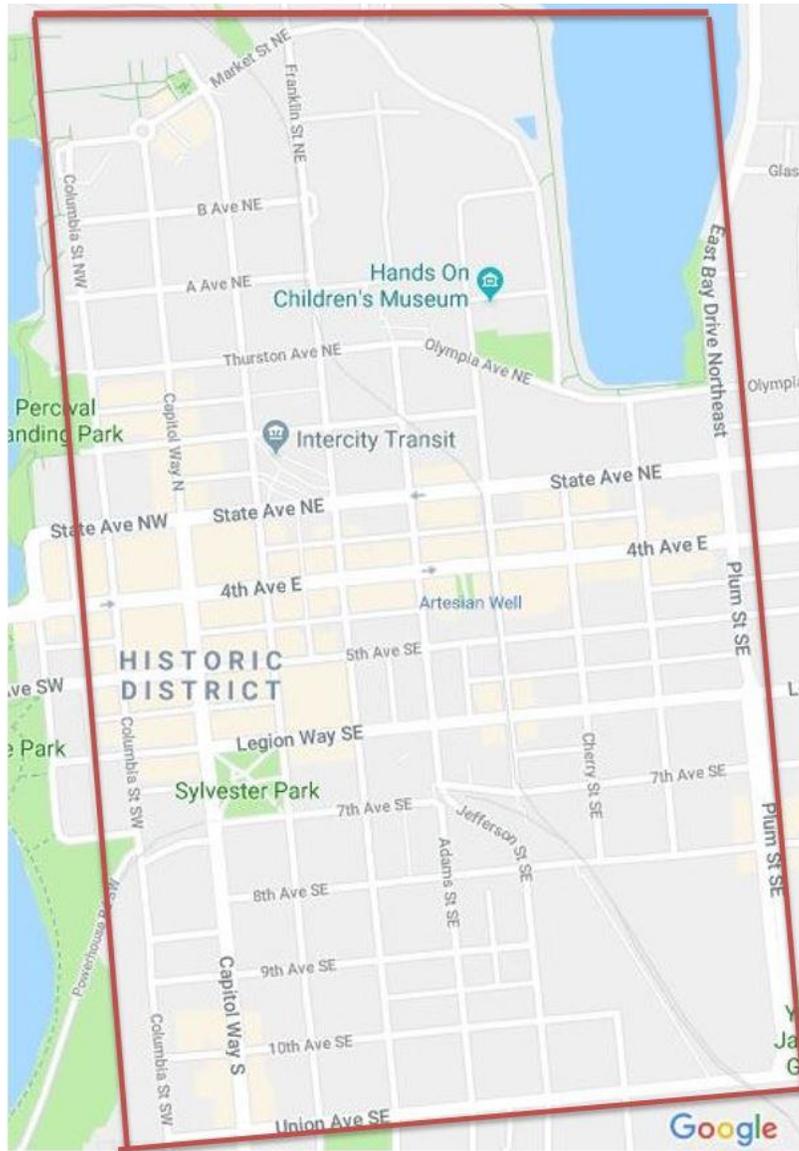
service businesses generally utilize more single-use and disposable items because their business model offers convenience and quick service for customers. Counter service was defined as any business the customer orders at a counter and no servers were present, whereas a table service business might have a counter option, but the main ordering method was from a server. Please see Appendix A for the full survey instrument.

These measures directly address the research question: are bioplastics an effective and environmentally sustainable alternative to traditional, petroleum plastics because they establish whether or not these products are used at all in downtown Olympia, and more importantly, whether or not they are used in a way that promotes appropriate use of bioplastics. In this context, appropriate use ideally means the bioplastic life cycle is a closed-loop cycle and potentially carbon neutral.

The sample frame for the survey was comprised of all food service businesses within the boundaries of East Bay Drive, Plum Street, Union Avenue SE, Columbia Street SW, and Market Street NE (see Figure 3.1). Businesses on both sides of the boundary streets were included in the sampling frame. These boundaries were determined using Google Maps and the researcher's personal knowledge of the location of the highest density of food service businesses in downtown. If a business was unreachable at the initial walk-in time a second and then final attempt to conduct the survey was made in person. If no attempts were successful, the business was not included in the final sample. Additionally, four food and beverage related multinational corporations within the sampling boundaries were excluded due to the lack of independence these businesses have individually and the difficulty of reaching a purchasing manager or owner at the multinational level. The final sample included sixty-three businesses, comprising three food trucks, six coffee and tea shops, five ice cream shops and bakeries, two specialty food

shops, and forty seven restaurants. The final sample represents 75% of all food service businesses in the downtown area (within the boundaries identified above).

Figure 3.1: Map of Boundaries in Downtown Olympia



Data were collected by a survey strategy modeled off the study by Meeks et al. (2015), in which audits of grocery stores were conducted in the greater Phoenix, Arizona area. The auditors visually assessed whether or not bioplastics products were present in a variety of grocery stores. The present survey was conducted by entering each business in-person, and verbally asking the

survey questions from a printed-out form. The present research also employed visual skills to make observations about bioplastics presence in each business as a backup measure. The study by Magnier et al. (2016) used an online survey, while others like Sijtsema et al. (2016) and Lynch et al. (2017) used in-person focus groups. By contrast, the in-person survey method ensures clarity about certain terms like, bioplastics and composting, in addition to using the contact for follow up interviews if the business did utilize bioplastic serviceware. Furthermore, the food service industry is fast-paced and many times phone calls and emails go unnoticed. The most efficient way of contacting food service businesses is entering during business hours.

Interviews

To address motivations, attitudes, and knowledge of bioplastics semi-structured interviews were conducted with owners, managers, or purchasers for businesses who used bioplastics. The interviews addressed the second research question: how are bioplastics being perceived and used within the food service industry, their most common application? Interview subjects were identified through the survey – any business that answered “Yes” to the survey question about their use of bioplastics was asked for a follow-up interview. In total, nine interviews were conducted, six in person and three over the phone. Interviews lasted 15 minutes on average and included eight semi-structured questions focusing on why the business uses bioplastics, how they receive and seek information about bioplastics, and the participants’ knowledge of labeling and standardizations of bioplastics (See Appendix B for the full interview protocol). Each interview was recorded with the subject’s permission, then transcribed verbatim. All interviews began by asking about the business operations using bioplastics, then moved to broader questions pertaining to attitudes and knowledge about bioplastics. The interview questions were intended to obtain information about the motivations, attitudes, and levels of

knowledge about bioplastics, waste streams, environmental impacts, and general experiences using bioplastics compared to petroleum-based plastics. The questions addressed Ecological Modernization Theory (Spaargaren & Mol, 1992) by asking business owners and employees about their role in the free market and bioplastics as a technology advancement. The interview questions did not overtly ask about EMT, rather they addressed EMT indirectly by inquiring about standardization knowledge, known environmental impacts, and decision making when purchasing bioplastic serviceware. The state as an actor in regulation, decision making and free market capitalism, environmental tradeoffs and technology advancements were anticipated themes in the questions for interview participants. The expected interview themes address EMT because they concentrate on the five foundations of the theory. For example, the business owners and managers participate in capitalism, they are market actors, consumers, and have a strong role in environmental reform especially through purchasing decisions. Through the purchasing of new technological advancements aimed at reducing environmental impacts they contribute examples of EMT as an applicable framework for bioplastics. The results and discussion chapters delve into these themes further and explore how bioplastics support Ecological Modernization Theory as a framework for thinking about society and its relationship to the environment.

Analysis of interview data was a multistep process. Provisional coding was used in this study, meaning pre-set codes evolved from earlier research and the literature review conducted by the researcher. The codes were then expanded once the preliminary read through was completed. The initial coding process for this study used codes informed by literature specific to the theoretical framework, Ecological Modernization Theory. First, interview transcriptions were read through one time. Next, the interviews were coded by hand using 12 pre-set themes. The

addition of five coded themes occurred after the initial reading and evolved from the researcher's interpretation of the interviews. The pre-set themes were: industry knowledge, technology advancement, pollution concerns, materialism & consumption, depletion of natural resources, industrial agriculture, composting/end-of-life problems, environmental benefit, environmental harm, higher costs, marketing/greenwashing, and consumer awareness. The five additional codes that emerged from the first round of coding were: quality concerns, sustainability & business integration, policy, local culture, and aesthetic. Finally, a third round of coding focused on adding more details or clarification to existing codes.

This coding process had similar elements to other studies focused on perceptions and the environment. In a study of perceptions on illegal marijuana cultivation, Rose, Brownlee, and Bricker (2016) coded interviews from government administrators, ecologists, and law enforcement agents without any prior codes, dissimilar to this research. However, the researchers did place the coded themes into larger generalized categories, similar to the methods in this study. Rose et al. (2016) also used multiple researchers who coded the interviews collaboratively, generated themes first, and then applied these themes to more broad categories. Parts of their method could not work for this particular study because of the lack of multiple researchers and the attempt to understand this study through the theoretical framework of Ecological Modernization with specific pre-codes. In another study related to environmental perceptions, Dutcher, Finley, Luloff, and Johnson (2004), did not use software to code, and used a priori and posteriori coding process, similar methods to this study. The codes and their larger categories are shown below in Table 3.1.

Table 3.1: Codes by Generalized Category

<i>General Categories</i>	Technology	Social	Environmental
Pre- Codes	<ul style="list-style-type: none"> • Technology advancement • Higher costs 	<ul style="list-style-type: none"> • Industry knowledge • Materialism & consumption • Consumer awareness • Marketing & greenwashing 	<ul style="list-style-type: none"> • Depletion of natural resources • Industrial agriculture • Pollution concerns • composting/ end-of-life problems • Environmental harm • Environmental benefit
Post- Codes	<ul style="list-style-type: none"> • Aesthetic • Quality concerns 	<ul style="list-style-type: none"> • Sustainability & business integration • Policy • Local culture 	

The codes were sorted into larger, more generalized categories to reinforce the theoretical framework, Ecological Modernization Theory. Spaargaren and Mol (1992) say

“the ecological modernization approach conceptualizes nature or the environment as one of the two spheres that are threatened by the dynamics of the industrial system, the other being the life world” (p. 337).

The larger categories from the interview data were created to mimic these spheres.

Social, Technology, and Environmental are interpretations of Spaargaren and Mol’s spheres of EMT (1992). They are building upon Huber’s (1985, 1989) earlier work where he differentiates spheres in present society like the sociosphere or life world and technosphere, or industrial system. Huber (1985, 1989) believes an additional sphere, biosphere or the environment is necessary to include when analyzing society. The environmental problems faced by modern

society are caused by domination of the sociosphere and biosphere by the technosphere according to Huber (1985, 1989). In order to change there must be reform of the technosphere by the socio and bio spheres. This change, or environmental reform, is what Huber refers to as ecological modernization. EMT focuses strongly on the industrial structure of society, not only the capitalist or production structures, and its interaction with the environment. Overall, the general themes shadow the spheres as described by Spaargaren and Mol (1992) and Huber (1985, 1989) to provide additional evidence bioplastics are a suitable example of EMT at work.

Beyond creating the codes and placing them into categories, the next steps of the data analysis included compiling quotes by respondent. After the last round of coding, the quotes from all nine respondents pertaining to each corresponding code were compiled into seventeen separate documents; there was one document for each code or theme. In this way, the prevalence of the individual codes in each interview was analyzed. The interview and survey results are discussed in the following chapter.

Chapter 4: Results and Discussion

This mixed method study first employed a quantitative survey of food service businesses in downtown Olympia, Washington, and second, conducted qualitative interviews with nine respondents from the survey. The findings from the survey and the interviews are presented in this chapter. The survey results, collected to gain a baseline understanding of bioplastic use in downtown Olympia, Washington are presented first, followed by the qualitative interview results.

Results: Survey

The survey gathered sixty-three responses from the eight-four businesses within the sampling boundaries for an overall response rate of seventy-five percent. There were seven businesses who chose not to participate and fourteen others could not be reached due to circumstances outside the researchers control like operating hours. Overall, there were twenty-eight table service businesses and thirty-five counter service businesses surveyed. There were seven more counter service businesses than table service in the sample. Twenty-nine of the businesses surveyed used bioplastics, and thirty-four did not use bioplastic serviceware, therefore forty-six percent utilize bioplastic serviceware, while fifty-four percent do not utilize any form of bioplastic serviceware. Of the twenty-nine businesses who do utilize bioplastic serviceware, ten were table service and nineteen were counter service. This is shown below in table 4.1.

Table 4.1: Bioplastics Use by Business Type

<i>Bioplastics?</i>	<i>Table Service</i>	<i>Counter Service</i>	Total
<i>Yes</i>	10	19	29
<i>No</i>	18	16	34
Total	28	35	63

In addition to business type and bioplastic use the survey gathered data on composting. The survey provided three answer options, compost with the city of Olympia, compost on their own, and does not compost. The results are shown below in table 4.2.

Table 4.2: Composting Practices of Businesses

Composting Practices	Total
Compost with the City of Olympia Commercial Organics Program	31
Compost on their own	10
Do not compost	22

Survey Results: Composting

Although no inferential statistical analyses were conducted, descriptive statistics illustrate the number of businesses who do or do not utilize bioplastics and compare those numbers to the

businesses that compost industrially with the city of Olympia, who compost on their own in home or backyard composting systems, or do not compost in any form thus sending their food scraps or organic material to the landfill. This comparison is significant due to the ideal end-of-life setting for bioplastics being an industrial or municipal compost. According to the Federal Trade Commission Green Guide, compostable and biodegradable claims on products must meet several requirements: one being the claim must not deceive about the end-of-life scenario where the product will end up. If a bioplastic ends up in a landfill the outcome of that product will be very different than if a bioplastic ends up in an industrial composting facility. However, there are issues with composting certain bioplastics, but generally, it is considered best practice to send bioplastics to industrial composting facilities. Table 4.3 demonstrates that only thirteen businesses utilize both bioplastic products as well as the city of Olympia composting program.

Furthermore, the same number of respondents do not compost in any form, but do utilize bioplastic products for a portion of their serviceware. The largest number of respondents, eighteen businesses, do not use bioplastics in any form, but they do compost with the City of Olympia program. Seven respondents do not use bioplastics and compost on their own. Composting on their own represents actions such as saving food scraps and scraping plates for home compost piles or feed for local livestock. Respondents typically clarified and stated that bioplastics were explicitly excluded from their compost. The smallest number of respondents use bioplastics and compost on their own. This might be the case due to the difficulty of separating wastes of various kinds, like food and serviceware.

Table 4.3: Use of Compost with Bioplastics

Bioplastics	Olympia compost	Own compost	No compost
Yes	13	3	13
No	18	7	9
Total	31	10	22

Survey Results: Table Service and Counter Service

The survey also included whether or not a business was table service or counter service. As demonstrated in Table 4.1 of the sixty-three total responses, twenty-eight were table service businesses and thirty-five were counter service businesses. Figure 4.1 demonstrates the proportion of businesses by type that utilize bioplastic serviceware. Approximately of the twenty-nine businesses that used bioplastics, one third were table service and two thirds were counter service businesses. These results were expected since most counter service businesses are considered fast, casual, and more commonly provide to-go serviceware items, whereas table service businesses typically use more durable goods and customers dine in the restaurant or storefront.

Figure 4.1: Bioplastic Use by Type of Business

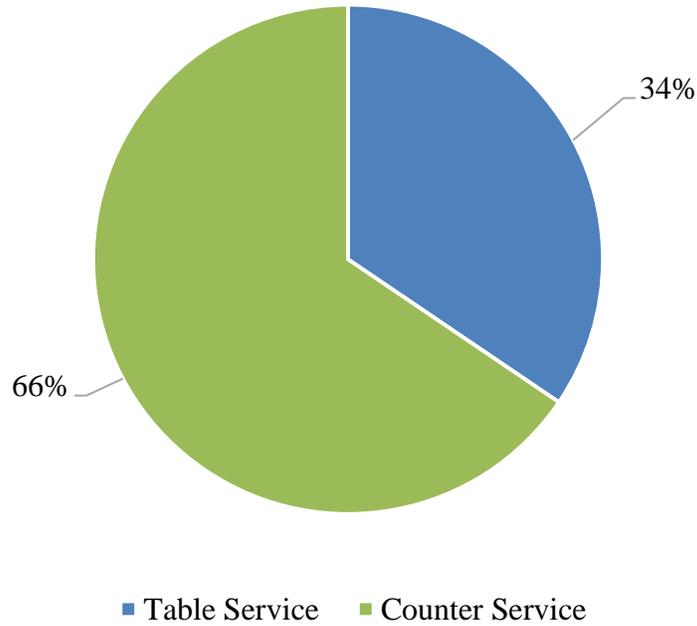


Table 4.4 demonstrates the quantity of bioplastics used by businesses in downtown Olympia. The quantity of bioplastics each business used was separated into four categories. The categories included one to two bioplastics; three to four bioplastics; five to seven bioplastics; and eight to ten bioplastics. The largest category across both business type was use of three to four bioplastic products. Both table service and counter service only had one business utilize eight to ten bioplastic serviceware products.

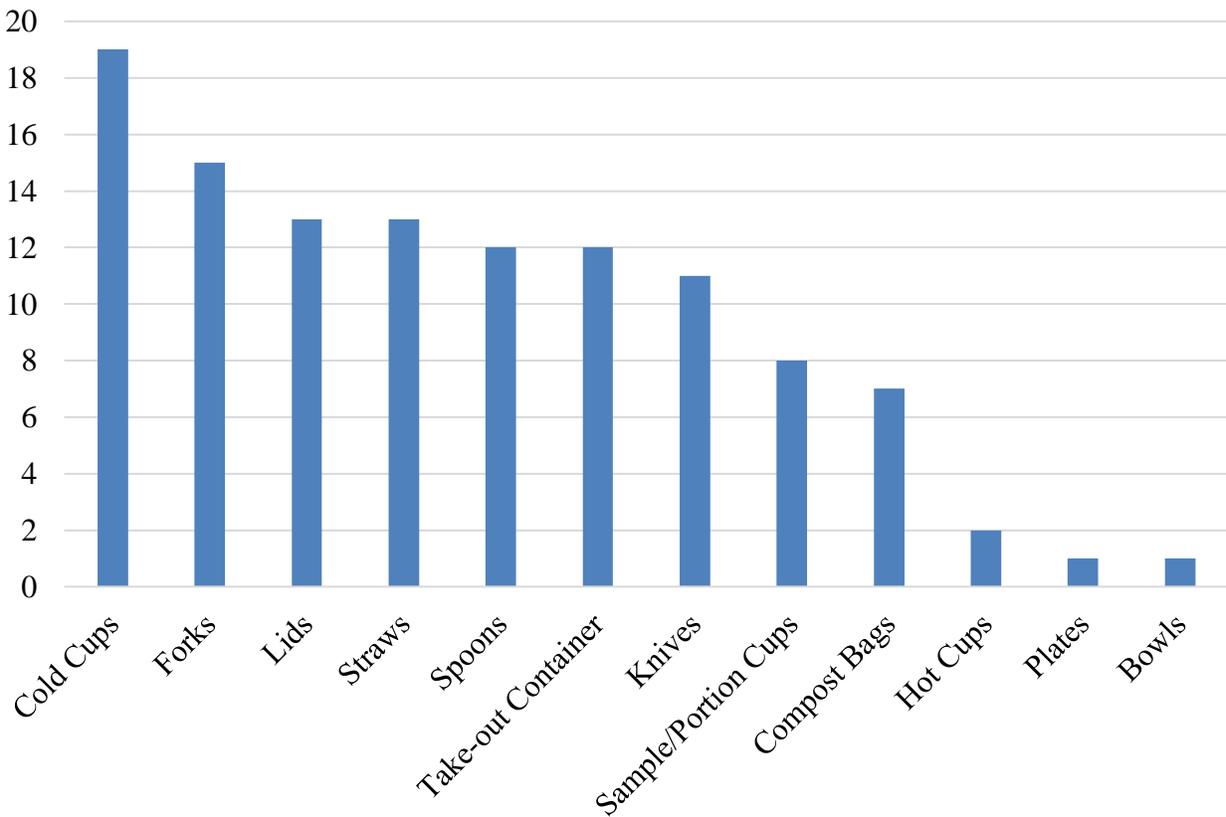
Table 4.4 Bioplastic Use by Number of Items Used

BIOPLASTICS?	TABLE SERVICE	COUNTER SERVICE	TOTAL
<i>Yes</i>	10	19	29
<i>1 to 2 Bioplastics</i>	3	6	9
<i>3 to 4 Bioplastics</i>	3	7	10
<i>5 to 7 Bioplastics</i>	3	5	8
<i>8 to 10 Bioplastics</i>	1	1	2

Survey Results: Bioplastic Product Form

The survey also collected data on the forms of bioplastics used. The serviceware items considered were pre-selected for the survey and no respondent had additional types to add. As shown in Figure 4.2 the most popular form of bioplastic serviceware were cups for cold beverages. The least common forms, plates and bowls, were only utilized by one business. It is important to note lids and straws were not as commonly used as cold cups, but many businesses serve beverages in a cup and include a (traditional plastic) lid and straw. Because of the effects of heat on bioplastics, bioplastic hot cups are generally not a popular product; this is reflected in the results. Considering that bioplastic spoons are less desirable for hot items such as soup, their popularity was relatively high.

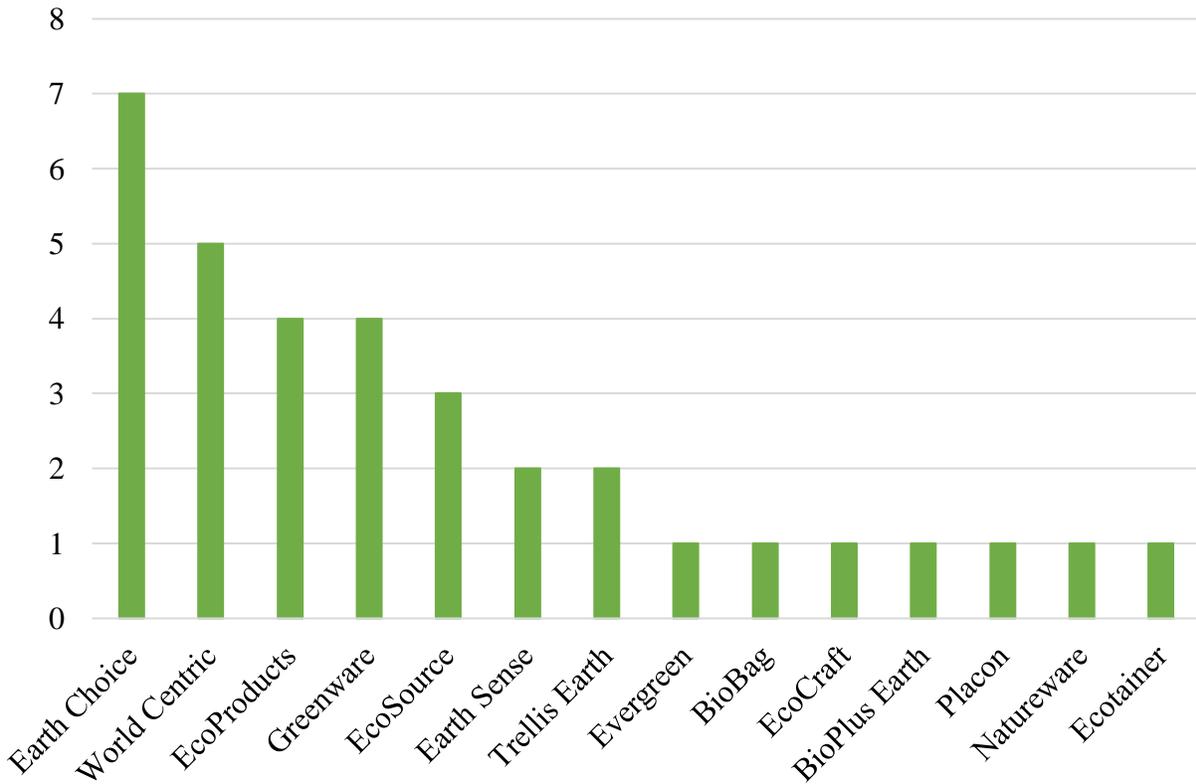
Figure 4.2 Most Common Forms of Bioplastics



Survey Results: Bioplastic Brand

The survey also asked for brand names of bioplastics. Not every business was able to give a response; therefore those responses were not included in Figure 4.3 below. There were fourteen bioplastic brands reported. Earth Choice was the most popular brand with seven references by respondents, followed by World Centric with five references by respondents. Many businesses surveyed used multiple brands. For example, one business used eight forms of bioplastics and at least five distinct brands of bioplastics.

Figure 4.3 Most Common Reported Bioplastic Brands



Knowing the brand of bioplastics used in downtown Olympia helps address this study’s research question in a few ways. First, because of the variable environmental conditions of industrial composting facilities some brands are better suited for disposal in an industrial compost facility, such as the city of Olympia’s compost program. Second, knowing the brands can provide more data for connecting the manufacturers, distributors, and composters to improve processes more holistically.

Survey Results: Number of Employees

Lastly, the survey collected data on the number of employees at each business to serve as a proxy for ‘size of business’. Table 4.5 indicates there is not a strong connection between the number of employees and the business decision to utilize bioplastic serviceware items. It was expected that the higher the number of employees, the more likely a business was to utilize

bioplastics due to the assumed larger profits and distribution levels. However, the largest use of bioplastics was from businesses with six to fifteen employees. There were twenty-two businesses with one to five employees, another twenty-two businesses with six to fifteen employees, thirteen businesses with sixteen to forty-five employees and six businesses with fifty or more employees. It is interesting to note that the majority of the businesses within the sampling boundaries have one to fifteen employees.

Table 4.5 Number of Employees and Bioplastic Use of Businesses

Number of Employees	Bioplastics	No Bioplastics
<i>1 to 5 Employees</i>	8	14
<i>6 to 15 Employees</i>	10	12
<i>16 to 45 Employees</i>	7	6
<i>50 + Employees</i>	4	2

Conclusion: Survey Results

In this study, the purpose of the survey was to identify potential interview participants of businesses currently using bioplastics, in addition to collecting data on the popularity of bioplastics and composting in downtown Olympia. The survey results demonstrated bioplastics are relatively popular among locally owned and operated businesses, with forty-six percent of businesses using bioplastic serveware of some form. Similarly, the city of Olympia composting program is well used by local downtown businesses, with forty-nine percent of businesses using the composting program. Due to the properties of bioplastics, in which they decompose at high

heat, it is not surprising the most common form of bioplastics is cold cups, followed by forks. Again, not surprisingly bioplastics were used at more counter service businesses than table service because their business model requires more single-use or to-go items, which must be packaged. Asking for brand names and number of employees was a part of the survey not for a hypothesis, but to investigate other factors in business decisions to use bioplastics. Number of employees did not seem to influence use of bioplastics. However, it is important to recognize in the sample over half of the businesses fell within the one to fifteen employee range. Therefore, there is potential that with a larger sample size or different location number of employees might have an influence on use of bioplastics. Overall, this survey sets the landscape for the following section detailing the results from the qualitative interviews.

Results: Qualitative Interviews

Unlike the survey methods, the qualitative data for this study was a purposive sample where only businesses who use bioplastics were asked for participation. The research question of this study asks about the environmental impacts and perceptions of bioplastics; thus, necessitating the participation of businesses who use bioplastics. This section delves into the perceptions and use of bioplastics by employees and owners of businesses in downtown Olympia. The qualitative interviews were conducted to address the second research question: How are bioplastics being perceived and used within the food service industry, their most common application? This section follows the theoretical framework of Ecological Modernization Theory. As described in the methods section, the nine interviews were coded using seventeen themes. The themes were then divided into three sections, like spheres in EMT, technology, environmental, and social. Of the nine interview participants, two represented table

service businesses and seven represented counter service businesses. The larger number of counter service representatives mirrors the survey results; the dominant user of bioplastics in the sampling boundaries is counter service businesses. The results from these interviews contributes to current knowledge on use and perceptions of bioplastics because the sample was focused on decision making personnel at each business, whereas previous studies have focused mostly on consumer use of bioplastics or availability in grocery stores (Lynch et al., 2017; Meeks et al., 2015; Sijtsema et al., 2016) The findings from the qualitative data are detailed by theme in the sections below. Interview participants are referred to as Respondent #1, Respondent #2, to preserve anonymity.

Social Category

In this section, themes from the pre-coding and post-coding are explored further. Social themes that all nine respondents spoke of include industry knowledge; materialism and consumption; consumer awareness; and marketing and greenwashing. Social themes mentioned by some, but not all respondents, include sustainability and business integration; and policy.

Industry Knowledge

The Industry Knowledge theme encompassed what respondents articulated about the standardizations and certifications of bioplastic products, the transition from traditional petroleum-based plastics to using bioplastics, and how their knowledge of the bioplastics industry impacted the transition. Generally, respondents knew very little about the standards and certifications, but said they did not struggle with the transition to using bioplastics. Respondent #1 said the businesses transition to using bioplastics became easier over time,

“I would say previously we had looked into bioplastics maybe, I don’t know the exact time frame, but we had considered it before –looked into pricing and things. It seemed

too complicated to handle, but anymore they are available everywhere. So, when we did make the transition it was a simple process for us”.

Respondent #7 spoke of the transition to bioplastics, expressed that they relied heavily on their supplier and did not know much about bioplastics. “I just called them and said, hey can you get these [bioplastics] and they were like ‘yes’. I didn’t do too much research on them.”

Respondent #8, who later mentioned they do their own purchasing for the business and do not use a supplier, discussed the difficulty of researching the bioplastic varieties and said, “It’s tough to take that time and go “what’s this and what’s that”. Once you do it for two years you kinda just know and you grab it, but it’s that process of growth and learning”.

After discussion of the transition to using bioplastics participants were asked about their knowledge of bioplastics and the standards and certifications. Overwhelmingly, respondents did not know about the standards or certifications and many expressed a wish to know more, but had only done surface level research. Respondent #2 said of their research process, “In general I would say Google. I googled bioplastics and fortunately there is a lot of information”.

Respondent #3 stated, “We’ve been looking into making healthy environmental choices even at a cost for 32 years. We’ve been researching and seeing what’s out there”. They also mentioned a lack of knowledge. They said, “I don’t know the standards. I’d like to learn more just as a personal interest” and “as far as certifications and what our manufactures go through for certifications before they send us products, I’ve never done that”.

Some respondents believed it is simple to find information about bioplastics, while others disagreed and believed the industry to be convoluted and difficult to fully understand. For example, Respondent #1 stated, “If you care enough about it to really figure it out, it takes about two seconds to figure it out. You don’t have to spend a lot of time researching it [standards and certifications]”. Respondent # 8 stated of their research,

“I can’t say that I’m an expert, but I understand that if it’s compostable it breaks down in compost and it becomes something useful. If it’s biodegradable that means that in a certain amount of time that’s never specified it may or may not return to a state in which it can. It’s not garbage... you know what I mean? That’s my understanding of it”.

Respondent # 5 expressed a popular theme of the inconsistency seen in the bioplastic industry and said, “it’s not as uniform as it seems [standardizations]. There isn’t a lot of consistency or standardization”. Respondent #5 shared a story about speaking with a representative of Thurston County who discussed with them the difficulties of composting bioplastics. Respondent # 5 said, “basically, they said that there isn’t a uniform set. There are a lot of testing companies and certification companies, but nothing that is all encompassing and guaranteed”. To conclude, Respondent #4 stated “besides knowing it will biodegrade my knowledge of what’s in the products is limited”.

The respondent’s industry knowledge of bioplastics, including the standardizations and certifications certainly was not a priority for their purchasing of bioplastics. Only one respondent mentioned the American Society for Testing Materials (ASTM). While many mentioned using Google, or relying on their supplier or distributor for information on bioplastics, overall the general industry knowledge was low.

Consumer Awareness

The second theme all respondents spoke of was consumer awareness. This theme encompassed their personal knowledge as consumers of bioplastics, in addition to the knowledge of customers of their businesses. Again, results were mixed on whether or not customers have any knowledge or opinions on bioplastics. Many respondents spoke of the labeling on the bioplastics and its influence on their customers. Respondent #1 stated, “I think they [bioplastic manufacturers] must be also required to let you know that you can’t put them in your kitchen

compost and expect that to work out for you because that seems to be there as well”. Respondent #2 mentioned the information on the cups also and stated,

“I do like the information on the cups, and I think people are getting used to looking for it. And so, it’s allowing the makers to make it a little more hidden I guess. All and all I would say I really like the labeling and it think it’s doing its job, especially with the names, ecotainer. They’re using really obvious words”.

Respondent #3 similarly spoke of cups and labeling and stated, “I know that ... a lot of our products say, ‘this is compostable’. That’s what the label says and I understand the gist of like what materials are used in the products to make them”.

Another important part of the consumer awareness theme for participants was engaging with consumers about the proper disposal of bioplastics meant for composting facilities. All respondents expressed difficulty with educating or encouraging customers to understand the disposal method of bioplastic serviceware products. Respondent #7 discussed the outreach and education they attempted at their business, “Part of the issue of what we ran into was I was having to explain to customers oh put your straws in here and put your lids in here and I had pictures up and it kinda worked”. Respondent #5 also discussed outreach and education for customers. They said, “We had another difficulty with a lot of our trash cans. Specifically, a can that says compostables only. You can put as many signs and bells and whistles on any of them and it just doesn’t relate”. Respondent #3 brought up a different issue. They stated many customers were concerned with recycled materials and did not know the difference between recycled content and recyclable. They said,

“Customers haven’t jumped on the compostable bandwagon yet. They want to know why somethings not recyclable and then when we tell them, well it’s compostable, it will fully breakdown. Recycling gets kind of complicated. It’s not recyclable, its cups made from recycled materials, it’s not in turn recyclable. Getting that message out to the customers is really hard”.

Respondent #6 discussed the role their employees play in ensuring compostable materials are going to the correct disposal site. They said,

“It’s hard because it’s definitely one of those things you want to be preaching to the customers about how to dispose of their item. So, it’s a fine line of what that looks like. But, I know that our baristas know that they should go in the compost and if they see one in the bus bin we’re gonna put it in the compost and not in the trash can or the recycling bin, but outside that, as far as customer education about the product we don’t have much. Except that we just share it is a compostable item. We don’t want to ostracize them or make them feel stupid because they don’t know how to dispose of their cup”.

The difficulty in educating customers, while also maintaining status as a business in the free market was expressed above by Respondent #6 and a few others. Respondent #7 remarked about educating customers and said, “But I can’t get too righteous because that really turns people off in this country for some reason. They just don’t like it.” Here, Respondent # 7 was not only speaking of education about waste disposal, but also single-use plastics and another coding theme, materialism & consumption. Consumer awareness was interpreted by the researcher in a few different ways. Included were things like when a respondent mentioned marketing and education materials prepared by the business, the strategies the business uses to ensure compostables are disposed of properly, and on the owner/employee side, the knowledge or awareness the respondent had about bioplastics and their usage. Generally, consumer awareness focused on the customers of the business and their interactions with bioplastics.

Materialism and Consumption

All nine respondents spoke of ideas or attitudes about materialism and consumption habits. In critique of EMT, the Treadmill of Production theory directly addresses materialism and consumption, arguing for a deindustrialization, or a reduction in the production of goods in order to alleviate environmental problems. Many respondents made statements in favor of reducing

single-use plastics, using more durable goods, raising awareness about consumption habits, and the sheer volume of products they use. Respondent #9 stated about their initial use of bioplastics, “Well I feel like I started out using mainly compostables because I don’t want to contribute to single use plastic usage”. Respondent #7 expressed discontent about the volume of plastic they receive from their supplier. They said, “Like the amount of plastic I get covering stuff... Even covering all those compostable cups. It all comes in plastic bags!” They also expressed their use durable goods before using bioplastics with their customers, “The goal is to get people to use less of them and to realize that it comes from somewhere”.

Many other respondents mentioned they typically use durable or reusable serviceware before using bioplastics. Respondent #6 said, “Typically we try to encourage if people are sticking around to take it in a glass so that we can just wash it”. Similar to this Respondent #2 stated, “We actually try to limit the use of the compostables and encourage people to use the real things. The metal- the tasting spoons that are metal”. Others mentioned incentivizing the reuse of durable goods. Respondent #3 stated, “I know some people like to retain their cup and use it a few times, bring it back into the store. We give them a discount for their own mug, if they bring the mug back in”. Respondent #1 did not mention an incentive for customers bringing in their own reusable goods, however they mentioned how people actually do, “I think, say out of several hundred people that shop with us a week, we have 2 people who bring a container to put their things in. Like a glass container, something like that”.

Many respondents voiced concerns about their role in producing waste and their choice to use bioplastics as a means for lessening impacts of materialism and consumption. Respondent #4 said, “I think the thing is, when you look at the sheer volume of products that restaurants in general use, if you’re in the position to do anything to sort of mitigate it, I think you should”.

Respondents were concerned with the waste their businesses generate and many used bioplastics in an effort to reduce the environmental impacts of their business. Single-use plastics and disposable to-go items are very prevalent due to customer demand, so many respondents chose to use bioplastics to mitigate the harms of plastic pollution.

Marketing and Greenwashing

The final theme all nine respondents mentioned during their interviews was marketing and greenwashing. Most respondents felt good about using bioplastics however, they did not think bioplastics were without flaws, especially as a product in the free market. The respondents acknowledged that marketing has a considerable influence on consumer perceptions. Respondent #1 felt especially strongly about greenwashing and bioplastics. They said about using bioplastics, “It’s kind of a sore spot with me. Because I think it gives people an excuse to say they are doing their part [for the environment] when it really counts for nothing. It’s a little bit like sharing a post on Facebook. I’m not a fan of those”. They continued on to talk about the labeling of the cup and how it advertises the brand name more than the composting requirements.

“I think the labeling is mostly disingenuous, the labeling will make you feel better about the plastic cup you have in your hand. If you look closely at the fine print. I think they must also be required to let you know that you can’t put them in your kitchen compost and expect that to work out for you because that seems to be there as well. Just always smaller and harder to come across than the part that tells you what a great person you are because you are holding a compostable cup”.

Most respondents agreed that they were concerned about greenwashing and corporate marketing in general. The labeling of bioplastics was particularly mentioned, in relation to sustainability certifications of all types, including fair trade and organic. Respondent #3 mentioned a lack of control over compostable claims. They said, “If I’m going to sell something

or serve something that claims to be fully compostable I want to know that it actually is, but I don't really have the control over whether it is 100% or not because I don't work for the company manufacturing the product". Respondent #6 expressed concerns about greenwashing and the uncertainty of what happens to the bioplastics. They expressed the sentiment, "I don't know about the grade of compostability, if that makes sense, if it actually composts. We think we're doing a great thing, but is it in the right environment to compost as fast as we think that it is? Or you know if it's in the landfill. We're thinking were doing this great thing, but it's like lasting just as long".

Respondent #7 mentioned marketing and greenwashing and the impact it has on business owners who are looking to provide a specific aesthetic to their business. They said, "I think labeling is really a sales point for the companies more than it is for the people. There's the whole greenwashing bullshit too. That's what I'm talking about – the hip factor. A lot of people get forced into it because it serves their customer base". Respondent #8 was not only concerned with greenwashing of bioplastics, but other "green" or sustainable labels like organic and fair trade. They said, "Because the Organic thing- it's a ticky tacky one. It's nice in saying, but Mexican produce has USDA organic, but it doesn't go through the same inspection process so it's like meh... Why do you go to top foods [Whole Foods] and the organic potatoes are on a Styrofoam sheet with plastic wrap?". Uncertainty about the bioplastic products and their manufactures was expressed by almost all respondents. The comment by Respondent #8 demonstrates that it is not only bioplastic certifications that make consumers weary, but sustainability certifications in general were mentioned by a few respondents and they overwhelmingly expressed concerns about validity of certifiers.

Sustainability and Business Integration

The sustainability and business theme emerged from post-coding and was interpreted as any efforts or attitudes respondents expressed about trying to reduce the environmental or social impacts of their business. Not every respondent spoke of this theme, but the majority of respondents believed sustainability to be a core value in their business. A few respondents spoke of their business plans or missions. This theme emerged because many respondents did not speak specifically about bioplastics, but their business as a whole, and how bioplastics played a role in their sustainability efforts. Respondent #2 said, “We opened the business with the intentions of always using bioplastics. It’s a part of our mission and actually an integral part of the business”. Respondent #3 also mentioned a mission of the business, “We have in our company, a guiding document and one of them is the relationship to our sustainable and environmental footprint”. Two more respondents mentioned the culture of their businesses and how they strive to make decisions that cause the least amount of harm to the environment. Respondent #5 said, “We are constantly looking at ways we can reduce our input, our environmental footprint and be as green a company as we can from start to finish”. Respondent #6 stated, “We’re a quality of life company which includes our neighborhood and community so the least amount of waste that we can put out the better”.

Beyond mission statements and business plans, many respondents commented on a variety of ways they continue to incorporate sustainability into their businesses beyond using bioplastics. Composting, buying local produce, and supporting other local farms and businesses were largely discussed by respondents. Respondent #7 stated, “I try to use more local stuff in the summertime. I work with a couple of the farms”. Respondent #9 mentioned their business approach would be lacking if they did not compost or utilize other sustainability initiatives. They

stated, “I mean a handful of people are like “oh so glad you compost”. It’s not very much, but you know it kinda goes along with our whole approach to food I think. I think it would be weird if we didn’t”.

Seven of the nine respondents mentioned their use of bioplastics as an example of the businesses’ mission to lessen their environmental impacts. In line with EMT, respondents alluded to the idea that green technologies, like bioplastics, can provide advancement in society in overcoming environmental crises. Respondent #7 said,

“If they would be incentivized to find a way to make it at a cost and the environment and they’d be spending science dollars on ways to make it less impactful because it’s like “oh well this cup is only going to be on the planet, nothing is just gonna go away”. But if they can make something that is going to go back into the ground that will maybe be positive. I’m sure there is a way and there’s science out there. If people get paid to do the science they’re gonna figure out a way. It a capitalist country, you have to get paid to do stuff”.

Respondent #8 mentioned their role in society, capitalism and restructuring production processes to increase environmental focus.

“This is how I choose to participate, by making the best choices and hoping in 5 to 10 years the demand for those products, the oil-based ones, will have disappeared and their prices will go up because there’s no demand for them. And the demand for these biodegradable or compostable ones will rise and supply will rise and somebody will be enterprising”.

They also said, “You can bitch about capitalism all day long. It is here and it is what it is. And I have kids to feed so I have to participate, no matter what I think about it”. Here, Respondent #8 is remarking about societal structures and their role as an actor within the structures.

The above comments were coded as the sustainability & business integration theme because they directly address business decision making and efforts to reduce environmental

impacts. The sustainability & business integration theme was created after the first round of coding because many respondents did not speak specifically about their perspectives on bioplastics, but rather they spoke about their businesses' environmental impacts and the tradeoffs they have to make in business decisions.

Policy

Along with the sustainability and business integration theme, many respondents spoke of policy at the local and national level and how it influences their business, their environmental practices, and their decision to use bioplastics or other environmentally conscious factors. On the local level Respondent # 6 said, "I know Seattle starting in July is requiring that all straws be compostable. So, I think we'll probably end up switching back to something like that". Here, Respondent #6 is commenting on a local change happening not in Olympia, but Seattle where the influences of those policies will affect their business's bioplastic usage. Respondent #7 spoke the most about policy and even argued for stronger state influence to incentivize production that is less environmentally harmful; a critique of EMT, which argues state intervention hinders free market innovations. Respondent #7 says, "If you're throwing something away that's biodegradable in the ground you should be paying less for it, but unfortunately that's not the way things are set up in this country". They went on to say, "We train everybody here [United States] to make it the cheapest. Who cares about the environmental impact of the thing – which is crazy. Crazy". Respondent #7 then suggested their own ideas for how to change the structures of society, "If they could incentivize doing it the right way. That's the tax thing I'm talking about. It's such a basic idea. If they could incentivize doing stuff and base it on the long-term effects on the planet it's a very simple math equation. And that's the only thing people in this country can

understand”. These quotes go a bit beyond bioplastics, but they are directly in line with Ecological Modernization Theory as envisioned by Spaargaren and Mol (1992).

Technology Category

The second category, Technology, is inspired by the technosphere defined by Spaargaren and Mol (1992). In this context, the term technology is used as a generalized category for the following pre- and post-coding themes, technology advancement, quality concerns, and higher costs. These themes fall under the technology category because they are largely focused on bioplastics themselves. Bioplastics are an example of a technology advancement, like electric vehicles, that can provide evidence of Ecological Modernization Theory today.

Technology Advancement

The technology advancement theme emerged in the form of respondent’s discussion of bioplastics development and recent arrival on the global market. Respondent’s agreed bioplastics were a novelty compared to traditional, petroleum plastics, but that they still needed more research and development. Respondent #3 commented on the newness of bioplastics and said, “I think I would say in the United States it is yet to be fully defined, especially in the compostable, biodegradable world. There’s still so much research and work to be done. I would classify it, especially in the beverage world as still a baby, it’s under 10-15 years old really”. Respondent #8 also addressed the difficulty of modern technology, “And with a newer product, or a newer entry into the field like this it’s not just about balancing the quality. The other difficult part about that is, at first it was good enough to be biodegradable. And then that wasn’t good enough. Now you have to be compostable”.

Respondent #7 spoke about green technology advancement in general, not just bioplastics and mentioned electric cars and solar as a renewable energy. They spoke of supporting green technology to build less environmentally harmful products- a main tenant of Ecological Modernization Theory. They said, “I got solar put on [the building] a couple of years ago and it’s kind of ludicrous because it literally covers... like maybe a fridge, but I got it because I want to buy into the industry. I want to buy into that technology”. In addition to solar energy they mentioned buying into an industry to make it stronger, like electric cars. They said,

“It’s like electric cars, it’s the science you have to buy into because people will tell you “oh, we’re using all these resources to make these batteries and then what do you do with the batteries?” And I’m like yeah, yeah, yeah, I get what you are saying, but the point is that until you continuing on building the... For me it’s like if I buy one that means that they can continue to make that product better”.

In contrast, some respondents were not convinced that bioplastics will be able to move society out of environmental crisis. Respondent #9 said, “We’re like “we’re going to figure out different things that are less bad to use”. Here, they are unintentionally criticizing EMT. Respondent #9 was discussing how as a society, rather than reducing impacts (i.e. stopping the treadmill), we continue to solve environmental crisis through advancements in science and technology, and bioplastics are an example of this.

Quality Concerns

Many of the respondents discussed concerns about quality, specifically the role that temperature plays in the degradation of bioplastics. This themed was categorized in the technology category because it directly addresses an issue related to the technological development of bioplastics. Respondent #4 discussed a problem they had seen with bioplastics and said, I know if you leave the cups out in the sun they turn to mush”. Respondent #6 also

mentioned temperature problems and said, “I just think the low temperature threshold, so if it ends up being warm, if you leave it in your car it melts”. Additionally, Respondent #8 mentioned the progress they’ve seen in bioplastic technology. They said, “The quality of the product - It’s gotten better. It used to be everything biodegradable just melted. You put hot food on it and the boxes would fall apart. But it’s gotten better. It’s gotten usable in the past five years”.

A few respondents spoke of the temperature effects, but understood that temperature alluded to efficient composting. Respondent #2 said, “The plastics they’re heat sensitive a lot of times. So, things will melt. Which I kind of like because it just breaks down even quicker”. Respondent #3 also spoke of issues with warm liquids and the preemptive disintegration of bioplastics and said, “Our cold cups are made from corn resin and that’s what makes them fully compostable. You have to make sure it’s all cold liquid in there. It affects the structure of the cup if you put anything warm in there”. Respondent # 5 made a unique point that no other respondent mentioned. They stated that failing serviceware could happen with traditional, petroleum based plastics as well. They said, “There was still the vulnerability that some might fail. Either the seams, or integrity of the cup, as far as being able to put the lid on. And even with a traditional plastic cup you can still have issues. If we have a cup that fails, regardless of if it’s a bio cup or a cup made from fossilized fuel there’s still that risk”.

Higher Costs

All respondents mentioned higher costs, and there was only one respondent with an opposing viewpoint. When asked about the cons of bioplastics Respondent #4 simply declared, “They’re just more expensive”. This point was reiterated by Respondent # 7 who stated, “I tried

to do some research, but it would come down to price. Obviously makes the difference. They're a lot more expensive. That's the hardest". They continued and gave a price estimate for some of the bioplastics, "Like a compostable garbage bag is I think like almost 40 cents apiece, as opposed to a plastic garbage bag is like 5 cents". When asked about how they chose the type of bioplastic, Respondent #8 said,

"Price. Absolutely. I wanted to say compostable because there's a difference between biodegradable and compostable. We go out of our way to make sure we look for compostable, but outside of that. Once we reach that place, price is the only thing that matters to me. Right off the bat it's 2-3 times more expensive for every piece that goes out and that's a crazy consideration for a tiny little business like us".

Respondent #2 disagreed with the other respondents and said, "Also, it's really affordable. In some ways it can be more affordable to use". Later in the interview, this respondent changed their mind slightly and said, "It depends on what you are buying, but in some cases price can be a con".

Overall, the themes within the technology category directly related to the business owners or employees' perceptions of bioplastics. Bioplastics are a relatively new polymer technology. Thus, quality problems still remain during their use, prices are higher than traditional plastics, and there is not as much public knowledge about them.

Environmental Category

The environmental category encompasses themes associated with environmental issues in society. There were no additional environmental themes that developed from the coding process. The themes are depletion of natural resources, industrial agriculture, pollution, composting/end-of-life problems, environmental harm, and environmental benefit.

Depletion of Natural Resources

The majority of respondents spoke of the depletion of natural resources theme by mentioning the use of fossil fuels and other raw materials, which is a core concern of Ecological Modernization Theory. Many spoke about using bioplastics as a means for lowering their footprint, whether it was their carbon emissions or waste footprint. Respondent #2 said of the pros of bioplastics in their mind is using less fossil fuels. They said, “One of the pros is definitely lowering our footprint. Although it does take a lot of energy to still break them down, were doing the best we can”. Respondent #5 also mentioned their businesses’ footprint and said, “Built into our business practice is to constantly be looking at ways to minimize our footprint and reduce our impact”. Respondent #3 mentioned the depletion of natural resources in terms of production of material goods. They said, “There’s a lot of to-go cups out there just in general. If you do the math how many people across the world are buying to-go cups every single day and how many of those end up in the trash every day. Whether they’re compostable or not, is an issue”. Additionally, Respondent #6 spoke of their choice to use bioplastics because they would not be contributing as much waste to landfills, adding to their footprint. They said, “We are trying to lessen the impact that we have globally with our company. So, if we can do something as easy as switching to a plastic that doesn’t stick around in the landfill as long that’s awesome”.

Some other respondents were not as convinced that bioplastics could lower their footprint. Respondent #7 questioned the environmental impacts of bioplastics and said, “Then basically there gets down to a point where they’re saying it takes more power to make the compostable cups and it still takes 20 years for them to biodegrade and you’re like OK...” Respondent #9 was also dubious of bioplastics and their fossil fuel usage. They said, “Like if the

energy you need [for bioplastics] you get from fossil fuel...if it all works out to be more earth friendly, I would assume. I would hope it's not a big scam".

The most common way respondents spoke of the depletion of natural resources theme was fossil fuel use, carbon or waste footprint, and the manufacturing of goods. Bioplastics were seen both as a product with the potential to reduce impacts to natural resources, but some respondents were not convinced bioplastics might contribute negatively to natural resource depletion.

Industrial Agriculture/Pollution Concerns

A limited number of respondents spoke of specific environmental concerns related to bioplastics production and manufacturing like industrial agriculture and pollution. Although, the interview questions were aimed at exploring environmental attitudes and perceptions, only four respondents mentioned industrial agriculture. Of the respondents who discussed industrial agriculture, Respondent #2 mentioned the use of corn for bioplastics, "I know corn is used, that's a big problem crop, I can only imagine. I don't really know what's out there for that". Respondent #5 discussed feeling better about bioplastics if they knew where the renewable resources were derived from. They said, "If it's coming directly from a genetically modified corn product or if it's coming from biomass of husks and stalks. If we had some clarity in where the actual product was coming from". Respondent #6 also questioned the renewable resources to produce bioplastics, like corn. They said about their products, "It is a corn based cup. Like, what is the environmental impact of monocrop and a bunch of extra corn being grown and processed? I don't know the environmental impact of that". Respondent #8 expressed concerns about corn as a feedstock for bioplastics, specifically the genetically modified species of corn. They said, "And now, oh well those are made from corn and corn is mostly GMO, you're supporting

GMO”. It can kinda become a cluster”. Due to the difficulty of knowing where and what a bioplastic’s feedstock is, many respondents have concerns about the industrial agricultural practices used to produce them.

Most respondents made general comments about industrial agriculture being harmful to the environment and did not know enough to feel comfortable expanding on the subject. Pollution concerns were few and far between in the interviews. However Respondent #7 did mention water pollution from chemicals used to wash durable good or serviceware and how they did not know which was better: using single-use items or durable ones. They said about washing and reusing their cups, “It takes water which is a very finite resource. A chemical to wash this cup that I’m flushing down the water drain to wash this cup, so it’s not even close to perfect”.

Composting/ End-of-Life Problems

Composting and end-of-life problems were the most common environmental theme discussed by respondents. Numerous respondents voiced distress about whether or not the bioplastics are composted and their intended end- of-life disposal, in addition to concerns about the actual decomposition or biodegradation of the plastics. Respondent #3 was discussing their role in distributing the products and said, “So if things aren’t going through the proper channels to be taken care of [compost, rather than landfill or recycling] it’s a moot point to begin with”.

Respondent #9 also spoke of concerns about if bioplastics are ending up in composting facilities and how composters are handling the products. They said, “And that I don’t know...How composting facilities... Like how much non-food can they take?”. Composting and end-of-life disposal for bioplastics serviceware is highly dependent upon the actions of the customer.

Respondents communicated a concern with leaving end-of-life decisions to the customer. However, they did not feel strongly about their role in changing behaviors.

Environmental Harm

This theme was used for any statements made from respondents about general harms caused by bioplastics or other products, or systems within society. Respondents spoke of single-use plastics, compost contamination, fossil fuel, increasing waste, and Styrofoam. Respondent #3 spoke of the environmental harm caused by packaging. They said, “That’s an issue, with how much packaging for food and beverage that human beings throw away every day. If it’s not addressed in a really serious matter it’s going to become a big problem in our landfill”. The environmental harms of Styrofoam were mentioned by a few respondents. Respondent #7, who uses only uses bioplastics or paper products for their service ware said, “Then you still go to places where they’re still using Styrofoam for everything. So, you’re like what the hell?”

Respondent #5 touched on concerns they had about bioplastics being harmful to the environment. They listed questions they had about bioplastics and the environmental harms that can evolve from their use. They said, “When you are utilizing plastic from a source that is also considered a food source, I mean there are several things – is it being composted? Are people throwing in and mucking up the recycling systems? Is it safe?”. Overall, environmental harms are present in all materials created for society and the respondents who spoke of environmental harms agreed there was not one material, bioplastic, or traditional plastic that was the definitive best choice; they did agree Styrofoam was the most environmentally harmful material.

Environmental Benefit

Many respondents shared the perception that bioplastics were an environmental benefit. One respondent said, “I mean, I don’t see any reason not to use it [bioplastics]. I know there’s people still using Styrofoam”. Styrofoam was mentioned in a few of the interviews, and most respondents believed that Styrofoam was an environmental harm and bioplastics were a beneficial solution to reducing environmental impacts from packaging. Respondent #5 said, “But thankfully we’re not in the Styrofoam cup era”. Again, the use of bioplastics as a replacement to historically destructive materials, like Styrofoam, was seen as an environmental benefit. One respondent generally stated of their decision to utilize bioplastic serviceware, “Again, I can’t reiterate it enough. It’s the right choice, and it’s a good choice. You know we’ve got to start somewhere”. Largely, respondents articulated the environmental benefits of bioplastics outweighed the harms, thus supporting their use of bioplastic serviceware products.

Discussion

The primary purpose of this research was to first provide a detailed overview of the standard test methods, certifications, and federal guidelines, then collect baseline data about bioplastics use through a quantitative survey, and lastly conduct qualitative interviews about the knowledge and use of bioplastics in downtown Olympia, Washington to gain a deeper understanding of perceptions about these ecologically innovative products. The survey results offer descriptive statistics of what types and how many businesses are using bioplastics, what forms are most common, are businesses using bioplastics and composting, how many employees do businesses have that use bioplastics, and what bioplastic brands are commonly found in downtown Olympia. A little less than half of the survey participants used bioplastics. The majority of businesses that used bioplastics were counter service operations with one to fifteen

employees. Commercial composting is common in downtown Olympia and thirty-one of the sixty-three participants utilized the city of Olympia's commercial organics composting program. Overall, the survey gave insights into the distribution of bioplastics in downtown Olympia.

Subsequently, the qualitative interviews provided a deeper understanding of the perception and level of knowledge about bioplastics among professionals in the food service industry. Generally, interview respondents expressed mixed feelings about their use of bioplastics, similar to other studies asking consumers about their perceptions (Sijtsema et al., 2016). Although, most participants did speak to their use of bioplastics as a means for incorporating the environment or sustainability into the business practices. Most participants shared the belief that using bioplastics was the right thing to do in order to mitigate their environmental impacts. All but one of the businesses represented by the nine interview participants either composted with the City of Olympia or on their own, further supporting their efforts to reduce environmental impacts.

The heart of this research analyzes whether or not, bioplastics offer a less environmentally harmful solution to their traditional, petroleum-based counterparts. The qualitative data presented in this study demonstrates that the redistributors of bioplastics in general have strong positive attitudes toward bioplastics. However, hesitations and doubts also exist owing to the complex structures surrounding bioplastics, such as the ambiguous and unregulated standards and certifications; uncertainties of compost facilities ability to decompose bioplastics; vague environmental claims of reducing greenhouse gas emissions or other environmental damage; and bioplastics inability to replicate traditional, petroleum-based plastics in price and quality. It is clear bioplastics have the potential to be an ecological innovation as

suggested by Ecological Modernization Theory, but EMT only offers a way of thinking about innovative products and environmental crisis. The bioplastic industry is a global force with many complexities.

The research in this study supports Ecological Modernization Theory because it demonstrates bioplastics are a prevalent, new green technology that many utilize because they feel bioplastics cause less environmental harm than their traditional, petroleum-based counterparts. The first two core foundations of Ecological Modernization Theory state first, science and technology may have caused environmental problems, but conversely, research and development provide a path to overcome and prevent future environmental crisis; and second, all market actors play a role in environmental reforms, not just state agents and governments (Spaargaren & Mol, 1992). The proliferation and demand for bioplastics via businesses in the free market embrace these two foundations, supporting Ecological Modernization Theory. Increasing demand of bioplastics by market actors, like local businesses, will lead to an increase in their supply and demonstrated by the qualitative interviews, these market actors generally perceive bioplastics to be environmentally beneficial.

However, like Ecological Modernization Theory, the bioplastic industry is not without flaws. Scarce federal regulation, varying industry standards and certifications, in combination with the dissociation of producers and manufacturers of bioplastics with end-of-life composting facilities has led to complications that weaken Ecological Modernization Theory as a useful framework for understanding the relationship between society and the environment. Ecological Modernization Theory claims when dealing with environmental regulation, less command-and-control style policies lead to environmental reform. In the example of bioplastics there is very little governmental regulation or policy which has led to a wide variety of industry standards and

certifications policing the industry. In order to reform bioplastics to be an authentic green technology, it may be necessary for federal regulation to be implemented. According to Schnaiberg (1980), EMT places too little emphasis on the role of state institutions and exaggerates the positivity of free market dynamics. During the qualitative interviews, a few of the respondents indirectly criticized EMT and expressed the attitude that a shift in federal regulation must occur for bioplastics to truly become an environmental benefit. Nevertheless, Ecological Modernization Theory, is just that: a theory for examining the relationships between society, its institutions, and the environment.

Chapter 5: Conclusion and Recommendations

Bioplastics were created with the intention of existing as an alternative to petroleum-based plastic to mitigate harmful environmental impacts like pollution and fossil fuel consumption. Although the creation of bioplastics may have been altruistic, the environmental benefits of bioplastics are not necessarily as they seem. The numerous problems surrounding bioplastics and their manufacturing, utility, and proper end-of-life treatment are discussed within the qualitative interviews detailed in this study, demonstrating that public knowledge of bioplastics is mixed.

The problems with bioplastics are highly systemic issues related to industrial agriculture and waste management policies. For example, if the practices of using pesticides and fertilizers in industrial agriculture were reformed to cause less damage to the environment, bioplastics may have an opportunity to reduce their environmental impacts.

The two-pronged data collection method used in this research attempted to provide a new approach to understanding environmental impacts of bioplastics. By reaching out to the middle user group of bioplastics, this study sought out the key stakeholder in society's interactions with bioplastics. The data collected suggests most of these middle user groups recognize their role in redistributing these products to customers, however they lack resources to change systemic problems hindering bioplastic's ability to alleviate the environmental harms of tradition, petroleum-based plastics. At its core, the research question asked in this study is about trade-offs, and pros and cons of bioplastics. By collecting quantitative data on the use of bioplastics amongst food service businesses in Olympia, Washington and following up with qualitative interviews, this research adds to the literature on bioplastics. This research provides results that

other researchers can build upon and include both quantitative and qualitative data to holistically understand bioplastics.

This study attempted to address a lack of research on a specific user-group of bioplastics and provide descriptive statistics in a case study setting. There are several limitations that must be noted. For example, using downtown Olympia as a case study constrained the survey sample size and interview participants to a specific geographic and cultural context, resulting in non-generalizable outcomes. Second, the qualitative interviews only included participants from businesses that were using bioplastics, rather than from businesses that both did and did not use bioplastics. This is limiting because it restricted perspectives on bioplastics solely to those who utilize them, resulting in a potential for biased responses. Only interviewing participants from businesses that used bioplastics emphasized why businesses utilize them, but this study lacked data on why businesses do not use them.

The limitations of this study indicate determining if bioplastics are less environmentally harmful than their traditional, petroleum-based counterparts is not simple. This study has strived to expand the literature on the perceptions, knowledge, and use of bioplastics. In conjunction with the peer reviewed literature, this study suggests that further research of the bioplastic industry is necessary. For example, more research on best practices for end-of-life disposal in real life, how and where bioplastics are being utilized, and environmental assessments that not only employ quantitative data, but brings together both quantitative and qualitative methods. Finally, more research is needed on how to effectively communicate between every step in a bioplastics life cycle

Bioplastics evolved out of a social desire to create a more sustainable plastic material. They use less fossil fuels, are derived from renewable feedstocks, contain properties for biodegradation, and can be fully composted. Bioplastics are a product of free market innovation, which suggests bioplastics are an appropriate and valid example for the theoretical framework used for this study, Ecological Modernization Theory. Bioplastics are growing on the global market and are expected to reach a market value of 30.8 billion dollars by 2020 (Bhilare, 2018). Many argue that bioplastics provide a viable option in combatting environmental crisis. However, bioplastics are not without flaws; this study identified areas of environmental concern, as well as problematic industry standardizations and certifications. This study also concentrated on a case study example to understand the perceptions and knowledge of bioplastics of professionals in the food service industry where bioplastics are most common, but largely this study aimed to demonstrate EMT as an applicable way of thinking about the role bioplastics have played and will continue to play in modern environmental reform.

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Appendices

Appendix A: Survey Questions

Name of Business

Type of Business (circle one)

Counter Service

Table Service

Combination

Number of Employees

Does this business compost through the City of Olympia commercial organics collection? (circle one)

Yes

No

Does this business compost without commercial pick-up? (circle one)

Yes

No

Not including paper or wood products, does this business purchase bioplastics, also known as compostable plastic packaging, to use in foodservice? (circle one)

Yes

No

What forms of bioplastics are used? (Circle all that apply)

Forks

Knives

Spoons

Cold Cups

Hot Cups

Lids

Straws

Sample/ Portion Cups

Take-out Containers

Bags

Plates

Bowls

What is the brand and/or type of bioplastic?

In the company, who is the most appropriate person to follow-up with for an interview regarding bioplastics and compostable plastic? This typically would be an owner, purchaser, or employee in charge of purchasing supplies.

Appendix B: Interview Questions

1. What was the transition to using bioplastics like?
2. How did you choose the types of bioplastics for this business?
3. Could you tell me about some reactions or responses from customers about your use of bioplastics?
4. In your mind, what are the pros of bioplastics?
5. What are the cons, if any?
6. Can you tell me what you know about the labeling of bioplastics?
7. Where did you find this information?
8. If any, what environmental concerns do you have regarding bioplastics?